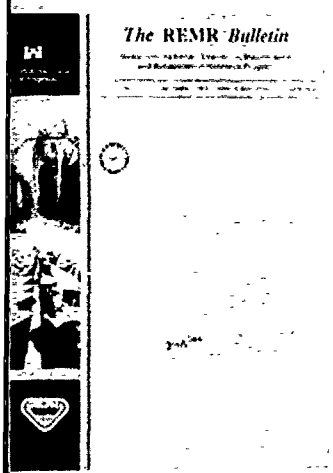
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REPAIR, EVALUATION, MAINTENANCE, AND REHABILITATION RESEARCH PROGRAM

TECHNICAL REPORT SL-REMR-CS-36

EVALUATION AND REPAIR OF CONCRETE STRUCTURES: ANNOTATED BIBLIOGRAPHY 1978-1988

Volume I

by

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13. ABSTRACT *(Maximum 200 words)*

This bibliography covers the period from 1978 through 1988 and contains 2,062 annotated references on evaluation and repair of concrete structures. The bibliography includes four sections relating to (a) concrete durability and causes of deterioration, (b) procedures for evaluating the condition of existing structures, (c) maintenance and repair materials, and (d) maintenance and repair techniques, and subject and author indexes. Sections a and b are in Volume I, and Sections c and d are in Volume II. The subject and author indexes are included in each volume.

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PREFACE

The work described in this report was authorized by Headquarters, US Army Corps of Engineers (HQUSACE), as part of the Concrete and Steel Structures Problem Area of the Repair, Evaluation, Maintenance, and Rehabilitation (REMR) Research Program. The work was performed at the US Army Engineer Waterways Experiment Station (WES) under Civil Works Research Work Unit 32303, "Application of New Technology to Maintenance and Minor Repair," for which Mr. James E. McDonald (CEWES-SC-R) was Principal Investigator. Dr. Tony C. Liu (CECW-EG) was the REMR Technical Monitor for this work. The annotated bibliography resulting from this study is published in two volumes.

Mr. Jesse A. Pfeiffer, Jr. (CERD-C) was the REMR Coordinator at the Directorate of Research and Development, HQUSACE; Mr. James E. Crews (CECW-O) and Dr. Liu served as the REMR Overview Committee; Mr. William F. McCleese (CEWES-SC-A), WES, was the REMR Program Manager. Mr. McDonald was the Problem Area Leader.

The work was performed at WES under the general supervision of Mr. Bryant Mather, Chief, Structures Laboratory (SL), and Mr. Kenneth L. Saucier, Chief, Concrete Technology Division (CTD), and under the direct supervision of Mr. McDonald, Research Civil Engineer, CTD, who along with Mr. Willie E. McDonald (CEWES-SC-CE), Civil Engineer, CTD, prepared this report.

Commander and Director of WES was COL Larry B. Fulton, EN. Dr. Robert W. Whalin was Technical Director.

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CONVERSION FACTORS, NON-SI TO SI (METRIC) UNITS OF MEASUREMENT

Non-SI units of measurement used in this report can be converted to SI (metric) units as follows:

Multiply	By	To Obtain
acre-feet	1233.489	cubic metres
cubic feet	2.831685	cubic metres
cubic yards	0.7645549	cubic metres
Fahrenheit degrees	5/9	Celsius degrees or kelvins*
feet	0.3048	metres
gallons (US liquid)	3.785412	cubic metres
gallons (US liquid) per minute	0.00006	cubic metres per second
inches	25.4	millimetres
miles (US statute)	1.609344	kilometres
pounds (force)	4.448222	newtons
pounds (force) per square inch	0.006894757	megapascals
pounds (mass)	0.4535924	kilograms
pounds (mass) per cubic foot	16.01846	kilograms per cubic metre
square feet	0.09290304	square metres
square yards	0.8361274	square metres
tons (2,000 lb mass)	907.1847	kilograms

* To obtain Celsius (C) temperature readings from Fahrenheit (F) readings, use the following formula: $C = (5/9)(F - 32)$. To obtain Kelvin (K) readings, use: $K = (5/9)(F - 32) + 273.15$.

EVALUATION AND REPAIR OF CONCRETE STRUCTURES

ANNOTATED BIBLIOGRAPHY, 1978 - 1988

INTRODUCTION

1. The bibliography contained in two volumes, in essence, is a continuation of the bibliography* previously prepared as part of the Concrete Research Program. The earlier bibliography covered a 51-year** period and contained 826 references. The current bibliography covers the ensuing 11 years; however, it contains 2,062 references. This large number of references reflects the significant increase in concrete evaluation and repair activities during recent years.

ORGANIZATION

2. The bibliography is divided into four sections relating to (a) concrete durability and causes of deterioration, (b) procedures for evaluating the condition of existing structures, (c) maintenance and repair materials, and (d) maintenance and repair techniques. Sections a and b are included in Volume I and Sections c and d in Volume II. A reference appears only in the section in which the title is most significantly identified, although the contents of some entries may be associated with two or more sections. Attempts were made to include all references relevant to evaluation and repair of concrete; however, considering the number of references in this broad field, relevant entries may have been omitted.

3. The bibliography contains 461 references in section A on concrete durability and causes of deterioration. The references address a variety of topics including alkali-aggregate reaction, chemical attack, corrosion of

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* Liu, T. C., O'Neil, E. F., and McDonald, J. E. 1978 (Sep). Maintenance And Preservation of Concrete Structures, Report 1, Annotated Bibliography, 1927 - 1977, Technical Report C-78-4, US Army Engineer Waterways Experiment Station, Vicksburg, MS, 409 pp.

** A table of factors for converting non-SI units of measurement to SI (metric) units is presented on page 3.

reinforcement, erosion damage, fire damage, and freezing and thawing durability.

4. Section B contains 396 references on procedures for evaluating the condition of existing structures. Many of these references describe nondestructive testing techniques to evaluate the condition of structures. Other major topics include condition surveys, core testing, inspection, petrographic examination, and strength evaluation.

5. Maintenance and repair materials are described in the 495 references contained in section C. These materials include bonding agents, coatings and sealers, fiber-reinforced concrete and mortar, polymer concrete and mortar, polymer-portland cement concrete and mortar, precast concrete, rapid-hardening materials, shotcrete, and silica-fume concrete.

6. Section D contains 710 references on maintenance and repair techniques including bonding new concrete to old, cathodic protection, concrete and masonry cleaning, concrete removal, grouting, overlays, patching, polymer impregnation, polymer injection, strengthening, surface preparation, underwater concreting, and waterproofing. Also, this section includes a number of case histories on maintenance and repair of architectural concrete, bridges, buildings, hydraulic structures, marine structures, pavement, parking structures, and tunnels. References on selection, specification and evaluation of repairs are also included.

7. A complete subject index and author index are provided in each volume as a guide for users of this bibliography.

ANNOTATED BIBLIOGRAPHY

SECTION A

CONCRETE DURABILITY AND CAUSES OF DETERIORATION

1978

A-1 Voves, B. 1978 (Jan). "Behaviour of Prestressed Concrete Structures During Fire," Stavebnicky Casopis, Vol 26, No. 1, pp 71-88, Bratislava, Czechoslovakia.

The behavior of prestressed concrete structures during fire is the primary focus of this paper. It contains a discussion of the results of fire resistance tests of pretensioned concrete specimens and the loading tests of those elements. The effects of fire and high temperatures on prestressing reinforcement, bond anchorage, and cold-drawn wire are also outlined. Conclusions of fire influence on the load-carrying function of prestressed concrete structures are pronounced on the basis of the described tests.

A-2 Browne, R. D., and Geoghegan, M. P. 1979. "The Corrosion of Concrete Marine Structures," Proceedings Conference on Corrosion of Steel Reinforcements in Concrete Construction, London, Feb 1978, pp 79-103.

Marine situations are examined that have presented corrosion problems in concrete structures along with a review of current developments in understanding the mechanics involved in steel corrosion in concrete linked to the spalling process. The practicing engineer must know how to design against corrosion, how to inspect for corrosion, and how to repair a structure if corrosion or other damage occurs. The approach to specification, inspection, and remedial work is also summarized, both for coastal and offshore structures where for the latter, depth of water, size, lack of accessibility and cathodic protection of steel attached to the reinforcement present unique problems.

A-3 Schmidty-Morsbach, J. 1978 (Feb). "Exposed Concrete - Factors Affecting the Concrete Surface," Betonwerk und Fertigteil Technik, Vol 44, No. 2, pp 64-73, Wiesbaden, Germany.

The first part of this article, from the Oct 1977 issue, was concerned with some fundamental aspects that frequently underlie complaints and claims arising from blemishes affecting exposed concrete. In this second part, the author deals in more detail with the interaction of the formwork face and the concrete surface formed against it, with particular reference to the treatment of variations in shades of grey such as frequently occur on concrete surfaces.

A-4 Unz, M. 1978 (Mar). "Performance of Galvanized Reinforcement in Calcium Hydroxide Solution," ACI Journal, Proceedings, Vol 75, No. 3, pp 91-99, Detroit, MI.

Galvanized steel is passivated by the saturated calcium hydroxide solution contained in moist concrete. Inherent corrosion currents develop, however, at excessive chloride contents and under conditions of nonuniform exposure. These currents lead to local chloride accumulation with intensive pitting, regardless of existing passivation films. The

corrosion resistance of galvanized steel reinforcement has been compared with that of bare steel.

A-5 Weise, J. 1978 (Feb). "Study of the Incendiary Behaviour of Prestressed-Concrete Solid-Ceiling and Hollow-Ceiling Slabs" (in German), Bauplanung-Bautechnik, Vol 32, No. 2, pp 62-65, Berlin, Germany.

Tests were made to determine the fire resistance of assortments of reinforced and prestressed concrete ceiling slabs. The tests made it possible to group the fire resistance of the elements and to draw conclusions on the construction precautions against fire. A safe anchorage of the reinforcement was found to exert a decisive influence on the fire resistance of the elements.

A-6 Ramaswamy, N. M., Nair, C. R., and Danke, P. S. 1978 (Mar). "Marine Concreting of Approach Jetty at Madras Atomic Power Plant, Kalpakkam," Indian Concrete Journal, Vol 52, No. 3, pp 78-80, Bombay, India.

This paper highlights some of the special corrosion problems encountered in marine concreting. The author stresses that high-quality durable concrete can be prepared by proper selection of cement and aggregate proportions. Marine environment and specific experiences at Kalpakkam are also discussed.

A-7 Hughes, B. P., and Guest, J. E. 1978 (Mar). "Limestone and Siliceous Aggregate Concretes Subjected to Sulphuric Acid Attack," Magazine of Concrete Research, Vol 30, No. 102, pp 11-18, Thomas Telford, Ltd, London, England.

The paper reports tests to determine the relative rates of erosion of siliceous-gravel and limestone-aggregate portland cement concretes subjected to sulfuric acid concentrations of 0.0016 percent and 0.02 percent by weight. Care was taken to simulate conditions not too divorced from practice. The limestone-aggregate concrete eroded to present a relatively smooth surface with no detritus. In contrast, the siliceous-aggregate concrete had a very irregular surface with considerable aggregate detritus. The rates of erosion of the siliceous-aggregate concrete were very sensitive to the quality of the cement paste matrix, whereas the rates for the limestone-aggregate concrete were relatively insensitive. The behavior of the limestone-aggregate concrete can be exploited in certain applications. There is no increasing surface roughness or accumulation of debris to reduce flow in channels, and damage with scrapers in sedimentation tanks can be minimized with a smoother surface. Design for erosion with limestone concretes entails estimating the thickness of a sacrificial layer of concrete appropriate for the rate of acid attack and the design life of the structure.

A-8 Pace, C. E., and Campbell, R. L. 1978 (May). "Structural Integrity of Brick-Veneer Buildings," Technical Report C-78-3, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

Floodproofing individual homes is an important aspect of the total

solution of flood damage reduction. This report gives insight into the structural resistance of brick-veneer walls subjected to hydrostatic water loading. There are many variables affecting the response of a brick-veneer wall; therefore, the approach of this study was to obtain limited experimental data by testing three walls, analyze these data, and compare them to analytical solutions.

A-9 Ropke, J. C. 1978 (Jul). "Trouble Shooting Concrete Floor Problems," Modern Concrete, Vol 42, No. 3, pp 31-32, 59, Cleveland, OH.

Problems with concrete floors are not always the fault of the concrete itself. Many other factors must be considered to ensure a problem-free concrete floor. Subgrade condition., and lack of protection for the concrete after finishing are two of the most common difficulties that can be overcome by the contractor and mason. Often the subgrade must be newly prepared, and the slab must be finished later than planned, resulting in overtime payments but a superior job.

Dusting, cracking, drying, shrinkage, discoloration, and other job site problems are also discussed in this article. An important attitude in the solution of these problems is one of careful inspection of all factors to ensure success of the project.

A-10 Chatterji, S. 1978 (Jul). "Mechanism of the $CaCl_2$ Attack on Portland Cement Concrete," Cement and Concrete Research, Vol 8, No. 4, pp 416-467, Elmsford, NY.

It is known that concentrated solutions of $CaCl_2$ can cause the breakdown of portland-cement concrete. Recently, it has been shown that the severity of a $CaCl_2$ attack decreases with increasing temperature and above 40° C concrete is not affected. From the above observation, it was inferred that the breakdown is due to some compound formation at temperatures below approximately 20° C. To gain a better understanding of the mechanisms of a $CaCl_2$ attack, powders of portland cement (both anhydrous and partly hydrated) were shaken in $CaCl_2$ solutions of various strengths up to 180 days. The temperatures of these suspensions were maintained to 40, 20, and 5° C. The results indicate that the breakdown of portland cement concrete, when placed in a concentrated $CaCl_2$ solution, is not due to the formation of another compound or the leaching of calcium hydroxide but associated with the formation of complex salts. Subsidiary experiments support the above hypotheses.

A-11 Oberholster, R. E. 1978 (Aug). "Alkali-Aggregate Reaction: Seminar on Quality Assurance and Cement Application," National Building Research Institute, Pretoria, South Africa.

Cracking of concrete structures due to expansive alkali-aggregate reaction has been known to occur since approximately 1940 when Stanton in the USA published papers on the cracking and deterioration of a concrete pavement in the Salinas Valley, CA. Alkali-aggregate reaction is now

known to occur in many countries. A review of alkali-aggregate reaction in South Africa was recently given by Oberholster, Brandt, and Weston.

A-12 Izumi, M., and Ichimasu, H. 1978 (Aug). "On Thermal Stress and The Extent of Cracking in Massive Reinforced Concrete Structures" (in Japanese), Concrete Journal, Vol 16, No. 8, pp 18-27, Tokyo, Japan.

Massive reinforced concrete structures on a Tokyo, Japan, metropolitan expressway were examined for thermal stresses and effects of cracking. Cracking conditions of mass concrete and methods for controlling cracking of reinforced mass concrete structures caused by thermal stress were predicted. The critical temperature rise of cracking was also investigated.

A-13 (Deleted)

A-14 Dante, J. E. Veronelli. 1978 (Sep). "Durability of Concretes" (in Spanish), Monografias 352, Instituto Eduardo Torroja de la Construccion y del Cemento, Madrid, Spain.

Alkali-aggregate reactions correspond to a very specific aspect of the general background of durability or chemical resistance of concrete.

Discussions include alkalies as raw materials in the technology of clinker production; cements and cement standards; their geological, petrographic, and mineralogical characteristics; their susceptibility to alkalies; the chemical scheme of the expansive reaction through the characteristics of the reactive elements; the required conditions and the influencing elements, either internal or external to concrete; and the inhibition of the expansive process.

Conclusions are made concerning causes of alkali-aggregate reaction, the necessary and cooperating conditions for it, measures to avoid it, and a code for its prevention.

A-15 Ashcroft, D. L., and Charlebois, G. W. 1978 (Sep). "Corrosion Pitfalls of the Closed Loop Chlorination Stages," Book 3, pp 509-518, TAPPI, Atlanta, GA.

The closed loop chlorination system has many problems of both a process and corrosion resistant nature. These problems are caused by the higher temperatures and increased chemical concentrations inherent in the system. The process problems have been resolved by introduction of new instrumentation, static mixers, elimination of washers and high density bleaching. Throughout this process development the severity and causes of corrosion to equipment under the new process conditions were treated with a casual concern. The operation of a closed loop system at EasTex abruptly demonstrated the importance of a need for better corrosion resistance for equipment and associated storage tanks. A summary is presented of the current theory for the mechanism of failure in both alloy and concrete structures. Based on an understanding of these theories, a method for preventing corrosion problems in the closed loop

system is proposed, supported by currently available methods and materials of construction.

A-16 Alekseev, S. N., and Krasovskaya, G. M. 1978 (Sep). "Features of Corrosion Resistance of Reinforcing Steel" (in Russian), Beton i Zhelezobeton, No. 9, pp 14-15, Moscow, USSR.

Case histories on the deformation of concrete structures caused by corrosion of reinforcements are discussed. Methods of constructing thermally strengthened reinforcement that is stable against corrosion under the stress conditions are described.

A-17 Rajagopalan, K. S., Chandrasekaran, S., Rengaswamy, N. S., Balasubramanian, T. M., Chandrasekaran, V., and Muralidharan, V. S. 1978 (Sep). "Field Exposure Studies on Corrosion of Reinforcing Steel in Concrete," Indian Concrete Journal, Vol 52, No. 9, pp 231-235, Bombay, India.

An investigation was undertaken in which treated and untreated concrete cubes, having reinforcement at varying amounts of cover thickness and containing varying amounts of corrosive salts, were exposed at eight different stations representing different climatic regions of India. The paper describes the experimental procedure and discusses the results obtained.

A-18 Thornton, H. T., Jr. 1978 (Sep). "Acid Attack of Concrete Caused by Sulfur Bacteria Action," Miscellaneous Paper C-78-14, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

The fact that concrete constituents are susceptible to attack and decomposition by acids is no new topic for discussion. The process by which certain genera of anaerobic bacteria produce acids has also been documented. However, most of the literature linking these phenomena with the deterioration of concrete structures has been addressed primarily to problems associated with concrete sewer pipes, and most of the reporting was done in the 1950's. This paper was extracted from a report of a recent investigation performed for the US Army Engineer District, Huntington, into the combined effects of these phenomena on structural concrete. The investigation starts with the manifestation of the problem, i.e., the concrete in the outlet tunnels of two lakes being reduced to a "mush" consistency to depths up to 1-1/4 in. over a period of about 5 years. The program of investigation includes a literature review, sample collection, and physical, chemical, and bacteriological tests. It is concluded that the deterioration is due to acid attack and is the final stage of a corrosive process caused by sulfur bacteria action. Immediate and long-range remedial measures are suggested for consideration for implementation at both sites. Attention is drawn to the fact that undetected deterioration of other concrete structures may be in progress.

A-19 Schupack, M. 1978 (Oct). "Survey of the Durability Performance of Post-Tensioning Tendons," ACI Journal, Proceedings, Vol 75, No. 10, pp 501-510, Detroit, MI.

Information on the actual performance of stress-relieved post-tensioning tendons in completed structures, both bonded and unbonded, is presented. This is based on known incidents of corrosion and opportunities to inspect post-tensioned tendons in completed structures that were exposed for various reasons after a period of time. This report is directed toward North American, Western European, and Japanese experience in tendons made of stress-relieved wires, strands, or high-strength bars, the types of prestressing steel primarily used in Canada and the United States.

The survey indicates that the general durability performance of post-tensioned prestressed concrete construction in the 1930's has been excellent. With proper choice of materials and details and with good construction practices, excellent corrosion protection is provided for both bonded and unbonded post-tensioning tendons. The relatively small numbers of corrosion incidents that have occurred have been the result of poor design details, inadvertent exposure to known corrosive agents, or poor construction practices. It is estimated that over 2.7 million tons of stress-relieved prestressing steel, equivalent to about 30 million tendons, have been used in the western world. Only some 28 corrosion incidents, comprised of 200 tendons using stress- relieved steel, have been reported for complete structures. These incidents could have been avoided if proper procedures had been used. To date, there has been no known catastrophic collapse of permanent structures in the western world due to corrosion of post-tensioning tendons utilizing stress-relieved wire, strand, or high-strength stress-relieved bars conforming to American Society for Testing and Materials specifications.

A-20 "Guide to Troubleshooting Site-Cast Architectural Concrete Problems." 1978 (Oct). Concrete Construction, Vol 23, No. 10, pp 578-612, Addison, IL.

Architectural concrete, concrete permanently exposed to view, requires careful preparation and application. This special issue is a collection of a number of bad experiences with architectural concrete reported to the "Problem Clinic" Department of Concrete Construction. The question and answer format has been retained for this collection of items received over a period of years. Not all questions are the result of bad experience (some are requests for information), and not all are from the field, but all are considered useful. Many of the answers originally given have been revised and updated to agree with what is presently known. The following topics are covered: mix proportioning, cements, colored concrete, forming, form liners, reinforcing steel, jointing, placing and consolidation, exposed aggregate finishes, sandblasting and waterblasting, bushhammered or fractured finishes, tie holes, sealers and paints, and discoloration and blemishes.

A-21 Jambor, J. 1978 (Dec). "Influence of Concentration of Aggressive CO_2 in Acting Carbonate Water on Rate of Concrete Corrosion" (in Slovak), Stavebnicky Casopis, Vol 26, No. 12, pp 881-897, Bratislava, Czechoslovakia.

The rate of corrosion of concrete by aggressive CO_2 solution has always been determined by joint action of several factors. There has been an investigation of the course of corrosion of specimens, made of plastic standard mortar and various cements and subjected to the action of aggressive CO_2 solutions of different concentration of the aggressive CO_2. This investigation has shown that the concentration of the aggressive CO_2 in the acting solution, as well as the period of time of its action on the concrete, belong to the most important factors affecting the rate of corrosion process and the attained degree of the concrete corrosion. With increasing concentration of the aggressive CO_2 in the acting solution, the rate of corrosion distinctly increases up to concentration of the solution of about 120 mg of the aggressive CO_2 per liter. A continuing growth of the concentration of the aggressive CO_2 in the solution affects the growth of the rate of the corrosion substantially less. Similarly spectacular is the growth of the attained degree of the corrosion due to the continuing action of the CO_2 solution, whereas the composition of the portland cement used for the confection of the specimens has been proved to be almost without substantial effect on the relative resistance of concrete to the aggressive CO_2 corrosion. On the basis of the obtained results, the author expressed quantitatively the effect of the concentration of the aggressive CO_2 on the rate of corrosion in a form of basic functional relationship by formula.

A-22 Tanaka, Y., Kurauchi, M., Nagi, H., and Masuda, Y. 1978. "Evaluation of Corrosion Protection of Unbonded Tendons," Post-Tensioning Institute, Phoenix, AZ.

This three-part report evaluates the corrosion protection of unbonded tendons. The first part presents an investigation of corrosion protection materials for unbonded tendons, particularly four greases used by the authors' company. The second part presents test results of the third-year investigation of a dummy tendon embedded in a building roof and the tendons in prestressed concrete prisms. The third part discusses marine atmosphere exposure tests of prestressed concrete prisms after 1 year of exposure.

A-23 Vassie, P. R. W. 1978. "Corrosion of Steel in Environments Simulating the Liquid Phase of Concrete," TRRL Supplementary Report 396, Transportation and Road Research Laboratory, Crowthorne, Berkshire, England.

Electrode potential, electrode polarization, and electrical resistance probe measurements have been used to investigate the corrosion of mild steel in calcium hydroxide solutions approximating to the solution found in the pores of concrete. The usefulness of the corrosion data obtained from these measurements is discussed and corrosion threshold sodium chloride concentrations are reported for saturated calcium hydroxide and 0.002M calcium hydroxide solutions. This threshold sodium chloride

concentration data fell into two categories depending on the method of investigation. Electrode potential and polarization techniques indicated threshold concentrations an order of magnitude lower than the polarization resistance and electrical resistance probe methods. This demonstrates that although the corrosion reaction may be thermodynamically feasible, the rate of corrosion can be limitingly low, thus emphasizing the advantages of the polarization resistance and electrical resistance probe techniques which deliver the results in the form of corrosion rates. The data recorded in this report cannot be quantitatively applied to a reinforced concrete structure.

A-24 Knofel, D. 1978. Corrosion of Building Materials, Van Nostrand Reinhold, New York, NY.

Describes corrosion processes of various construction materials along with preventive techniques. Types and processes of corrosion, factors that cause the destructive reactions in building materials, and ways in which materials are affected by various corrosive agents are covered. Chemical reactions involved in hydration of cement, methods for detection of corrosion and assessment of its extent, and the nature of attacks on concrete by water, chemicals, subsoils, gases, sulfates, alkalies, and solvent and swelling action are explained in the section dealing with corrosion of set concrete by external media. Corrosion and relevant protective measures involving reinforcement steels, ceramic glass, and a host of other nonmetallic inorganic building materials - gypsum, natural stone, calcium silicate stone, asbestos and anhydrite cement, aerated and silicate concrete, and magnesia and slaked lime mortar are discussed. Corrosion of building metals is also covered.

An entire section of the book is devoted to simple tests of corrosive media that can be carried out by the nonchemist and without the use of a laboratory. Data in tabular form present the forms and effects of corrosion; soil conductivity, resistivity, and aggressivity; properties of various kinds of paint; relationships between paint used, surface to be painted, and the degree of rust removal needed.

A-25 Barthelemy, B., and Kruppa, J. 1978. "Fire Resistance of Structures: Steel-Concrete-Wood" (in French), pp 277, 165 F, Editions Eyrolles, Paris, France.

This book presents the latest research results dealing with the fire resistance of concrete structures, steel structures, composite concrete-steel structures, and wood structures. The reader will find not only useful calculation methods illustrated with charts and numerical examples but also the theoretical bases for the methods.

Contents cover: principles of safety; the role of fire resistance; fire resistance of concrete structures; effects of temperature on concrete; mechanical and thermophysical properties of concrete; reinforced and prestressed concrete steels in relation to temperature; heating of concrete structural elements; calculation of the fire resistance of reinforced concrete and prestressed concrete structures; fire resistance of

steel structures; protection materials and techniques; heating of steel structures; critical temperatures; nonuniformly heated structures; fire resistance of steel-concrete structures; hollow posts filled with concrete; mixed beams; slabs with steel; fire resistance of wood frames; fire behavior of wood; protection materials and techniques; and forecasting the fire resistance of nonprotected frames.

A-26 Norwegian Institute of Technology. 1978. "Concrete Structures," Tapir, Trondheim, Norway.

This symposium gives a first-hand account of the status, developments, and problems of concrete structures. Brief historic reviews are also presented. Contents include such reports as: the design of Condeep platforms; the corrosion of concrete marine structures; underground concrete structures, particularly for hydroelectric power plants; and the influence of the direction of reinforcement on crack widths.

A-27 Roberts, J. J. 1978. "Crazing of Concrete Made with White Cement," Technical Report 42.524, Cement and Concrete Association, London, England.

Tests have been made over a 6-year period on more than 90 columns made from white cement concrete. The results support the hypothesis that concrete always crazes, but that often this crazing cannot be detected by the unaided eye. A number of factors were considered, including the use of various surface treatments, but few were found to have any significant long-term effect on the incidence of crazing. The most important parameter dictating the degree of crazing is the type of form face, dense smooth surfaces leading to much more visible crazing than more open-textured, permeable formwork. The use of mixes with high cement contents also increases the severity of this esthetic defect.

A-28 Perkins, P. H. 1978. "Use of Portland Cement Concrete in Sulphate-Bearing Ground and Groundwater," Publication 45.034, pp 6, 75, Cement and Concrete Association, Wexham Springs, England.

It is well known that sulfates in solution in soil and groundwater, when they reach a certain concentration, are likely to cause deterioration in concrete made with portland cement. Since its introduction in Britain in the early 1950's, sulfate-resisting portland cement has been used in continually increasing quantities.

Under suitable conditions explained in this publication, the use of sulfate-resisting portland cement will usually give assurance of a virtually unlimited life to high-quality concrete in contact with soil or groundwater containing sulfates, provided other aggressive chemicals are not present in harmful concentrations.

A fundamental point in the use of sulfate-resisting portland cement is that the concrete itself must be of good quality and, when mature, must have low permeability; in other words, it must have an adequate cement content and a relatively low water-cement ratio and be properly

compacted. Unless the concrete is basically of a high quality described in the article, the use of sulfate-resisting portland cement is unlikely to have a significant effect in preventing sulfate attack.

A-29 Andrade, C., and Gonzalez, J. A. 1978. "Prediction of Potential Corrosivity of Concrete Additives by the Joint Determination of Pitting Potential and Polarization Resistance" (in Spanish and English), Research Working Paper 33, Instituto Eduardo Torroja de la Construccion y del Cemento, Madrid, Spain.

A brief theoretical review is given of the electrochemical methods currently in use to evaluate either the susceptibility of reinforcement steel to localized attack or its instantaneous corrosion rate. Results of $Ca(OH)_3$-saturated solution and mortar tests on the corrosion effects of concrete additives are reported.

A-30 Cady, P. D. 1978. "Corrosion of Reinforcing Steel," Significance of Tests and Properties of Concrete and Concrete-Making Materials, ASTM STP 169B, American Society for Testing Materials, Philadelphia, PA.

Mechanisms of corrosion of steel in concrete are described and the effects of various parameters (chloride ions, moisture content, concrete mixture variables, construction variables) on corrosion are discussed Techniques to assess the probability of active corrosion in the absence of physical evidence on the concrete surface are described. Also, potential corrosion preventive procedures are presented.

A-31 Erlin, B., and Woods, H. 1978. "Corrosion of Embedded Materials other than Reinforcing Steel," Significance of Tests and Properties of Concrete and Concrete-Making Materials, ASTM STP 169B, American Society for Testing and Materials, Philadelphia, PA.

This chapter deals with materials, other than conventional reinforcing steel, which are sometimes used in conjunction with concrete. Emphasis is given to the possible degradable aspects relative to their use, and conditions that may render them serviceable or unserviceable.

The materials described include metals, and inorganic and organic substances. Among the metals are aluminum, lead, copper and copper alloys, zinc, special alloys of iron, Monel metal, stellite, silver, and tin; among the inorganic materials are glass, asbestos, and concrete; and among the organic materials are a variety of plastics, and wood and similar cellulosic materials. Fiber-reinforced concrete is gaining in use, and information about some fibers is included.

A-32 Lane, R. O. 1978. "Abrasion Resistance," Significance of Tests and Properties of Concrete and Concrete-Making Materials, ASTM STP 169B, American Society for Testing and Materials, Philadelphia, PA.

This paper reviews the effects of important factors such as strength of concrete, mixture proportioning, selection of concrete-making materials,

finishing procedures, and surface treatment on the wear resistance of concrete surfaces as determined by recent research.

A-33 Newlon, H., Jr. 1978. "Resistance to Weathering," Significance of Tests and Properties of Concrete and Concrete-Making Materials, ASTM STP 169B, American Society for Testing and Materials, Philadelphia, PA

The purpose of this paper is to discuss the significance of current standardized testing procedures for evaluating the resistance of concrete to weathering under service conditions.

A-34 Tuthill, L. H. 1978. "Resistance to Chemical Attack," Significance of Tests and Properties of Concrete and Concrete-Making Materials, ASTM STP 169B, American Society for Testing and Materials, Philadelphia, PA

This chapter summarizes the general problem of chemical attack and the means for producing concrete to resist it, then proceeds with a more detailed discussion of the significant aspects of how these chemical actions damage concrete, what can be done to combat them, and in some cases what tests can be used to measure the degree of attack or the success of corrective measures.

A-35 Smith, P. 1978. "Resistance to High Temperatures," Significance of Tests and Properties of Concrete and Concrete-Making Materials, ASTM STP 169B, American Society for Testing and Materials, Philadelphia, PA.

The mechanisms and consequences of high temperatures on the thermal and mechanical properties of concrete are described.

A-36 Diamond, S. 1978. "Chemical Reactions other than Carbonate Reactions," Significance of Tests and Properties of Concrete and Concrete-Making Materials, ASTM STP 169B, American Society for Testing and Materials, Philadelphia, PA.

Mechanisms and consequences of noncarbonate alkali-aggregate attack are reviewed, along with a description of methods of avoiding alkali-aggregate reaction problems.

A-37 Walker, H. N. 1978. "Chemical Reactions of Carbonate Aggregates in Cement Paste," Significance of Tests and Properties of Concrete and Concrete-Making Materials, ASTM STP 169B, American Society for Testing and Materials, Philadelphia, PA.

The chemical reactions between carbonate aggregates and portland-cement paste are many and varied. To date, there is only one type of chemical reaction known generally to cause premature deterioration of concrete pavements and structures. This is the expansive alkali-dedolomitization reaction. The reaction is most active in high alkali cements and occurs expansively with only a very restricted type of rock. The rocks contain nearly equal amounts of calcite and dolomite, a substantial amount of illite, and possess a texture of dolomite rhombs in "dirty" micrite. Rocks of this composition can occur in any of the carbonate sequences.

They have most often been found in Ordovician formations. The exp ive alkali-reactive carbonate rocks occur in relatively small quantit in limited areas or time zones. Thus, selective quarrying is often a re- ferred method of dealing with them when they occur.

Petrographic examination (ASTM Recommended Practice C 295) and the rock cylinder method (ASTM Test C 586) are valuable screening procedures to detect aggregate mate ials that are potentially susceptible to the alkali-carbonate rock reaction. A test method for length change of concrete prisms being developed by ASTM Subcommittee C09.02.02 appears to offer the most dependable means of evaluating the susceptibility of cement-aggregate combinations to expansive effects of this reaction.

A-38 Dolar-Mantuani, L. 1978. "Soundness and Deleterious Substances," Significance of Tests and Properties of Concrete and Concrete Making Materi ls, ASTM STP 169 , American Society for Testing and Materials, Philadelphia, PA.

During the past 100 or more years many tests have been developed and applied to assess the quality of concrete aggregates. This paper is a discussion of the significance of five aggregate quality tests currently in use. One of them, the sulfate soundness test (ASTM Test for Soundness of Aggregates by Use of Sodium Sulfate or Magnesium Sulfate (C 88)), is perhaps the most widely used of all methods for determining the overall quality of aggregate. The other four tests are used to determine the presence of specific harmful particles or substances that influence the mix proportions of fresh concrete or its early-stage hardening or damage the concrete surface under specific circumstances.

A-39 Hudec, P. P. 1978. "Effect of Deicing Salts on Deterioration and Dimensional Changes of Carbonate Rocks," Durability of Building Materials and Components, ASTM STP 691, American Society for Testing and Materials, Philadelphia, PA.

The deleterious effect of deicing salts on concrete has long been recognized. This study deals with effect of salt solution treatment on the expansivity and durability of carbonate rocks.

Two groups of carbonate rocks from operating quarries of Southwestern Ontario were tested for their durability by magnesium sulfate and freeze-thaw test methods. The silica and the alumina content were determined, as well as the water adsorption after treatment in 3-weight percent chloride salt solution. Isothermal expansion upon wetting of the dry treated and untreated rocks also were studied.

The results indicate that the carbonate rocks show a direct, significant relationship between isothermal length change on wetting and clay content, water adsorption, and durability. Clay and chert content and water adsorption were reliable indicators of rock durability. Water adsorption, before and after salt treatment, could be used to predict the effect of deicing salts on the durability of rocks.

A-40 Cole, W. F., and Beresford F. D. 1978. "Influence of Basalt Aggregate on Concrete Durability," Durability of Building Materials and Components, ASTM STP 691, American Society for Testing and Materials, Philadelphia, PA.

Basalts are the major source of aggregate for concrete and roadmaking in Melbourne, Australia. Although they have generally performed satisfactorily, some green basalts containing secondary clay minerals have failed in roadways, and concern has been expressed about their possible poor performance in structural concrete. As a consequence, research was undertaken to assess the influence of aggregate instability of stone from a new quarry at Deer Park and other basalts from the Melbourne area on concrete durability. The mineralogy of the basalts is described and results are reported on the behavior of the aggregates with regard to cycles of wetting and drying. Concrete testing provided data on compressive and tensile strength, dimensional movement, and modulus of elasticity of specimens for practical strength grades exposed to cyclic conditions for 3 years. The investigation established the durability in concrete of the altered basalt from Deer Park while showing that aggregate instability can seriously affect the long-term durability of concrete. The reliability of current specifications used in Victoria, Australia, for detecting unstable aggregates for concrete is questioned. It is proposed that durability should be determined by shrinkage measurements of aggregate and concrete.

A-41 Gillott, J. E., Jordaan, I. J., Loov, R. E., and Shrive, N. G. 1978. "Durability Studies of Sulfur Concrete," Durability of Building Materials and Components, ASTM STP 691, American Society for Testing and Materials, Philadelphia, PA.

Sulfur concretes are typically brittle. Sulfur concretes that are less brittle have been produced and tested for durability. Specimens were immersed continuously for up to 200 days in various salt solutions and seawater. Comparison of these specimens with companion specimens kept in air and distilled water showed no adverse effects in terms of compressive strength and modulus of rupture; no cracking was observed and dimensional changes were similar for all specimens. When subjected to temperature cycling, compressive and flexural strengths of some sulfur concretes were reduced, the largest effect being observed in flexure. Preliminary tests for resistance to freezing and thawing showed no detrimental effects and material left outdoors for 18 months has suffered negligible change due to weathering. The abrasion indexes of these materials are between typical portland cement and asphaltic concretes. Comparison is made with results for a typical brittle sulfur concrete.

A-42 MacInnis, C., and Nathawad, Y. R. 1978. "The Effects of a Deicing Agent on the Absorption and Permeability of Various Concretes," Durability of Building Materials and Components, ASTM STP 691, American Society for Testing and Materials, Philadelphia, PA.

The ultimate goal of this research is the development of test methods for the prediction of the frost durability of concrete. The absorption

and permeability properties of three different precast concrete paving slabs and five laboratory fabricated slabs were investigated using water and three different concentrations (2, 4, and 10 percent) of sodium chloride in water. Concrete parameters investigated included water-cement ratio, air entrainment, and method of slab manufacture. The absorptivity and permeability of the various concrete slabs appeared to be more affected by the water-cement ratio of the concretes than by the salt solution concentration or air entrainment.

A-43 Harnik, A. B., Meier, U., and Rosli, A. 1978. "Combined Influence of Freezing and Deicing Salt on Concrete-Physical Aspects," Durability of Building Materials and Components, ASTM STP 691, American Society for Testing and Materials, Philadelphia, PA.

The observation that the durability of concrete often is lower under the combined influence of frost and deicing salts than under frost influence alone is discussed with regard to several physical aspects and mechanisms, for e.g., hydrodynamic effect, capillary effect, supercooling, lowered melting point of water in smaller pores, and layer-by-layer freezing. It is concluded that some of the most detrimental factors with regard to the durability of concrete are supercooling of water and aqueous solutions and a higher degree of saturation of the concrete in the presence of salts. The differing effects of dry application of deicing salts on snow-and-ice-covered concrete (temperature shock) compared to the preventive salt application on humid concrete (prevention of ice formation, but with some negative aspects) are discussed.

A-44 Rosli, A., and Harnik, A. B. 1978. "Improving the Durability of Concrete to Freezing and Deicing Salts," Durability of Building Materials and Components, ASTM STP 691, American Society for Testing and Materials, Philadelphia, PA.

The resistance of concrete to freezing and deicing salts depends mainly on the durability of its outermost zones. The material properties of these outermost zones appear to be rather inhomogeneous. Thus, variability of material properties is inevitable in these zones. In addition, external influences may cause other inhomogeneities in the concrete, e.g., gradients of water saturation, salt concentration, or temperature. Thermal gradients, especially those created by the temperature shock during the process of ice melting by means of deicing salts, can cause the development of internal stresses in the concrete. An estimation of the internal tensile stresses is determined on the basis of temperature shock experiments; they may reach the order of magnitude of the tensile strength of concrete under unfavorable circumstances ice (thickness of 0.5 mm and more; high salt concentration).

A-45 Frohnsdorff, G., and Masters, L. W. 1978. "The Meaning of Durability and Durability Prediction," Durability of Building Materials and Components, ASTM STP 691, American Society for Testing and Materials, Philadelphia, PA.

The concept of durability is not well defined. The term durability is

often used to imply the possession of qualities associated with long life. In some standards for building components, it is nonquantitative and implies that design requirements are likely to be exceeded for the design service life or some other specified period. The new ASTM Recommended Practice for Developing Short-Term Accelerated Tests for Prediction of the Service Life of Building Components and Materials (E 632 - 78) is outlined. The application of the recommended practice to service life prediction is illustrated by an example for work being planned on protective coatings for steel.

A-46 Farhi, E. 1978. "Methodologies for Assessing Durability of New Materials and Components in Building," Durability of Building Materials and Components, ASTM STP 691, American Society for Testing and Materials, Philadelphia, PA.

Innovations and new techniques in the field of building construction have multiplied to a remarkable extent in Europe and France during the last 30 years.

In France, in particular, the very great increase in the rate of construction of dwellings since the 1950's has led to the adoption of new building methods, and to new building materials that have allowed the demand to be met.

The questions that arose at the outset of the use of these materials and of these methods were the following: What will be the durability of this method, especially in comparison with that of known traditional building methods? How will this substitute material last compared with a traditional material of known durability?

These questions were of some importance because durability was an important aspect of the techno-economic choices that had to be made at that time between these materials and these methods.

In France, this was dealt with easily by means of a certificate of suitability for use and durability in service known as an agreement certificate. This certificate was instituted in 1945, revised in 1958, and transformed into the Avis Technique (Technical Opinion) in 1969.

But what were the methodologies for the assessment of durability? How have they developed with time?

These are the questions addressed and answered in this paper.

A-47 Boyd, D. W. 1978. "Weather and the Deterioration of Building Materials," Durability of Building Materials and Components, ASTM STP 691, American Society for Testing and Materials, Philadelphia, PA.

Early attempts to predict the effects of the weather on the deterioration of building materials were often little more than speculation. The inadequacy of the results is discussed using freeze-thaw cycles and the annual driving rain index as examples. More precise empirical

relationships must be based on laboratory or test-site observations and may require special weather analyses such as the humidity tables prepared for a study of corrosion of metals. More complex relationships are being found and the analysis of the weather often will involve the study of the coincident values of two or more elements. The research scientist should be aware of the weather data now generally available and the types of analyses that could be provided.

A-48 Regourd, M., Hornain, H., and Mortureux, B. 1978. "Microstructure of Concrete in Aggressive Environments," Durability of Building Materials and Components, ASTM STP 691, American Society for Testing and Materials, Philadelphia, PA.

All the constituents of concrete can be attacked. Some degradations occur after a long period of time. So, it is important to know the chemical and physical mechanisms of the corrosion and the behavior of built structures. In our studies on the durability of concrete, chemical and technological tests have been completed by microstructure examination with scanning electron microscopy and X-ray diffraction. In the present stage of our research into the attack of concrete by seawater, several factors can be noted. The formation of expansive ettringite is related to the content, the crystalline form, and the granularity of tricalcium aluminate. The carbonation reaction transforms ettringite into thaumasite. The dissolving of lime-rich compounds like hydrated silicates (C-S-H) brings about their progressive transformation into Ca-Mg silicates. Some aggregates have reacted with alkalis. A dense concrete with a high cement content will offer a good resistance to chemical and physical attacks.

A-49 Ludwig, U. 1978. "Durability of Cement Mortars and Concretes," Durability of Building Materials and Components, ASTM STP 691, American Society for Testing and Materials, Philadelphia, PA.

This paper presents the results of theoretical and experimental studies concerning the durability of cement mortars and concretes.

The behavior of different cements in mortars and concretes which are exposed to attack by carbon dioxide in the atmosphere, sulfate ions or the alkali silica reaction (ASR) is described. The principal results obtained during the past 10 to 15 years also are summarized.

Carbonation of cement mortars and concretes follows a $\sqrt{t}$ relation. The increasing total lime content of mortars and concretes with portland cement, together with the compaction of the microstructure due to carbonation, leads to better durability of this type of cement as compared with cements of lower lime content.

The attack of sulfate solutions causes the initial cracking by topochemical ettringite formation followed by the formation of gypsum as a secondary reaction. The latter explains the often observed interim rehealing.

The ASR is considered as the result of dynamic osmosis equilibrium. The minimum relative humidity necessary for ASR is $80 << x < 85$ percent. The delayed ASR leads to an increased deterioration of the structure. Water repellent agents are suitable to prevent the ASR. Pozzolans and blast furnace slags in cements reduce or prevent the ASR. The maximum expansion forces are observed to be 1.7 N/mm^2. The damages on buildings can be determined on drill-core samples.

A-50 Hammond, A. A. "Durability of Bauxite-Waste Pozzolana Cement Concrete," Durability of Building Materials and Components, ASTM STP 691, American Society for Testing and Materials, Philadelphia, PA.

The durability of calcined bauxite-waste pozzolana cement was evaluated against sulfate, seawater, and soft water attacks to establish acceptance criteria for forecasting its performance under anticipated environmental conditions during the lifetime of its concrete building.

The tests consisted of preparing mortar bars containing 10 to 40 percent addition or replacement of cement by the pozzolana and storing in sulfate solutions, seawater, and soft water. Measurements and recordings of defects of the mortar bars were taken for a period of about 3 years.

The most remarkable results were obtained from specimens of the pozzolana calcined at 900° C above optimum calcining temperature. The results obtained so far indicated that resistance to the various conditions was favorable for specimens with less percentage replacement or addition. But on the whole, adding the pozzolana to the cement proved more successful than replacing it.

A-51 Friede, H. 1978. "Depth of the Corroded Zone in Concrete Exposed to Carbonic Acid," Durability of Building Materials and Components, ASTM STP 691, American Society for Testing and Materials, Philadelphia, PA.

Based on a number of test methods, the thicknesses of corroded zones have been calculated as a function of exposure time. Representative values for the relevant rate of progression of the corrosion have been obtained. The increase of the cross-sectional area of the dimension necessary to provide the required strength of structural elements exposed to aggressive media can be calculated by the developed method.

A-52 Mohan, D., and Rai, M. 1978. "Deterioration of Concrete in Fertilizer Factories," Durability of Building Materials and Components, ASTM STP 691, American Society for Testing and Materials, Philadelphia, PA.

The paper deals with causes leading to the deterioration of concrete floors and columns in three fertilizer plants. All the three plants have massive reinforced concrete and some exposed steel structures. In various processing sections, extensive chemical corrosion of concrete and steel had been observed. Spillage of chemicals acidic in nature, high humidity and condensation of vapors and gases, and intense vaporization and crystallization effects-particularly in reinforced cement

concrete prilling towers-appear to be the main causes of deterioration of concrete.

Physico-chemical investigations of the specimens of concrete indicated the possibility of formation of calcium nitroaluminate and sulfoaluminate hydrates, calcium sulfate and nitrate, calcium carboaluminate hydrates, etc.

1979

A-53 Malinowski, R. 1979 (Jan). "Concretes and Mortars in Ancient Aqueducts," Concrete International: Design & Construction, Vol 1, No. 1, pp 66-76, Detroit, MI.

Some ancient types of water conduits such as tunnels, arch construction, and pressure conduits, are dealt with. Building materials for lining, concrete, mortar, and plaster based chiefly on lime as binding material as well as a paste for sealing joints in pressure ducts were examined. Experiments were carried out to imitate an expanding sealant described by Vitruvius. The causes for the great tightness, strength, and resistance of the ancient carbonate concretes were analyzed.

A-54 "Appearance of Concrete-Outcome of the Design" (in German). 1979 (Jan). Beton Herstellung und Verwendung, Vol 29, No. 1, pp 21-23, Dusseldorf, West Germany.

When judging the appearance of concrete, two aspects have to be taken into consideration: the appearance as a result of the architectural design and the appearance as a result of the construction work. The majority of the criticism refers to construction defects. This article discusses the influence of design and takes a look at the problems of weathering, soiling, and rainwater.

A-55 Rodway, L. E. 1979 (Feb). "Void Spacing in Exposed Concrete Flatwork," Concrete International: Design and Construction, Vol 1, No. 2, Detroit, MI.

Exposed sidewalks, curb, and gutter in the city of Calgary were used as examples of a means of improving concrete durability. Nearly 200 items affect durability of concrete both in temperate climates and cold regions. The Calgary concrete was subject to rigorous inspection at the time of placing and each year following, for 25 years. At placing, it met standard compressive strength requirements, the plastic entrained air requirements, and slump, i.e., it had conventionally accepted specifications and materials and was subjected to conventional enforcement. It was estimated that up to 16 percent of this type of concrete placed in the 25 years prior to 1972 had failed because of scaling, spalling, pitting, and general lack of durability.

A-56 Fromm, H. J. 1979. "Bridge Rebar Corrosion -- The Canadian Picture," Corros/'79, NACE, Katy, TX.

This paper provides an overall review of damage to portland-cement concrete structures in Canada, with special emphasis on concrete bridge decks. The damage is largely caused by corrosion of the reinforcing steel (rebars) and is manifest by cracks and spalls in the surface of the structure. The problem of corrosion of rebars in concrete bridge decks is not new; however, it has been only within the last 10 years that its full extent has been realized. The premature deterioration of these decks has now become one of the most serious problems facing transportation agencies across Canada.

A-57 Freedman, S., and Greening, N. R. 1979 (Apr). "Glass Stains: Causes and Remedies," Modern Concrete, Vol 42, No. 12, pp 36-39, 72, Chicago, IL.

In the past several years, a number of precast concrete firms have been the targets of lawsuits because glass stains and etching made new structures look shabby. This article on the properties of cement and concrete is intended to provide producers with some insights into the problem and facts with which to answer charges that alkalies in concrete are solely to blame. Causes of staining, problems with concrete and other materials, ways to minimize staining, and cleaning of glass are discussed.

A-58 "Concrete Finishing and Related Problems." 1979 (Apr). Concrete Construction, Vol 24, No. 4, pp 247-258, Addison, IL.

Common finishing problems encountered during placing and finishing, their prevention, and remedies are reported. Segregation, excessive bleeding, plastic cracking, surface blisters, pickup or peeling, scaling, dusting, and crazing are surface defects examined in the article.

A-59 Campbell-Allen, D. 1979 (May). "Reduction of Cracking in Concrete," Cement and Concrete Association of Australia.

Considerable attention is paid to the problem of cracking, but little to the significance of the crack in the situation in which it occurs. Some cracks are not harmful, but others cause serious defects in the strength, function, and appearance of concrete.

Particular kinds of cracks are examined including those leading to corrosion, failure, and malfunction. The causes of cracking, its relation to durability, flexural crack width and spacing, and carbonation are also discussed. The influences of types of material and temperature and shrinkage cracking are examined. Case studies with investigations of design defects, stresses, reinforcement, loads, and construction defects are given in detail. Conclusions and recommendations and two questionnaires on ways to reduce cracking of concrete are included in the appendix.

A-60 Gutt, W. H., and Nixon, P. J. 1979 (May). "Alkali Aggregate Reactions in Concrete in the UK," Concrete, Vol 13, No. 5, pp 19-21, London, England.

The deterioration of concrete in the United Kingdom due to alkali aggregate reaction (AAR) has only recently been recognized. In this paper a description is given of the nature of the reaction, the factors which are significant in causing it, and the precautions that can be taken against it. Research into the AAR of cement-aggregate combinations in the United Kingdom is being actively pursued. This paper is intended to give interim information to specifiers and users of concrete to enable them to decide if precautions against AAR are necessary for a particular structure and, if so, what precautions should be taken.

A-61 "Troubles with Architectural Concrete Finishes." 1979 (May). Concrete Construction, Vol 24, No. 5, pp 323-326, Addison, IL.

Imperfections in architectural concrete finishes, such as bugholes, honeycomb, sand streaks, discoloration, and dusting can result from a variety of circumstances. This article discusses ways to avoid these troubles.

A-62 "Twin Box Girder Bridges Develop Cracks in Joints." 1979 (May). Engineering-News Record, Vol 202, No. 22, pp 8-9, New York, NY.

One joint in each of a pair of concrete box girder bridges across the Kishwaukee River in Illinois has developed cracks. One of the structures is completed, while work had only recently begun on the other and is now suspended pending an investigation. The five-span bridges are made up of precast concrete segments. State bridge engineers, contractors, and designers say both structures, however, can be repaired.

Most serious is the interior crack in the deck slab of the completed bridge, resulting from a 5/8-in. drop of one corner of the first segment coming off the first pier out from an abutment. State officials say that the crack appears to be related to a failure of the epoxy used to achieve shear friction between the segments; the spalling pattern on the box indicates that the girder has been twisted. On the second bridge, a crack opened up 1/4 in. in the bottom of the center joint of six segments placed on falsework at the abutment.

A-63 Samarin, A. 1979. "Chemical Weathering of Concrete in Sub-Tropical and Tropical Regions," Controle de Qual des Struct en Beton, Stockholm, Sweden, 17-21 Jun, 1979, Vol 1, pp 275-282, Swedish Cement and Concrete Research Institute, Stockholm.

Concrete structures in subtropical and tropical regions are usually subjected to leaching action of neutral (rain) water in cycle with drying and high temperatures. A considerable volume of research has been carried out assessing durability of concrete in aggressive environments (acid attack, salt solutions, etc.), but long-term quality control of concrete durability in tropics is generally badly defined. To fill this

gap, an accelerated weathering test intended to evaluate durability of concrete under "normal" conditions of exploitation in tropical and subtropical regions is proposed, and some of the investigation techniques discussed.

A-64 Slater, J. E. 1979 (Jun). "Corrosion of Reinforcing Steel in Concrete: Magnitude of the Problem," Materials Performance, Vol 18, No. 6, pp 34-37, National Association of Corrosion Engineers, Katy, TX.

Magnitude of effects on concrete produced on steel corrosion from deicing salts and the economic consequences of these effects is discussed. Attention is given to deicing salt effects only, mainly on bridges, but not including attacks by sea marine environments. Mechanism of steel corrosion in concrete, detection methods, deck repair procedures, attack rates, and other details are presented.

A-65 Nixon, P. J., Collins, R. J., and Rayment, P. L. 1979 (Jul). "Concentration of Alkalies by Moisture Migration in Concrete-A Factor Influencing Alkali Aggregate Reaction," Cement and Concrete Research, Vol 9, No. 4, pp 417-423, Elmsford, NY.

The concentration of alkali metal ions caused by the movement of moisture in concrete has been examined by chemical analysis and x-ray microprobe analysis. It has been found that there is a significant increase in the concentration of these ions near the surface from which moisture is evaporating with local very high concentrations that have been due to the crystallization of alkali sulfates. The significance of this effect in promoting alkali-aggregate reaction is discussed.

A-66 Jambor, J., and Zivica, V. 1979 (Jul). "Concrete Corrosion Due to Action of Magnesium Chloride Solutions" (in Slovak), Stavebnicky Casopis, Vol 27, No. 7, pp 457-466, Bratislava, Czechoslovakia.

A description and results of tests of concrete corrosion due to the action of $MgCl_2$ solutions on concrete are reported. Formulas for the rate and degree of corrosion for specimens made of various cements are presented.

A-67 Grimes, W. D., Hartt, W. H., and Turner, D. H. 1979 (Jul). "Cracking of Concrete in Sea Water Due to Embedded Metal Corrosion," Corrosion, Vol 35, No. 7, pp 309-315, National Association of Corrosion Engineers, Katy, TX.

The phenomenon of concrete cracking in seawater has been investigated by impressing an anodic direct current upon the embedded metal and monitoring time to cracking. Various embedded metals were employed, and these are ranked in order of increasing concrete cracking time. Additional complementary experiments were conducted to consider the chemistry of the pore water in the vicinity of the metal-concrete interface of the impressed current specimens. These involved step-wise titration of a concrete saturated distilled water solution with various metal chlorides, and it was determined that certain chloride ion concentrations

can cause a pH shift to the acid range. The pH determinations from such titration experiments are in general agreement with pH measurements upon fractured faces of the concrete specimens employed in the impressed current tests. The experimental results are discussed within the frame of present theories for concrete cracking. It is concluded that concrete pore-water chemistry and corrosion product solubility are important variables with regard to concrete cracking.

A-68 Mather, B. 1979 (Sep). "Concrete Need Not Deteriorate," Concrete International: Design & Construction, Vol 1, No. 9, pp 32-37, Detroit, MI.

"Guide for Durable Concrete," prepared by ACI Committee 201, was published in the Dec 1977 ACI Journal. It classified the factors that can cause deterioration of concrete into five categories: (1) freezing and thawing, (2) aggressive chemical exposure, (3) abrasion, (4) corrosion of steel and other embedded material, and (5) chemical reactions of aggregates. The simple explanation of what one needs to do to achieve concrete that does not deteriorate is to follow the rules set forth in the Committee 201 report. However, it is believed useful to point out certain threads that run through the understanding of deterioration-producing processes and to consider the degree to which one appropriately balances increased protection against increased cost. Concrete will not deteriorate if the specifications covering its production are correct and are followed. It follows, therefore, that when concrete does deteriorate, the specifications were improper or they were violated. A proper specification is one that covers the requirements relating to the materials selection, mixture proportioning, and construction practice so that the concrete that is produced possesses the appropriate levels of relevant properties so as to resist, to a reasonable degree, for the intended length of time the deterioration-producing influences that will act upon it in the environment in which it must serve.

A-69 Shilstone, J. M. 1979 (Nov). "Surface Blemishes in Formed Concrete," Concrete Construction, Vol 24, No. 22, pp 719-725, 762-765, Addison, IL.

In this article, a concrete blemish is defined as any surface condition that causes a visual variation from a consistently smooth, uniformly colored concrete, and includes honeycombs, void pockets and pinholes, rock pockets, sand lines, bleed lines, lift lines, and color variations. The six general classifications of factors that can, singly or in combination, cause surface blemishes in concrete are: general work conditions, the concrete mix, placement techniques, compaction effect, forms, and other influences. These factors are discussed, and a table accompanying the article summarizes primary and secondary causes of surface blemishes in concrete.

A-70 Randall, F. A., Jr. 1979 (Nov). "Carbonation of Fresh Concrete Floor Surfaces," Concrete Construction, Vol 24, No. 11, pp 735-736, 749-750, Addison, IL.

Fresh concrete floor surfaces may be damaged within the first 24 hr of placing by the carbon dioxide from the exhaust gases of unvented heaters, but the chemistry is not well enough understood to explain why it happens sometimes and not others. Liquid membrane-forming curing compounds or plastic sheeting can be used to help protect the surface, thereby reducing the carbonation. Very efficient direct-fired heaters produce little carbon dioxide and may be effective, but the effectiveness of these preventive measures is not fully understood.

The state of the art requires careful monitoring of carbon dioxide and construction operations coupled with seasoned judgment or the use of vented heaters, if good hard concrete floor surfaces are to be built in the wintertime.

A-71 Chatterji, S., and Christensen, P. 1979 (Nov). "Mechanism of Breakdown of Limestone Nodules in a Freeze-Thaw Environment," Cement and Concrete Research, Vol 9, No. 6, pp 741-746, Elmsford, NY.

Sand and gravel quarried in Denmark and North Germany usually contain a significant fraction of limestone. Use of these aggregates in concrete making tends to give rise to so-called "winter popouts." These popouts, though disfiguring to the concrete surfaces, are not known to cause any damage to the concrete structures as such. The types of limestone nodules which give rise to winter popouts in concrete are liable to fracture during the winter months if left exposed in their quarries. In this paper, some field observations and some laboratory experiments on the breakdown of free limestone nodules due to freezing are described. These observations may have some relevance to frost damage of concrete.

A-72 Copier, W. J. 1979 (Nov). "Spalling of Gravel Concrete and Lightweight Concrete When Exposed to Fire" (in Dutch), Cement, Vol 31, No. 11, pp 499-503, Amsterdam, The Netherlands.

The project was carried out to determine which factors were responsible for the explosive spalling of large and small pieces of concrete from a surface exposed to heat. It was demonstrated that the moisture content of the concrete played the greatest part. The reduction of moisture content in concrete structures takes years. The more concrete cover on the reinforcement, the more the chance of spalling is reduced. Moreover, there are forms of spalling which are influenced by other factors. The author states that these tests have to be placed within the general framework of fire-resistant concrete construction.

A-73 "Special Issue: Challenge for Severe Environments" (in Japanese). 1979 (Nov). Concrete Journal, Vol 17, No. 11, pp 2-91, Japan Concrete Institute, Tokyo, Japan.

This special issue is divided into two parts: concrete under severe

environments and concrete construction under severe conditions. The first part covers: concrete exposed to high temperatures; liquid natural gas storage tanks; chemical plants and concrete; abrasive and scouring damage to concrete dams; and concrete in the ocean environment. Topics in the second part include: dam construction in frigid zones; concreting in the Middle East; and setting and hardening of mortar under continual sea wave.

A-74 Fraczek, J. 1979 (Dec). "ACI Survey of Concrete Structure Errors," Concrete International: Design & Construction, Vol 1, No. 12, pp 14-20, Detroit, MI.

Two hundred and seventy-five cases of errors in concrete structures were reported in a survey of consulting engineers and government agencies in North America conducted by ACI Committee 348. The survey indicated that about three-quarters of the errors were actually detected by the structure, with 39 cases of collapse and 172 cases of distress, cracking, spalling, leakage, settlement, deflection, or rotation reported. About one-half the errors originated in the design and the other one-half occurred during construction, with each phase responsible for about the same number of collapses. Of the errors due to faulty construction, almost three-quarters were detected during construction and over one-half resulted in failure or distress. Most design errors, however, were detected during occupancy and most resulted in serviceability problems. The survey only reported 11 errors detected prior to construction, with about 60 percent detected during construction and the remaining 40 percent detected during occupancy.

A-75 International Commission on Large Dams. 1979. "Transactions -- Proceedings, 13th International Congress on Large Dams, New Delhi, India, 29 Oct - 2 Nov 1979, Vol 4, Paris, France.

The four volumes contain 229 papers presented at the Congress and ten general reports from national committees, all of which are indexed separately. Also included are general reports on three of the four questions discussed at the Congress. The papers are grouped under the four discussion questions, which are: interface problems of dams; deterioration or failure of dams; large capacity spillways and outlets; and seismicity and aseismic design of dams. The questions are considered for the various types of dams and related works and for the various types of materials used in dam construction, including arch dams, buttress dams, gravity dams, earthfill and rockfill dams, concrete dams, cofferdams, hydraulic structures, spillways, bottom outlets, and others.

A-76 Davis, D. E. 1979 (Dec). "Cement Aggregate Reaction," Concrete/Beton, No. 16, pp 8-11, Johannesburg, South Africa.

The precise mechanism of the cement-aggregate reaction causing deterioration of some concrete in the South Western Cape, South Africa, is still obscure. Nevertheless, investigations overseas and in South Africa have identified three conditions that must be satisfied to enable the reaction to take place. In this paper, these conditions are

described in some detail and the salient features associated with this type of reaction are explained.

A-77 Hobbs, D. W., and Gutteridge, W. A. 1979 (Dec). "Particle Size of Aggregate and Its Influence Upon the Expansion Caused by the Alkali-Silica Reaction," Magazine of Concrete Research, Vol 31, No. 109, pp 235-242, London, England.

Measurements of the expansion behavior of mortar bars containing various proportions of a reactive porous opaline rock are described. It is shown that the age at which cracking occurred is essentially independent of particle size, and that the alkali-silica reaction rate is primarily a function of particle volume.

A-78 Shimada, H., Okada, H., and Nishi, S. 1979 (Dec). "Corrosion Resistance of the Cu-W Bearing Steel Bar Embedded in Reinforced Concrete Exposed in Salt Water Environments" (in Japanese), Concrete Journal, Vol 17, No. 12, pp 89-98, Tokyo, Japan.

The application of sea sands in concrete building in Japan has increased due to lack of river sands; however, chloride ions contained in sea sands have a harmful effect (corrosion) on the steel reinforcing bars in concrete structures. In 2 years of exposure tests of various steel reinforced concrete blocks at the splash zone in Tokyo Bay (mostly corrosive environments), it was found that the "Cu-W" bearing steel bar shows much higher resistance against localized corrosion attack due to chloride ions than the ordinary commercial steel bars.

The same steel bars examined in the accelerated field test were prepared for laboratory tests. The anodic polarization of the passivated film and metal of these specimens were examined by means of potentiostatic electrolysis. In addition, the variation of the static potential of these specimens with time difference was examined. All of the obtained results proved that the Cu-W bearing steel bar is superior to the commercial ordinary steel bar in the resistance against localize corrosion attack due to chloride ions.

A-79 Pat, M. G. M., and Reinhardt, H. W. 1979. "Erosion of Concrete," Instituut TNO voor Bouwmaterialen en Bouwconstructies, Delft, Vol 24, No. 3, The Netherlands.

Within the context of this research, erosion is taken to mean the wearing away of a surface by water and the sediments carried along in it. In structures in the sea, erosion may be a phenomenon of attack if water carrying sand and silt regularly flows to and fro past the structure. The construction of the surge tide barrier in the Oosterschelde (Eastern Scheldt) was the direct reason for undertaking this research. Two testing methods were applied in this research, namely, abrasion testing on an Amsler machine and erosion testing in a specially built circular flume. The research comprised of 15 concrete mixes with the following variables: the cement content, the water-cement ratio, the aggregates, the curing treatment, and the addition or absence of an admixture. The

28-day cube strengths ranged from 21 to 48 N/sq mm. All the erosion tests resulted in a generally similar erosion behavior pattern: initially (in the first 40 hr) there was considerable wearing away of the outer skin of the concrete (a few millimeters), after which the wear increase slowed down and was followed (after 80 hr) by a period of fairly constant rate of wear lasting to the end of the test (240 hr). The latter part of the test appeared most suitable for assessing the behavior of a structure with an intended long working life.

A-80 Dumitrescu, I., and Manoliu, S. 1979. "Influence of Reactive Aggregate with Alkalies in Cement on the Freezing-Thawing Resistance of the Concretes," Technical Scientific Papers - Institutul de Studii si Projectari Hidroenergetice, Vol 5, Bucharest, Romania.

The paper discusses a freeze-thaw successive durability test to determine alkaline reactions in concretes made with reactive aggregates, as well as accumulated experimental data on freeze-thaw durability. Results confirm the assumption concerning the negative influence exerted by the presence of the reactive particles in the aggregates on the sensitivity of the concrete to frost, as a result of the reaction between the aggregates and alkalies in the cement.

A-81 Campbell-Allen, D., and Lau, B. 1979. "Cracks in Concrete Bridge Decks," Civil Engineering Transactions, Vol CE 21, No. 1, pp 1-9, Barton, Australia.

A study of cracks in concrete bridge decks as reported in the literature and observed in New South Wales, Australia, shows that certain types of cracks are predominant in particular bridge types. Cracks in composite bridges and in cast-in-place curbs and cantilever deck slabs are shown to be largely due to the combination of temperature, shrinkage and traffic effects and may be controlled by increasing the amount of reinforcement. Cracks in bridges incorporating pretensioned units or constructed as voided slabs are apparently largely caused by settlement and can be corrected by appropriate construction procedures.

A-82 "Durability of Concrete Bridge Decks," 1979. NCHRP Synthesis No. 57, Transportation Research Board, Washington, DC.

This synthesis of design and construction practices will be of special interest and usefulness to bridge engineers and others seeking information on design, construction, and maintenance of bridge decks. Detailed information is presented on the causes, prevention, evaluation, and rehabilitation of deck deterioration related to corrosion of steel reinforcement. The report reviews design and construction techniques currently in use to prevent deterioration of new bridge decks and also evaluation and rehabilitation techniques used to extend the service life of existing decks. Recommendations are included for research needs related to bridge deck durability.

A-83 de Sousa Coutinho, A. 1979. "Aspects of Sulfate Attack on Concrete," Cement, Concrete, and Aggregates, Vol 1, No. 1, pp 10-12, American Society for Testing and Materials, Philadelphia, PA.

This paper discusses three aspects of sulfate attack on concrete that are important in understanding the development of sulfate-resisting concretes. These are: the importance of a precipitated layer of reaction products at the surface of the concrete, the role of aggregate type in the formation of ettringite, and the importance of the alkalinity of the medium in which the ettringite is formed. It is shown that alumina of kaolinized feldspar react with sulfates in a supersaturated lime medium, giving rise to expansive ettringite. It is also shown that lowering the concentration of lime in the medium inhibits expansion; this is accomplished by replacing 40 percent or more of the cement with pozzolan.

A-84 Babovic, A. 1979. "Special Conditions and Measures for Providing Durability of Reinforced Concrete Objects in Sea Waters on Sea-Shore - A Proposition for Amendment of Regulations Relevant for Concrete and Reinforced Concrete" (in Yugoslavian), Nase Gradevinarstvo, Vol 33, No. 5, pp 12-14, Belgrade, Yugoslavia.

Special measures are required to ensure the stability and durability of marine structures exposed to the aggressive influence of seawater. In the article, the mechanism of corrosive attack of seawater on concrete is analyzed emphasizing sulfate attack. The mechanism of reinforcement corrosion in reinforced and preconstrained concrete is also described. Special measures are proposed for concrete and reinforced concrete construction in seawater and on the shore.

A-85 Kaczkowska, D. 1979. "Influence of Porosity Structure on the Cellular Concrete Resistance to Frost" (in Polish), Inzynieria i Budownictwo, No. 2, pp 67-70, Warszawa, Poland.

The purpose of tests on cellular concrete porosity and frost resistance was to find the difference in porosity structure of frost resistant and nonresistant samples. No dependence of the general volume of pores on the cellular concrete resistance to frost was found. A strong influence of pore volume distribution and of the manufacturing technology was observed. The porosity factors and their limit values for frost resistant cellular concrete were determined.

A-86 Copier, W. J. 1979. "Spalling of Normalweight and Lightweight Concrete on Exposure to Fire," Vol 24, No. 2, Heron, The Netherlands.

Under certain circumstances concrete can show violent spalling in fire tests. In real buildings, however, the conditions for violent spalling are rarely present. The results of fire tests can be evaluated in the following categories:

1. Explosive dislodging of a few large pieces of concrete from the surface; this results in serious damage and possible failure of the particular member.

2. Dislodging of small pieces of concrete at a few points on the surface; spalling occurs at the edges of members.

3. Gradual reduction of a cross section; this occurs mainly at very high temperatures.

4. Explosive dislodging of small pieces of concrete from the surface, occurring continuously; this results in serious damage and failure, especially in lightweight concrete.

From tests and practice it appears that both forms of destructive spalling (Points 1 and 4) are closely related to the moisture content of the concrete. To avoid or diminish the probability of spalling, the moisture content must be as low as possible. The drying time should also be as short as possible.

Along with the findings in this report and the causes of spalling related to moisture content, a number of other measures are considered to ensure a certain degree of fire resistance. These are applicable to normal weight and lightweight concretes.

The report, giving results of research, comprises literature research on spall of normal weight and lightweight concretes, theoretical experimental research on the behavior of moisture content in concrete under practical conditions, supplemental experimental research on spalling of lightweight concrete during a fire, conclusions, and recommendations.

A-87 Escalante, E., and Ito, S. 1979. "Bibliography on the Corrosion and Protection of Steel in Concrete," NBS Special Publication No. 550, National Bureau of Standards, Washington, DC.

This is a bibliographic list of published papers, reports, and talks about the corrosion of steel in concrete and related subjects. The references are presented in two forms: a subject index divided into six major subheadings and an author index in alphabetical form. A total of 394 references are listed covering the period from 1964 to November 1978.

The subject index is divided into the following subheadings: general survey and review; research on factors affecting the corrosion of steel in concrete; detection and measurement techniques; corrosion protection techniques; the effect of concrete mixture, admixture, and structural design on the corrosion of steel; and other fields relating to the corrosion of steel in concrete.

A-88 Netherlands Committee for Research. 1979. "Concrete and Sewage" in Dutch, Codes and Specifications for Concrete, Rapport No. 96, Zoetmeer, The Netherlands.

Reinforced concrete sewage treatment facilities and other structures that come into contact with sewage are often damaged, which necessitates protecting the concrete against attack. However, the extent and

seriousness of the damage has not been fully investigated. Inspections of 56 sewage treatment plants and 47 sewage pumping stations were carried out, and damage was investigated. It was concluded that attack of concrete takes place predominantly in locations where hydrogen sulfide is liberated from the sewage and where, at the same time, moisture content is high and ventilation is poor.

Concrete deficient in quality or not sufficiently dense is highly vulnerable to damage in a sewage environment. The placing, compaction, and curing of concrete in such circumstances must therefore be done with considerable care. Recommendations for the prevention of damage are given.

In highly aggressive environments it is necessary to take protective measures. The report offers some guidelines for this. Research on the behavior of a number of coatings and waterproofing agents was conducted. The investigations show that these protective treatments often fail to give adequate protection.

A-89 Darter, M. I., LaCoursiere, S. A., and Smiley, S. A. 1979. "Structural Distress Mechanisms in Continuously Reinforced Concrete Pavement," Transportation Research Record 715, Transportation Research Board, Washington, DC.

A study of distress types and mechanisms in continuously reinforced concrete pavement in Illinois is reported. The major purpose of the study was to determine types and amounts of distress so that improved maintenance and design procedures could be developed. The approximately 1,979 km (1,230 miles) of interstate highway surveyed consisted of 18- to 25-cm (7- to 10-in.) slabs over granular and stabilized subbases. Edge punchouts, steel ruptures, D-cracking, blowups, joint failures, lug rotation, longitudinal cracking, construction-related distress, pumping, and shoulder deterioration were found. Since the edge punchout is the major structural distress, its mechanism was studied in depth. Heavy truck loads, excess free moisture, deicing salts, construction practice, and poor aggregate quality in the slab are the major causes of distress. Slab thickness and foundation support have a very significant distress effect on the development of structural D-cracking and are causing severe deterioration on several projects. Overall, the performance of the thicker 23- to 25-cm (9- to 10-in.) slabs has been excellent under heavy truck traffic, but a number of thinner 18- to 20-cm (7- to 8-in.) sections have performed poorly and are showing an accelerated rate of distress development over time. The amount of distress expected to occur in the future indicates a need for more efficient and durable ways of maintaining continuously reinforced concrete pavement and for revised design procedures.

A-90 Jahlenius, A. 1979. "Damaged Concrete Balconies" (in Swedish), Bulletin 1/79, Royal Institute of Technology Department of Structural Engineering and Bridge Building, Stockholm, Sweden.

Previous investigations have found a reduction of load-bearing capacity

due to the presence of two or three separate layers of concrete in balcony slabs. This phenomenon was thought to be caused by frost action. This report comprises the manufacture of slabs with separate layers, test loading of the slabs, and the construction of a theoretical model. The separation into layers does not in itself constitute a risk factor; however, in combination with a method of construction providing no reinforcement support or inadequate reinforcement, there is an imminent risk of failure under standard loads.

A-91 Brown, R. W. 1979. Residential Foundations: Design, Behavior and Repair, 99 pp, Van Nostrand-Reinhold, New York, NY.

This book explains the causes of foundation failure and provides systematic techniques for diagnosis, repair, and prevention. Water behavior in soils, soil mechanics, and clay mineralogy are discussed as a background for understanding foundation design and stability. Foundation types are also examined, indicating how design is dictated by such factors as bearing soils, climate, construction, and structural load. The basic kinds of foundation failure are included with procedures for diagnosing the causes.

Intended as a reference for engineers, architects, appraisers, realtors, lenders, and homeowners, this volume provides photographs that depict the signs of foundation distress. Simple and economical maintenance procedures that can reduce foundation failure up to 50 percent are included information.

A-92 Berg, J. H. 1979. "Concrete Structures - Maintenance Considerations," Symposium on Concrete 1979, Cases and Concepts, Canberra, Australia, 28 Aug 1979, No. 79/9, pp 12-15, Institution of Engineering, Barton, Australia.

The most common types of serviceability problems requiring maintenance are those of water entry or loss, undesirable visual effects and the matter of public safety. Although the basic causes for the occurrence of such defects often involve a combination of what might be termed 'theoretical' effects (e.g., the properties of the materials used), the majority of the defects are caused by such 'practical' effects as inadequate detailing and construction deficiencies.

A-93 Everett, L. H., and Treadaway, K. 1979. "Deterioration Due to Corrosion in Reinforced Concrete," BRE News, No. 50, Winter 1979, pp 8-9, Building Research Establishment, Garston, Watford, England.

Some previous examinations of premature structural deterioration have involved corrosion of reinforced concrete. This final article discusses ways of assessing the deterioration caused by corrosion, methods of repairing the concrete, and the implications for future design and construction.

1980

A-94 Klose, N. 1980 (Jan). "Sulphides in Sewage Installations - Causes, Consequences, Countermeasures," (in German), Beton Herstellung und Verwendung, Vol 30, No. 1, pp 13-17, Dusseldorf, West Germany.

Since the last century, the use of concrete in sewage systems has proved very successful. Concrete resists the weak attack of the sewage without special protective measures. Under certain conditions, however, problems may arise in term of corrosion, odors, and job safety. The paper describes in detail the causes of sulfide formation in sewage systems, its consequences, and necessary countermeasures.

A-95 Vrable, J. B., and Wilde, B. E. 1980 (Jan). "Electrical-Potential Requirements for Cathodic Protection of Steel in Simulated Concrete Environments," Corrosion, Vol 36, No. 1, pp 18-23.

Experiments have been conducted to establish the conditions of potential, pH, and chloride ion concentration under which steel will corrode and can be protected against corrosion in simulated concrete environments. The hydrogen evolution potentials of reinforcing bars in these environmental conditions have been determined. The following results have been shown:

1. No corrosion occurs in AISI Grade 1036 steel exposed in the freely washed condition in saturated $Ca(OH)_2$ solutions containing amounts of NaCl. In crevices corrosion will occur when chloride ion concentrations are greater than 0.02 mole. Complete cathodic protection can be obtained by the use of an electrical potential.

2. Data obtained on the specimens indicate that the basic potential/pH diagram is correct for predicting susceptibility to corrosive attack.

3. Potentiodynamic anodic polarization studies indicate that in the presence of corrosive solutions some carbon steels will pit if the corrosion potential is greater than the critical pitting potential.

4. Hydrogen-bubble-evolution potentials on reinforcing bars are determined regardless of the chloride ion content of the solution and surface condition of the reinforcing bar. Decreasing the pH of the corrodent shifted the hydrogen-bubble-evolution potential upward.

A-96 Walker, C. H. 1980 (Mar). "Durability of Parking Structure Floors," Concrete International: Design & Construction, Vol 2, No. 3, pp 47-50, Detroit, MI.

The causes of deterioration of concrete structure floor slabs have been investigated and several types of deterioration are discussed. Relative durability characteristics of various types of parking deck floor slabs are presented and design and construction guidelines for durable concrete parking structure floors are proposed.

A-97 Deen, R. C., et al. 1980 (Mar). "Cracking in Concrete Pavements," Proceedings, American Society of Civil Engineers, Vol 106, No. TE 2, pp 155-169, Philadelphia, PA.

Several theories explaining the mechanisms and intervals of cracking of portland cement concrete pavements are reviewed. For plain and jointed pavements, the cracking interval was approximately twice the strength of the concrete. For new concrete with a 30-psi tensile strength after only a few hours, the drying shrinkage or cooling crack interval is approximately 60 ft. A theory of differential temperature expansion-contraction between concrete and steel explains the ultimate crack interval of continuously reinforced concrete pavements between 2 and 9 ft.

A-98 Peterson, C. A. 1980 (Mar). "Survey of Parking Structure Deterioration and Distress," Concrete International: Design & Construction, Vol 2, No. 3, pp 53-61, Detroit, MI.

Parking structures in the United States are subjected to different thermal, moisture, and chemical environments. This article primarily deals with observed deterioration and distress of open, unheated parking structures located in climates where deicing salts are used on nearby roads and highways. Some of the observations made, however, may apply to other structures and exposures.

A-99 Pettifer, K., and Nixon, P. J. 1980 (Mar). "Alkali Metal Sulphate - A Factor Common to Both Alkali Aggregate Reaction and Sulphate Attack on Concrete," Cement and Concrete Research, Vol 10, No. 2, pp 173-181, Elmsford, NY.

Cases of deterioration of concrete in which evidence of both sulfate attack and alkali aggregate reaction has been detected are described. A possible connection between these two mechanisms of attack on concrete is discussed with reference to theories of the enhancement of alkali hydroxides in the pore solution of concrete. It is suggested that sulfate attack on concrete by alkali metal sulfates may promote alkali aggregate reaction.

A-100 Hansen, O. R. 1981. "Durability of Concrete Bridges in Denmark" (in Swedish), Nordisk Betong, Vol 25, No. 6, pp 31-33, Stockholm, Sweden.

Seventy-nine bridges representative of the majority of recent motorway bridges in Denmark have been examined. Correlations between defects, consecutive damages, and crack grades are studied.

A-101 Kalyanasundaram, P., and Prasad, A. K. 1980 (May). "Performance of Concrete and Reinforced Concrete Components in Marine Environments," Report TR 11, Indian Institute of Technology Madras, India.

The report mainly pertains to the durability aspects, with particular reference to the corrosion of embedded reinforcing steels in concretes in marine environments. Part I of the report deals with an analytical

review of the available literature on the topic. In Part II, experimental investigation undertaken in the laboratory on incidence of corrosion of reinforcement in flyash admixed concretes in marine conditions is discussed in detail.

A-102 Kaneuji, M., Winslow, D. N., and Dolch, W. L. 1980 (May). "Relationship Between An Aggregate's Pore Size Distribution and Its freeze Thaw Durability in Concrete," Cement and Concrete Research, Vol 10, No. 3, pp 433-441, Elmsford, NY.

The relationship between the freeze-thaw durability of coarse aggregates and their pore structure was investigated. The pore size distribution of 14 aggregates was determined by mercury intrusion and compared to the durability factor derived from standard laboratory freeze-thaw tests. The results show that both the total pore volume and the median pore diameter influence the durability. Specifically, a lesser volume and a larger median diameter are associated with more durable aggregates and vice versa. An equation was developed that allows a prediction of the freeze-thaw durability from a measurement of the pore size distribution. The predictive equation was applied to aggregates removed from several Indiana highways and gave results that correlated well with the observed field performance of the concrete.

A-103 Figg, J. W. 1980 (May). "Rusting Reinforcement - The No. 1 Problem of Concrete Durability," Concrete, Vol 14, No. 5, pp 34-36, London, England.

Although the alkaline environment of hydrated cement acts as protection for embedded steel in reinforced concrete, rusting frequently occurs and is the single most important cause of poor durability of structural concrete. A significant proportion of corrosion damage in concrete construction is due to rusting. This rusting of manufactured steel reinforcement is costly and wastes natural resources.

To better understand this problem, the chemical reactions of the constituent materials must be studied. Portland cement materials are not pure compounds and the high solubility of sodium and potassium often present results in an excessively alkaline cement paste. Base metals such as steel are manufactured by energy-intensive processes which make them highly susceptible to reversion to a low-energy state. The high alkalinity of some cements is a perfect medium for steel to revert to this low-energy state, causing corrosion or rusting. Metals which corrode in this way are called electronegative because corrosion results when ions leave a negative charge on the metal.

A-104 Forrest, J. C. M. 1980 (Jun). "International Review of the Fire Resistance of Lightweight Concrete," International Journal of Lightweight Concrete, Vol 2, No. 2, pp 81-94, Hornby, England.

Lightweight concrete is generally chosen for its lower dead load rather than normal, or dense, concrete. Nevertheless, in building structures, its intrinsic thermal properties of high insulation result in buildings

with a higher fire resistance than those constructed from normal concretes. It is no coincidence that the increasing use of all concretes, normal or lightweight, for good fire-resistant properties has proceeded apace with the introduction of more stringent fire regulations for buildings.

This article reviews international guidelines and reports on fire resistance of lightweight concretes. For the design for fire resistance, two FIP/CEB reports contain all the needed information and recommendations. The reports are "FIP/CEB Guide to Good Practice - Recommendations for the Design of Reinforced and Prestressed Concrete Members for Fire Resistance" and "FIP/CEB Report on Methods of Assessment of the Fire Resistance of Concrete Structural Members." The article then reviews international reports on fire-resistant construction of tall structures using lightweight concrete and structural steelwork, and reports on fire attacks on lightweight concrete structures. In all cases of fire, the fire resistance of the structure was good, and the building was restored to usefulness with a minimum of repair or even no repair.

A-105 O'Brien, T. P. 1980 (Aug). "Concrete Deterioration and Repair," Proceedings, Institution of Civil Engineers, Part I, Design and Construction, Vol 68, pp 399-408, London, England.

Structural concrete is a durable material, capable of giving very long, maintenance-free service. Despite this, many owners have been faced with the need for extensive repairs to their concrete structures, and, sometimes, to programs of regular maintenance. The causes of deterioration in concrete are sufficiently well understood for the requirements necessary to produce sound concrete to be known. In "normal" buildings, concrete deterioration is avoidable. Problems may still be apparent, however, in the course of innovation and development. The technology of concrete repair has received insufficient attention in research and development. A range of techniques are available, but careful evaluation of a problem is required before the correct technique can be selected.

A-106 "Weathering of Concrete Buildings." 1980 (Aug). New Zealand Concrete Construction, Vol 24, pp 8-12, Porirua, New Zealand.

Some buildings weather better than others, and there are a variety of finishes that can be employed to facilitate uniform, esthetic weathering. Dirt, rainwater, and wind cause weather staining of buildings. Dirt that is not completely washed away by water is particularly a cause of unsightly staining. Rainwater flow can be controlled by the shape and texture of the surface, by facing the structure to direct rain, and by incorporating design features to prevent rainwater from flowing freely on the surface. Using these procedures, water is directed to completely clean each surface. Streaking and blotching result from incomplete washing.

Drip troughs on sills or exterior beams help prevent the flow of water across the underside of a projection. Full attention should be directed to this horizontal channeling of water.

Although simple and straightforward in themselves, plain walls are perhaps the most unpredictable of surfaces in regard to weather staining. Each side of a building may not weather the same because of different exposures to rain. Furthermore, the flow of water is often directed to the outer edges of the walls, leaving them relatively clean compared to the rest of the wall. Exposed aggregate finishes tend to channel water between the particles, forming streaks of stain. Joints in precast concrete cladding panels must be detailed carefully so leaks and stains do not occur.

Run-off from parapets should be directed to fall off roofs, not on the building facade. Openings for windows and doorways should be designed so that rainwater flows evenly over them. Window frames should be stain-resistant and sills should be sloped to discourage accumulation of dirt.

A-107 Whitehurst, E. A. 1980 (Aug). "D-Cracking and Aggregate Size," Concrete Construction, Vol 25, No. 8, pp 593-598, Addison, IL.

The term D-cracking has been used for many years to describe a form of deterioration periodically observed in concrete pavements. The phenomenon has warranted increased concern recently and an extensive study has been completed in Ohio.

According to the Ohio study, D-cracking is a series of closely spaced cracks appearing "at the pavement wearing surface adjacent and roughly parallel to transverse and longitudinal joints and cracks, and the free edges of pavement slabs, and also to associated cracking preliminary to that appearing at the wearing surface." Maintenance operations often remove deteriorated D-crack sections, but the cause of the cracking is not eliminated.

The Ohio study evaluated approximately 4,500 miles (7,200 kilometers) of pavement, including surveys of joints and extent of cracking. The wide range in pavement ages at which no extensive D-cracking was observed suggested that the range of coarse materials which had been used provided a clue to determining susceptibility to D-cracking. The studies revealed D-cracking was initiated in the coarse aggregate rather than in the cement paste.

A test procedure similar to the one described in ASTM C 666 was used to identify durability of coarse aggregates, particularly when subjected to rapid freezing and thawing. In a series of laboratory tests, a maximum particle size scale was determined. The optimum size was approximately 1-1/2 in., with smaller variations within the acceptable range depending on aggregate quality.

It is recommended that each source of coarse aggregate be evaluated on an individual basis in regard to its potential for D-cracking. Gradation of coarse aggregate, with particular reference to maximum particle size, must be considered the single most important factor affecting the development of D-cracking. An aggregate found to be associated with D-cracking should be evaluated for these factors.

A-108 Aleksandroviskij, S. V., and Shtanko, A. E. 1980 (Sep). "Peculiarities of Frost-Related Decay in Cellular Concrete" (in Russian), Beton i Zhelezobeton, No. 9, pp 41-42, Moscow, USSR.

The decay of cellular concrete has been studied using the holographic method on both the freezing of the volume and freezing penetration from one side. The essential difference in strength deterioration in the surface layer and the internal body of the concrete is established together with the estimated deformation of the structure of concrete during cyclic freezing.

A-109 Dorussen, H. L. 1980 (Sep). "Corrosion of Concrete by Waste-Water" (in Dutch), Cement, Vol 32, No. 9, pp 532-536, Hertogenbosch, The Netherlands.

Several chemical processes which may cause corrosion of concrete when it is in contact with wastewater are reviewed. The aggressiveness of the environment is evaluated, a distinction being made between the external environment (groundwater, soils) and the internal environment (wastewater, air above the wastewater) of the concrete. Finally, consideration is given to a number of measures for the prevention or limitation of corrosion of concrete.

A-110 Piralov, T. S., Nevskij, V. A., and Ilyevskij, Yu A. 1980 (Sep). "Method of Rapid Determination of the Frost Resistance of Concrete" (in Russian), Beton i Zhelezobeton, No. 9, Moscow, USSR.

Data on the practical application of a method for the rapid determination of the frost resistance of concrete are discussed. The method is based on the successions of physical and mathematical models for the destruction of concrete by freezing.

A-111 Mather, K. 1980 (Oct). "Factors Affecting Sulfate Resistance of Mortars," Miscellaneous Paper SL-80-17, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

The ability of a mortar made using portland cement, fine aggregate, and water to resist attack by sulfates is affected by the proportions of the mortar (water-cement ratio and cement content), the maturity, the amount of tricalcium aluminate in the portland cement, the presence of tricalcium aluminate-sodium oxide solid solutions with different structures and reactivities, and the composition, reactivity, and amount of pozzolan used together with the portland cement.

Cements investigated included portland cements of Types I, II, III, and V meeting ASTM C 150 standards, blended cements including Type IP's meeting ASTM C 595 standards that were made from the same clinkers as the Type I's, and Type I's blended with pozzolans including fly ashes produced by burning bituminous, subbituminous, and lignitic coals, calcined natural volcanic glass high in silica, and silica fume. Silica fume forms glassy microspheres that may contain over 90 percent SiO_2; it is a by-product of the production of silicon metal.

Some of the fly ashes produced from subbituminous and lignitic coals replacing 30 percent by volume of cements increased the expansion of mortars containing the blends when stored in sulfate solutions. This behavior reflects SiO_2 below 50 percent, Al_2O_3 16 to 26 percent, and CaO 5 to 30 percent. Other investigations show that Al_2O_3 and CaO in the fly ash glass are readily available to combine with sulfate to form ettringite. With cement of lower C_3A content, some of the subbituminous and lignitic fly ash blends improved the sulfate resistance of mortars, except when SiO_2 in the fly ashes was 38 percent or less.

Type IP blended cements made with portland cement clinkers containing up to 11 percent calculated C_3A and about 20 percent fly ash show substantial improvement in sulfate resistance of mortars compared with Type I cements made from the same clinkers.

A-112 Ellingwood, B., and Shaver, J. R. 1980 (Nov). "Effects of Fire on Reinforced Concrete Members," Proceedings, American Society of Civil Engineers, Vol 106, No. ST 11, pp 2151-2166, Philadelphia, PA.

Recently developed thermal and structural analysis techniques show considerable promise for alleviating the extensive testing otherwise required for determining fire ratings for structural assemblies in the United States. In this study, temperature distributions computed in reinforced concrete members for several realistic fire exposures are examined and compared to the distributions measured in a standard test. Structural behavior during the different fire exposures is also considered. Analytical predictions of behavior are validated using experimental data.

A-113 Niel, E. M. M. G. 1980 (Nov). "Durability of Concrete Made with Blast-Furnace Cement in Sea Water Surrounding Countries with a Warm Climate" (in Dutch), Cement, Vol 32, No. 11, pp 730-735, Hertogenbosch, The Netherlands.

Laboratory tests were carried out concerning the durability of concrete in 30 °C sea water. The concrete was made of blast furnace cement (70 percent slag content) or of sulfate-resistant portland cement, and western European river gravel or material from the Middle East as aggregate. Corrosion processes developed considerably faster in warm sea water than in colder water (e.g., the North Sea). The concrete containing blast furnace slag behaved more favorably in the warm water than did the portland-cement concrete.

A-114 Kubic, J., and Zybura, A. 1980. "Analysis of Physico-Chemical Processes During Corrosion of Reinforced Concrete" (in Polish), Archiwum Inzynierii Ladowej, Vol 26, No. 3, pp 481-501, Warsaw, Poland.

A consistent analytical approach is applied to determine spreads of corroding concrete and reinforcement. Presented solutions lead to a method for calculating the changes in internal forces, thus to the life prediction of reinforced concrete structures under corrosive agencies. Diffusion equations are attempted to describe corrosion of concrete, and their integrals are analyzed qualitatively. Classes of functions are found for the time-dependent spread of corroded concrete. Concerning the corrosion of reinforcement, experimental evidence is reviewed, and an analytical description suggested.

A-115 Kubik, J., and Zybura, A. 1980. "Stress Changes in Reinforced Concrete Due to Corrosion" (in Polish), Archiwum Inzynierii Ladowej, Vol 26, No. 4, pp 639-656, Warsaw, Poland.

The influence of a chemically active environment on stress state is investigated. Reinforced concrete is treated as a homogeneous material with time-dependent mechanical properties. Equations for statically indeterminate structures are derived, based on the properties of aging systems. A reinforced concrete frame is analyzed whose beam is subject to corrosion in three different ways. The method can be applied when the class of corrosion is lower than the third according to Moskwin.

A-116 Netherlands Committee for Research, Codes and Specifications for Concrete. 1980a. "Spalling of Normalweight and Lightweight Concrete on Exposure to Fire" (in Dutch), CUR Report No. 98, Zoetermeer, The Netherlands.

In fire tests and actual fires, concrete structures can show limited areas of violent spalling. Fire tests can be evaluated by four categories: explosive dislodging of large pieces of concrete, resulting in member failure (destructive spalling with large pieces); dislodging of small pieces at edges of beams or columns (local spalling); gradual reduction of a cross section, usually at very high temperatures (sloughing off); and explosive dislodging of small pieces, resulting in member failure especially in lightweight concrete (destructive spalling with small pieces).

Tests showed both forms of destructive spalling to be diminished when the moisture content of the concrete was 5 to 7 percent or less. Usual initial moisture contents of 12 to 16 percent can be lowered by use of artificial drying or by providing an environment with strong drying action. The hygroscopic curve, diffusion resistance coefficient, and initial moisture content are combined in a formula for determining the drying process.

To obtain the shortest drying time, the hygroscopic curve should descend rapidly from the initial moisture content; pores and voids should be as coarse as possible. Moisture content, heating applied to

one or two sides, thickness, compressive stress from prestress or external loads, and reinforcement were the parameters that showed influence in fire tests. Material properties of porosity, permeability, heat conductivity, and tensile strength; coarse aggregate (for lightweight concrete); moisture distribution over a cross section; magnitude of compressive stress; and amount of reinforcement showed little influence in fire tests but can be expected to influence spalling during an actual fire.

In addition to the relation of moisture content to spalling, the report also presents possible measures for ensuring a degree of fire resistance in concrete structures.

A-117 Stark, D. C. 1980. "Alkali-Silica Reactivity: Some Reconsiderations," Cement, Concrete, and Aggregates, Vol 2, No. 2, pp 92-94, Philadelphia, PA.

This article examines failure of current methods to prevent deleterious alkali-silica reactivity, including use of low-alkali cements with certain volcanic aggregates. ASTM C 227, "Test for Potential Alkali Reactivity of Cement-Aggregate Combinations (Mortar-Bar Method)," may fail to detect this reactivity because the testing is usually applied only to high-alkali cements.

Concurrent testing, using both a range of high- and low-alkali cements, is recommended to determine the maximum safe cement alkali level for each aggregate. The traditional limit of 0.06 percent alkali is not sufficient for certain volcanic aggregates that require an even lower alkali, use of suitable pozzolanic materials, or both, to avoid deleterious reactivity.

A-118 Fagerlund, G. 1980. "Durability of Concrete Structures" (in Swedish), CBI Report No. 4:80, Swedish Cement and Concrete Research Institute, Stockholm, Sweden.

The concrete has many enemies but, in spite of this, the potential durability of concrete structures is very high. In moderately aggressive environments, the general durability level of the concrete can become even higher during a very long time. However, the durability of many concrete structures has been found to be defective. In many cases, this is due to the fact that the knowledge of the processes of disintegration which occur in the concrete was inadequate when these structures were constructed. In other cases, the damage was attributable to negligence in design or workmanship.

The long service life and high durability can imply that the durability problems relating to existing structures will increase in the future. In fact, theoretically speaking, the corrosion of reinforcement will take place sooner or later in all outdoor structures. It is therefore very important to evolve good methods for detecting corrosion while it is in process of development, for stopping corrosion, and for repairing concrete damaged by corrosion.

New structures shall be designed in such a way as to ensure very high durability. As early as the design stage, it is necessary to carry out a service life prediction for the structure, and to consider not only its short-time properties. At the present time, we have methods that render possible relatively reliable service life predictions, e.g., regarding the corrosion of reinforcement and the resistance to frost action.

A-119 Netherlands Committee for Research, Codes and Specifications for Concrete. 1980b. "Erosion of Concrete" in Dutch, CUR Report No. 99, Zoetermeer, The Netherlands.

Sand and silt flowing past sea structures is a form of erosion damage. Construction of a surge tide barrier in the Netherlands was the direct reason for this research on the resistance of concrete to erosive action. The accelerated tests most commonly used intensify the erosive action and result in an indication of long-term wear, although they are not absolute predictors of magnitude and behavior of individual materials.

The abrasion tests, one of two methods used in this research, were performed on an Amsler machine. Fifteen concrete cube specimens of varied mix proportions were examined. This standard test does not precisely resemble the conditions of running water erosion, but in the first stages the statistical results correlate well with the second test method, erosion testing in a specially built circular flume.

The flume erosion tests have many similarities with reality, but use abrasive material (gravel) different from that found in the sea. The erosion tests resulted in a generally similar erosion pattern: considerable initial wearing of the concrete skin was followed by a slower to constant rate of wearing. The latter part of the test that found the constant rate to be over 240 hr was most useful in assessing long-term durability of the structure.

The research found erosion decreased as compressive strength of concrete increased; poor quality concrete was quickly attacked by erosion. Good curing improved erosion resistance, thus reducing the detrimental effect of low compressive strength. Admixtures played no role in erosion resistance except when associated with changes in compressive strength. Only a slight relation existed between quantity of aggregate and erosion resistance.

In the literature surveyed on this subject, compressive strength was also found to be a key consideration. Coarse and fine aggregate additions had both been made with success.

A-120 Okada, K., and Miyagawa, T. 1980. "Chloride Corrosion of Reinforcing Steel in Cracked Concrete," Performance of Concrete in Marine Environment, Publication SP-65, American Concrete Institute, Detroit, MI.

This paper deals with corrosion of reinforcing steel, the most critical

problem for the durability of reinforced concrete structures in marine environment.

The results of tests using various electrochemical methods are summarized as follows:

(1) As the water-cement ratio of concrete increases, the natural potential of reinforcing steel becomes less noble and the electric resistance of wet concrete becomes lower due to low permeability which accelerates the corrosion of reinforcing steel.

(2) Cracks in reinforced concrete structures make reinforced concrete so heterogeneous as to cause macrocell corrosion of reinforcing steel.

(3) According to the experimental method used here, it may be considered that critical crack width is between 0.1 and 0.2 mm.

(4) Water-cement ratio influences both the macrocell corrosion rate at cracks and the mechanism of corrosion.

(5) It is concluded that the potential difference between macro anode (vicinity of cracks) and cathode (in concrete) is the electromotive force giving rise to the macrocell corrosion.

(6) As the ratio of cathodic area to anodic area increases, the macrocell current density and the corrosion rate at cracks becomes larger.

A-121 Mehta, P. K. 1980. "Durability of Concrete in Marine Environment--A Review," Performance of Concrete in Marine Environment, Publication SP-65, American Concrete Institute, Detroit, MI.

Case histories of deteriorated portland-cement concretes exposed to sea water, both in mild and cold climates, show that permeability is the most important characteristic determining the durability of concrete. Whether due to improper mix proportions, poor concreting practice, or cracking of concrete, permeable concretes tend to deteriorate in marine environment. This is because the hydration products of portland cement are chemically unstable to certain aggressive components present in sea water.

In this paper, the chemical reactions between the aggressive components of sea water and the constituents of hydrated portland cement are reviewed. The physical processes of deterioration associated with these chemical reactions are discussed. Also discussed are the fundamental anodic and cathodic reactions involving corrosion of reinforcing steel in concrete exposed to sea water. A summary of recent work on the effectiveness of various admixtures in reducing the permeability of hydrated portland cement is given.

A-122 Haynes, H. H. 1980. "Permeability of Concrete in Sea Water," Performance of Concrete in Marine Environment, Publication SP-65, American Concrete Institute, Detroit, MI.

For fully hydrated concrete of excellent mix proportions, the minimum void volume is about 10 percent. The largest portion of the void volume is located in the cement paste which, viewed by itself as a solid matrix, has a minimum void volume of 28 percent. The size of the voids in the hydrated cement paste are submicroscopic, but water molecules can move about and permeate the paste. Hence, the best concretes are permeable to water; however, the quantity of permeated water may be extremely small. Most of the published work on the permeability of concrete was based on using freshwater in the experiment. This paper summarizes some of the past work and presents results from a few studies on concrete exposed to seawater. One important new finding is that concrete permeated by seawater shows a decreasing permeability rate and it appears that permeability eventually stops. It is postulated that the reason for the decreasing permeability rate is the blocking of pore space by crystallization or precipitation of chemical products created by the interaction of seawater and hydrated cement.

A-123 Makita, M., Mori, Y., and Katawaki, K. 1980. "Marine Corrosion Behavior of Reinforced Concrete Exposed at Tokyo Bay," Performance of Concrete in Marine Environment, Publication SP-65, American Concrete Institute, Detroit, MI.

Reinforced concrete test specimens of 23 kinds were exposed on the sea in Tokyo Bay for about 1,000 days, and corrosion of the reinforcement in the concrete was measured. As the result, the following were disclosed: 1) Corrosion of the reinforcement in concrete is affected greatly by both the cover thickness and water-cement ratio; 2) Test specimens exposed from seawater into air had no corrosion produced in the submerged portion but had corrosion produced at a particular height above the sea surface; 3) Test specimens exposed in air above the sea surface had irregular partial corrosion produced; 4) Electric resistance of the concrete where corrosion occurred was low, and so was the natural potential of the reinforcing steel, and the corrosion occurred at valleys of the distributions of electric resistance and natural potential; and 5) From the foregoing, partial corrosion of the reinforcing steel in concrete is due to macro-corrosive current flow as the potential distribution in the reinforcing steel had peaks and valleys produced.

A-124 Yuan, R. L., and Chen, W. F. 1980. "Behavior of Sulfur-Infiltrated Concrete in Sodium Chloride Solution," Performance of Concrete in Marine Environment, Publication SP-65, American Concrete Institute, Detroit, MI.

This paper describes an experimental investigation into the behavior of sulphur-infiltrated concrete in a sodium chloride solution with respect to corrosion of the reinforcing steel. The plasticized

sulphur-infiltrated concrete as well as the elemental sulphur-infiltrated concrete were used in the investigation. The electrical measurement, both for natural process and accelerated process, has been used in this study as the criterion for the determination of the time to corrosion. The minimum sulphur loading is determined for concrete with different water-cement ratios, above which, the corrosion of reinforcement in concrete will not occur.

A-125 Beslac, J., Bjegovic, D., and Hranilovic, M. 1980. "Durability of Reinforced Concrete Elements and Structures Placed by Tremie in the Sea and with Slipforms by the Sea," Performance of Concrete in Marine Environment, Publication SP-65, American Concrete Institute, Detroit, MI.

The paper discusses the results obtained by testing concrete quality and the degree of reinforcement protection in the piles of the submarine tunnel for the Coke Plant at Bakar and in the walls of the water intake for the Rijeka Thermo-Power Plant, both placed by the tremie method. The shafts of the high chimney stacks of the Rijeka Thermo-Power Plant and the Bakar Coke Plant, erected by slipforms, were similarly investigated

The results obtained by tests and observations show that concrete for thin and highly reinforced elements, to be placed by tremie, must be made with pure portland cement, or portland cement incorporating slag having a low need of water for standard consistency, (measured according to Vicat), and with clean well-graded sand and coarse aggregate. Otherwise, mass concrete structures are preferred. Slipform erection of structures by the sea should be avoided, or, if used, the surface of the concrete should be protected additionally and completely (while slipform advancement is still under way) with cement mortar reinforced by the addition of polymer binders. This operation must be planned at the design stage and clearly specified.

A-126 Schrader, E. K., Dikeou, J. T., and Gill, D. 1980. "Deterioration and Repairs of Navigation Lock Concrete," Performance of Concrete in Marine Environment, Publication SP-65, American Concrete Institute, Detroit, MI.

Deterioration of navigation lock wall concrete due to freeze-thaw cycles is a serious problem usually attributed to ineffectiveness or a lack of air entrainment in the concrete. Most affected structures were made many years ago before air-entrained concrete was widely used. But, one of the largest locks in the world, Lower Monumental in Washington State, has been in service for only 10 years and also has serious surface deterioration.

A-127 Holm, T. A. 1980. "Performance of Structural Lightweight Concrete in a Marine Environment," Performance of Concrete in Marine Environment, Publication SP-65, American Concrete Institute, Detroit, MI.

The performance of structural lightweight concrete in a marine environment is reviewed beginning with the construction of concrete ships

in World War I. Major laboratory programs, utilizing different methods of evaluating the durability characteristics of structural lightweight concretes are described. Physical properties that influence the weathering characteristics of structural lightweight concrete that differ significantly from corresponding properties of normal weight concretes are reported. Long term field exposure of lightweight concrete structures, including a 60-year-old ship and a 25-year-old bridge deck are reported. Criteria for the construction of durable lightweight concrete structures exposed to marine conditions are recommended.

A-128 Lin, C. Y. 1980. "Bond Deterioration Due to Corrosion of Reinforcing Steel," Performance of Concrete in Marine Environment, Publication SP-65, American Concrete Institute, Detroit, MI.

Electrolysis has been used to investigate the deterioration of flexural bond in reinforced concrete structures under combined effects of exposure to marine environment and heavy sustained loads. Beams were loaded to develop specific crack widths, and loadings were then maintained to simulate the service condition. Direct current was impressed on the beams to accelerate corrosion of reinforcement so that the crack of concrete could be observed within the time limit of this investigation. The effects of impressed current on the reinforced concrete in relation to the crack width, sustained load, and overload are described.

Beams designed with tension reinforcement overlapped at midspan were subjected to impressed current until the concrete cracked. The average ultimate bond stress of the cracked beams was calculated based on the tension force developed in the reinforcement. A reduction in average ultimate bond stress due to corrosion of reinforcement is reported.

A-129 Tuutti, K. 1980. "Service Life of Structures with Regard to Corrosion of Embedded Steel," Performance of Concrete in Marine Environment, Publication SP-65, American Concrete Institute, Detroit, MI.

This report deals with a calculation model for the corrosion of steel in concrete. The aim has been to make a highly complicated durability problem sufficiently simple to obtain a survey of the importance of various factors for the service life of the concrete structure. Some researchers will doubtlessly regard the model as an excessively rough simplification of the actual process, but 90 to 95 percent of all corrosion problems that occur in practice agree well with this theory.

The service life for concrete structures with regard to reinforcement corrosion is broken down into an initial stage and a propagation stage. This breakdown is suitable since the primary parameters are different in the two subprocesses.

The penetration of various passivation-breaking and activation substances to the steel is studied in the initiation stage, as well as the concentrations giving rise to corrosion or a marked increase in corrosion.

The corrosion rate has increased considerably in the propagation stage and the factors determining the rate of corrosion thus become interesting. In addition, the degree of corrosion permitted with regard to load bearing capacity, esthetic aspects, etc must be determined.

The report also presents examples of a number of material coefficients which are necessary for the model.

A-130 Fidjestøl, P., and Nilsen, N. 1980. "Field Test of Reinforcement Corrosion in Concrete," Performance of Concrete in Marine Environment, Publication SP-65, American Concrete Institute, Detroit, MI.

The use of large offshore concrete structures for oil and gas production created several questions regarding the behavior of reinforced concrete in a marine environment. Some of these questions concerned corrosion of exposed and embedded steel.

This study reports the up-to-date results and conclusions from a test program that has been running since Dec 1976. A total of 70 reinforced concrete beams, some of them cracked, are submerged in the sea on the west coast of Norway. All specimens have been monitored intermittently by electrochemical methods, and some specimens were removed and broken open after 18 months of exposure.

A-131 Browne, R. D. 1980. "Mechanisms of Corrosion of Steel in Concrete in Relation to Design, Inspection, and Repair of Offshore and Coastal Structures," Performance of Concrete in Marine Environment, Publication SP-65, American Concrete Institute, Detroit, MI.

The corrosion of steel in concrete exposed to maritime conditions is dependent on the rate of chloride penetration to activate the steel, the resistivity of the concrete, and the oxygen diffusion through the cover regions. Reinforcement corrosion may result in spalling of the concrete depending on the depth of cover, the physical shape of the member, and the strength of the concrete.

The paper considers the mechanisms involved and relevant measurements made by the author's laboratory and others particularly in relation to offshore, coastal, and land based concrete structures in the North Sea, UK, and overseas. This work has implications both to the specification of concrete design details, inspection techniques, and remedial measures where corrosion or damage has, or might occur.

A-132 Malhotra, V. M., Carette, G. G., and Bremner, T. W. 1980. "Durability of Concrete in Marine Environment Containing Granulated Blast Furnace Slag, Fly Ash, or Both," Performance of Concrete in Marine Environment, Publication SP-65, American Concrete Institute, Detroit, MI.

This progress report describes the CANMET research project for the determination of durability of portland-cement/granulated blast-furnace slag/fly ash concretes in marine environment. The research project has been divided into three phases. Experimental work associated with

Phases I and II is partly completed, and the experimental work for Phase III will commence in May-June, 1980.

The work entails making mixtures of 0.1 m^3 size with water to cementitious materials ratios ranging from 0.40 to 0.60. The cementitious materials used employed various replacements of portland cement with fly ash and granulated blast-furnace slag. The prisms and cylinders have been installed at a natural weathering station at Treat Island, Maine, where they are exposed to the effects of the alternating conditions of immersion of the specimens in seawater then to cold air and the effects of more than 100 cycles of freezing and thawing per winter. The test specimens at Treat Island are being monitored at yearly intervals for visual deterioration, and measurements are being taken to determine changes in pulse velocity and fundamental resonant frequency.

A-133 Regourd, M. 1980. "Physico-Chemical Studies of Cement Pastes, Mortars, and Concretes Exposed to Sea Water," Performance of Concrete in Marine Environment, Publication SP-65, American Concrete Institute, Detroit, MI.

In a marine environment, the durability of permeable concrete is a function of the chemical resistance of the hydrated cement paste to sea water.

Portland cements with various amounts of C_3A, blast-furnace slag cements, and pozzolan cements were investigated. The test specimens were stored both in laboratory and natural sea water conditions.

The sequence of chemical reactions between the hydrated components and the aggressive ions dissolved in sea water was followed by scanning electron microscopy, electron probe microanalysis, and X-ray diffraction. It is concluded that as a result of diffusion of Cl^- and SO_4^{2-} ions, degradation of $Ca(OH)_2$ and C-S-H occurs due to the substitution of Mg^{2+} for Ca^{2+} and formation of secondary products such as $CaSO_4 \cdot 2H_2O$, $C_3A \cdot CaCl_2 \cdot 10H_2O$, $C_3A \cdot 3CaSO_4 \cdot 32H_2O$, and $CaSiO_3 \cdot CaSO_4 \cdot CaCO_3 \cdot 15H_2O$.

A-134 Conjeaud, M. L. 1980. "Mechanism of Sea Water Attack on Cement Mortar," Performance of Concrete in Marine Environment, Publication SP-65, American Concrete Institute, Detroit, MI.

Five kinds of commercial portland cements and one C_3S sample were used for the study. The test prisms were made of mortar with a cement-sand ratio of 1:3 and a water-cement ratio chosen to give an ASTM flow of 110 ± 5 percent. After 28 days water curing, the test prisms were immersed in seawater, then, at fixed periods, up to 3 years, they were investigated by means of strength tests, chemical analysis, X-ray diffraction, and scanning electron microanalysis. Results obtained show that SO_3 and especially Cl diffuse rapidly in the cement mortars, but their penetration is soon slowed down by the formation of an almost impermeable $Mg(OH)_2$ and/or aragonite layer on the mortar. It is postulated that this formation of a protective layer that occurs with all the cements investigated is the main reason why immersed cement mortars

are little attacked by seawater, even when the cement is C_3A-rich, whereas attack is greater at tide level where the $Mg(OH)_2$ and/or aragonite layer is subject to cracking.

A-135 Treadaway, K. W. J., Brown, B. L., and Cox, R. N. 1980. "Durability of Galvanized Steel in Concrete," Corrosion of Reinforcing Steel in Concrete, STP 713, American Society for Testing and Materials, Philadelphia, PA.

This paper discusses the results obtained from the galvanized steel specimens and compares them with those for the untreated steel examined in these studies. The results can be divided into a number of categories. Similar good performance (in terms of cracking of the cover induced by expansive corrosion of the reinforcement) has been exhibited by mild, high-yield, and galvanized steel in dense-aggregate good-quality chloride-free concrete. Where dense aggregate has been substituted by lightweight aggregate, cracking due to corrosion of the unprotected steel occurred at low cover, whereas identical prisms containing galvanized bars remained uncracked. The addition of high levels of calcium chloride (3.0 percent by weight and above with respect to the cement) to the dense-aggregate concrete caused severe corrosion of the high-yield bar and resulted in massive cracking of the cover. To date, this cracking has been less severe in similar specimens reinforced with galvanized steel, but results of weight loss measurement indicate extensive zinc loss in some specimens. However, much less loss of zinc has been measured on bars removed from concrete made without deliberate addition of chloride and from concrete to which up to 1.5 percent calcium chloride (by weight of cement) has been added. In the more permeable concrete mixed without added chloride, where carbonation has reached the test bar, plain steel has corroded and resulted in cracking of the cover, whereas with the galvanized bar some zinc loss has occurred but without fracture of the cover. The results suggest that, although some delay in cracking of the cover is achieved by the use of galvanized reinforcement, the greatest benefit would occur where it has been used in low-quality relatively permeable concrete containing low or minimal quantities of chloride.

A-136 Locke, C. E., and Siman A. 1980. "Electrochemistry of Reinforcing Steel in Salt-Contaminated Concrete," Corrosion of Reinforcing Steel in Concrete, STP 713, American Society for Testing and Materials, Philadelphia, PA.

Corrosion rates of reinforcing steel have been measured in concrete using the polarization resistance technique. The corrosion rates have been calculated for seven different sodium chloride contents and two different surface conditions of steel in concrete. The results from partially coated reinforcing steel specimens indicate the existence of a critical sodium chloride concentration between 0.1 and 0.2 percent by weight of concrete at which the rate of corrosion increases significantly. Anodic and cathodic Tafel slopes have also been determined experimentally. The high values of Tafel slopes may be attributed in

part to IR drop; however, more research is needed to clarify this matter.

A-137 Rider, R., and Haidersbach, R. 1980. "Degradation of Metal-Fiber-Reinforced Concrete Exposed to a Marine Environment," Corrosion of Reinforcing Steel in Concrete, STP 713, American Society for Testing and Materials, Philadelphia, PA.

The object of this research was to determine the effects of a marine environment on the integrity of metal-fiber-reinforced concrete. Metal-fiber-reinforced concrete has potential for uses in marine structures where the metal fiber may introduce tensile strength, abrasion resistance, and fatigue properties that might justify the added cost when compared with conventional concrete. Metal-fiber-reinforced concrete specimens were tested in flowing seawater and freshwater laboratory exposures. Comparisons were made to specimens exposed in the tidal zone of Narragansett Bay. Freeze-thaw experiments were also conducted. Results were obtained using standard and modified ASTM testing procedures as well as electrochemical corrosion rate monitoring techniques. The results indicate that stainless steel fibers are needed in marine applications.

A-138 Griess, J. C., and Naus, D. J. 1980. "Corrosion of Steel Tendons Used in Prestressed Concrete Pressure Vessels," Corrosion of Reinforcing Steel in Concrete, STP 713, American Society for Testing and Materials, Philadelphia, PA.

The purpose of this investigation was to determine the corrosion behavior of a high-strength steel, "Specifications for Uncoated Seven-Wire-Stress-Relieved Strand for Prestressed Concrete" (ASTM A 416-74, Grade 270), typical of those used as tensioning tendons in prestressed concrete pressure vessels in several corrosive environments, and to determine the protection obtained by coating the steel with two commercial petroleum-base greases or with portland-cement grout. In addition, the few reported incidents of prestressing steel failures in concrete pressure vessels used for containment of nuclear reactors were reviewed. The susceptibility of the steel to stress-corrosion cracking and hydrogen embrittlement and its general corrosion rate were determined in several salt solutions. Wires coated with the greases and grout were soaked for long periods in the same solutions and changes in their mechanical properties were subsequently determined. All three coatings appeared to give essentially complete protection; however, flaws in the grease coatings could be detrimental, and flaws or cracks less than 1 mm wide (0.04 in.) in the grout were without effect.

A-139 Rasheeduzzafar and Dakhil, F. H. 1980. "Field Studies On the Durability of Concrete Construction In a High Chloride-Sulphate Environment," International Journal for Housing Science and Its Applications, Vol 4, No. 3, pp 203-231, Pergamon Press, Elmsford, NY.

Field data are presented on the deterioration of concrete structures in habitations on the Gulf coast where the environment is characterized by

several interactive aggressive influences. The methodology of these durability studies is sequentially based on regional condition surveys, detailed studies of structural deterioration of concrete, chemical examination of samples from the deteriorated structures, and an interpretation of the deterioration mechanism based on the data from the aforesaid studies.

The relative importance of the operative causal factors is ascertained and the nature and incidence of reinforcing bar corrosion, concrete spalling, surface mortar deterioration, and early-age cracking are assessed. Field concrete from deteriorated structures is analyzed for the levels of chloride and sulfate concentrations, and the effect of sulfate-chloride interaction on steel corrosion is presented. Chloride migration in concrete is also studied in relation to the condition of the field samples. In the last section, recommendations are developed for obtaining improved durability of new concrete construction.

A-140 Wiebenga, J. G. 1980. "Durability of Concrete Structures Along the North Sea Coast of the Netherlands," Performance of Concrete in Marine Environment, Publication SP-65, American Concrete Institute, Detroit, MI.

Inspections were carried out on 64 normal weight reinforced concrete structures situated along the North Sea coast of the Netherlands. Almost all had been made with various amounts of blast-furnace slag cement. At the time of inspection, the ages ranged from 3 to 63 years. Visible signs of deterioration above the low water level were looked for, such as, spalling of the concrete surface, corrosion of the reinforcement, and cracks. Also, the concrete cover and the depth of the carbonation were measured at some places.

From five of these structures cores of 16- to 49-year-old concrete were taken, and their compressive strength, the depth of carbonation, total porosity, and cement content were determined. In addition, the amount of chloride penetrated into the concrete as a function of the depth was measured, both away from and near the cracks.

Conclusions are given herein determining which properties appear to be decisive for the durability of such structures in the sea environment.

1981

A-141 Kawadkar, K. G., and Krishnamoorthy, S. 1981 (Jan). "Behaviour of Cement Concrete Under Common Salt Solution Both Under Hydrostatic and Atmospheric Pressures," Cement and Concrete Research, Vol 11, No. 1, pp 103-113, Elmsford, NY.

As part of a study of durability of cement concrete in seawater, its behavior in common salt solution under large hydrostatic pressures is studied by employing accelerated testing techniques using small-sized specimens and increased concentrations of sodium chloride in the curing agent. The effect of common salt is brought out by studying scanning

electron micrographs and x-ray diffraction patterns and properties such as compressive strength, tensile strength, modulus of elasticity, permeability, pH value, and ultrasonic pulse velocity. Pressure produces accelerated effects of deterioration.

A-142 Pfeifer, D. W. 1981 (Feb). "Steel Corrosion Damage on Vertical Concrete Surfaces. Part I - Causes of Corrosion Damage and Useful Evaluation Tests," Concrete Construction, Vol 26, No. 2, pp 91-93, Addison, IL.

Good concrete provides an ideal environment for reinforcing steel because of its low permeability and high alkalinity that protects the steel. The iron in steel, however, tends to rust when design or construction inadequacies, long service life, or changes in service conditions occur. The steel loses strength as it rusts. Age of the structure, orientation of the concrete on the structure, intensity of the corrosive environment, and insufficient concrete cover for the steel all contribute to corrosion damage. The presence of dissimilar electrically conductive metals that accelerate corrosion, significant amounts of soluble chloride ion in the concrete, permeability of the concrete cover, and failure of previous repairs must also be considered.

A powerful arsenal of test methods is available to aid in the assessment of deterioration. Visual inspection, core samples, aggregate reactivity tests, sonic tests, and magnetic measurements are among the methods used. Active corrosion can be detected by direct measurement of current voltage potential. These tests are performed by skilled professionals and evaluated carefully.

A-143 Suga, Y. 1981 (Feb). "Instruction from the Defects of Reinforced Concrete Structures" (in Japanese), Concrete Journal, Vol 19, No. 2, pp 12-20, Tokyo, Japan.

Five categories of defects in structural design and construction are discussed. They are: defects in foundation work, including lack of bearing capacity of soil or pile, improper design of sheathing and retaining wall, settlement of first floor slab; defects of cantilevered structures, including corner design of cantilevered slab, cantilevered slab with concrete handrail on its top end, landing of concrete outdoor stair, long-spanned cantilevered beam; defects of slab, including cracking, deflection, and vibration hazard of long-spanned slab; defects of beams; and defects of columns, including shearing reinforcement and reinforcement of corner columns.

A-144 Schorr, K. 1981 (Mar). "Chloride Corrosion in Reinforced Concrete," Betonwerk und Fertigteil-Technik, Vol 47, No. 3, pp 150-152, Wiesbaden, Germany.

In the international regulations drafting committees, no agreement has been reached on the maximum permissible content of chloride in reinforced concrete. In Germany, occupying a middle position, individual

codes of practice for prestressed concrete with pretensioned tendons establish a limit of 0.2 percent chloride, based on cement weight.

A-145 Seki, H. 1981 (Mar). "Deterioration of Reinforced Concrete Wharf," Concrete International: Design & Construction, Vol 3, No. 3, pp 57-65, Detroit, MI.

The reinforced concrete pierced wharf inspected is located at the western part of Japan (the northern part of Kyushu Island) and has been exposed to comparatively mild natural and sea environments for 20 years. The structures are composed of reinforced concrete piles at the lower part and a reinforced concrete beam-slab system at the upper part. In each reinforced concrete member there is a different seawater condition, construction methods (concrete cast in situ, precast concrete), quality of concrete, and cover of reinforcement. The deterioration was discussed based on the field observation and the laboratory testing results of core specimens. The experimental results consist of such items as concrete compressive strength, estimation of mix proportioning, neutralization of concrete, salt content accumulated in concrete, cover, and corrosion of reinforcements.

Concrete members exposed to the tidal zone tend to contain higher salt content than those exposed above or in the seawater.

A-146 Vennesland, O., and Gjorv, O. E. 1981. "Effect of Cracks on Steel Corrosion in Submerged Concrete Sea Structures," Corrosion/81, Toronto, Canada, 6-10 Apr 1981, National Association of Corrosion Engineers, Houston, TX.

For submerged concrete structures, the effect of cracks cannot be considered without also taking into consideration the galvanic coupling with larger parts of the embedded rebar system. To simulate realistic testing conditions, a new experimental technique was developed. This technique is based on simulation of a large embedded rebar system by use of coupling to a separate stainless steel plate. Some preliminary test results on the effect of cracks are also presented.

A-147 Roberts, M. H. 1981 (Apr). "Carbonation of Concrete Made with Dense Natural Aggregates," Information Paper 6/81, Building Research Establishment, Garston, Watford, England.

The carbonation of normal dense concrete that results from the reaction of atmospheric carbon dioxide gas with hydrated cement compounds is discussed. Assessment of corrosion risk to embedded steel is emphasized. The carbonation process is described; how to measure carbonation extent is shown. Factors influencing depth and rate of carbonation and possible effects produced in hardened concrete are indicated. Applying organic coatings to concrete surfaces to prevent or delay carbonation effects is mentioned.

A-148 Nishibayashi, S. 1981 (Apr). "Resistance of Concrete to Seawater: Present Situation and Prospects of the Research in this Field" (in Japanese), Cement and Concrete, No. 410, pp 2-9, Tokyo, Japan.

This article explains factors influencing the deterioration of concrete in seawater. Results of international research on the resistance of concrete to the chemical action of seawater are presented. The durability of concrete immersed in seawater for a long time, evaluation of resistance of concrete to seawater by means of accelerated tests, and relations between chemical components produced during immersion, and the deterioration of concrete are covered. In conclusion, details are provided on two recent international meetings on submarine concrete structures and the most important research in this area that will be done in the near future.

A-149 Perkins, P. H. 1981 (Apr). "Corrosion Resistance of Concrete Sanitary Engineering Structures," Concrete International: Design & Construction, Vol 3, No. 4, pp 75-81, Detroit, MI.

The sanitary engineering structures covered by this article are tanks, pipelines, and tunnels holding and conveying domestic and industrial sewage and potable water. The article describes the fundamental requirements for resistance to corrosion in these structures. Details are given of the basic properties of portland cement, aggregates, and reinforcement that help to ensure long-term durability in reinforced concrete structures. The need to assess as accurately as possible the corrosion hazards when the structure are in contact with aggressive environments is discussed. Information is provided on the principles of protection for new structures and techniques for dealing with deterioration in older structures.

A-150 Mrazek, L. G. 1981 (Apr). "Resistance of Concrete Structures to Ozone Penetration," Concrete International: Design & Construction, Vol 3, No. 4, pp 69-74, Detroit, MI.

Ozone is presently used as a disinfecting agent in both water and wastewater treatment plants and is also used to treat odors in industrial and municipal facilities. Since ozone is an active oxidizing agent, the author initiated an extensive investigation and testing program to determine what, if any, detrimental effects the vaporous gas would have on concrete and reinforcing steel. The results of these investigations and subsequent recommendations should be of interest to consulting engineers, municipal engineers, and governmental agencies. Investigations included the following: use of special coatings, membranes, and linings, posttensioning for crack control; special concrete practices emphasizing crack control; galvanized reinforcing; and tests of concrete specimens in 3-percent ozone atmosphere for about 1 year. Based on the results of these investigations, the author recommends: using special concrete practices to control cracking and crack widths; minimizing expansion joints but employing control joints; and using galvanized reinforcing above liquid level.

A-151 Kish, G. D. 1981. "Control of Stray Current Corrosion on Reinforced Concrete," Corrosion/81, Toronto, Canada, 6-10 Apr 1981, National Association of Corrosion Engineers, Houston, TX.

Extensive underground concrete structures associated with direct-current railways are subject to deteriorating effects of stray current. While every effort should be made to effectively insulate the track system so that stray current leakage to structures is minimal, experience indicates that secondary measures for stray current control should also be taken. These measures must be applied during design and construction of the system. If stray current is allowed to traverse unplanned routes and gaps in such routes are indeterminate, current concentration of deteriorating magnitude can occur even if total stray is relatively small. Electrical continuity of all structures in sectionalized lengths is recommended provided with controllable gaps that can be monitored. Large underground buildings should be provided with an array of sensing electrodes to permit the detection and evaluation of small strays not otherwise manageable.

A-152 El-Sayed, H. A., Sayed, S. M., and Gouda, V. K. 1981 (May). "Factors Affecting the Premature Failure of a Reinforced Concrete Construction," Cement and Concrete Research, Vol 11, No. 3, pp 351-361, Elmsford, NY.

The factors responsible for the premature failure of reinforcement in the Pumping Station at Manzala Lake in Egypt have been investigated. Concrete analysis indicated that the water used contained a high concentration of salts. The total alkalinity of the cement showed that ordinary concrete has been used instead of dense concrete. General and pitting attack were observed microscopically on the reinforcement outside the building. Transgranular corrosion cracking was observed on the reinforcement of an external column carrying the building as well as on the reinforcement taken from two locations close to the pumps inside the building. The combined action of repeated stress due to the building vibration during operation of the pumps and the corrosive environment resulted in reinforcement cracking.

A-153 Bensted, J. 1981 (May). "Chemical Considerations of Sulphate Attack," World Cement Technology, Vol 12, No. 4, pp 178-184, London, England.

Chemical considerations of sulfate attack are briefly discussed. The effects of different sulfates; the causes of sulfate attack; sulfate concentrations; means of counteracting sulfate attack, the effects of slag, pozzolanic, and high-alumina cements; and the general basis of the phenomenon are considered.

A-154 "Hydrogen Attacks Prestressing." 1981 (May). Engineering News-Record, Vol 206, No. 20, pp 26-27, New York, NY.

Hydrogen embrittlement of steel prestressing tendons until now has been considered a rarity, but a draft report from Great Britain's National Physical Laboratory documenting such failures may force designers and contractors to reassess the threat. Hydrogen embrittlement, usually

accompanied by normal corrosion, results when hydrogen atoms from atmospheric moisture penetrate steel and upset its molecular structure. Examples of prestressing tendon failure due to hydrogen embrittlement in bridges in the US and Great Britain are discussed. It is noted that wire-wrapped tanks are the most common victims in the US.

A-155 Frey, H., Siebel, E., and Werse, H. P. 1981 (May). "Comparison Between Two Methods for the Determination of the Frost and Salt Resistance of Concrete" (in German), Beton Herstellung Verwendung, Vol 31, No. 5, pp 185-188, Dusseldorf, West Germany.

An investigation compared two test methods for determining the frost and salt resistance of concrete. The purpose of this study was to find out whether both methods produce corresponding results and support the field experience that a properly made air-entrained concrete has sufficient frost and salt resistance.

A-156 "Concrete in Sulphate-Bearing Soils and Groundwaters." 1981 (Jun). Digest 250, Building Research Establishment, Garston, Watford, England.

Factors responsible for sulfate attack on concrete below ground level are discussed. These are amount and nature of sulfate present, water table level and its seasonal variation, groundwater flow and porosity, form of construction, and concrete quality. Selecting the appropriate type of cement and concrete quality hinders ingress of naturally occurring sulfates. Sites are divided into five categories of increasing severity, based on sulfate content of soil and groundwater, to recommend cement type and minimum content. This discussion is supplemented by a table listing appropriate selections. Sampling and testing of groundwater and soil sampling and sulfate extraction are also briefly covered.

A-157 Tanaka, H., and Ishibashi, T. 1981 (Jun). "Repairs of Railway Structures Damaged by Fire" (in Japanese), Concrete Journal, Vol 19, No. 6, pp 3-11, Tokyo, Japan.

Because the space under railway viaducts is used for many purposes, fires sometimes occur under the structures. This paper describes reinforced concrete structures damaged by fire and some repair plans.

A-158 Rehm, G., Nurnberger, U., and Frey, R. 1981 (Jul). "On the Corrosion and Stress Corrosion of Prestressing Steel in Post-Tensioned Buildings" (in German), Bauingenieur, Vol 56, No. 7, pp 275-281, Berlin, Germany.

The necessary conditions for the appearance of stress corrosion cracking of prestressing steels in posttensioned buildings are exposed and explained. Investigation of a new case of damage is described. It was discovered that stress-corrosion cracking under natural conditions has to be traced back to hydrogen-induced-corrosion cracking. Corrosion scars multiply the tendency for crack formation. In this sense, water solutions of concrete in the tubes are relevant as they may induce intensive pitting corrosion by local contact with the steels.

A-159 Efes, Y., and Wesche, K. 1981 (Jul). "Judgement on Dissolving Attack of Mortar and Concrete" (in German), Beton Herstellung Verwendung, Vol 31, No. 7, pp 260-262, Dusseldorf, West Germany.

Test results are discussed; a distinction is made between corroded and eroded layers. Both layers may be identical, but essentially the corroded layer is thicker than the eroded.

A-160 Figg, J. W. 1981 (Aug). "Concrete Durability and Alkali Reactions,". Concrete, Vol 15, No. 7, pp 18-22, London, England.

The problem of concrete alkalinity as well as the benefits of the high pH of portland cement concrete are discussed. The alkalinity of the cement depends on the raw materials used for the manufacture of the cement; sea-dredged or high-alkali argrillaceous materials as well as use of dry-process or modern preheater cement kilns increase the eventual alkali metal content of the cement.

Aspects of the alkalinity problem including adverse effects of a high pH, alkali-aggregate reactions, and the parameters affecting reactivity are explained. Symptoms of the alkali-silica reaction such as map cracking, popouts, and damp spots are described. Preventive measures as well as possibilities for remedial action are outlined.

A-161 Kaminetzky, D. 1981 (Aug). "Failures During and After Construction," Concrete Construction, Vol 26, No. 8, pp 641-649, Addison, IL.

This article reviews many kinds of failures from nonconformity with design expectations through structural collapse, emphasizing that failures can be reduced by more competence in design, construction, and construction supervision. The author emphasizes that dangerous situations exist because facts about failure are not made public while litigation to assign liability proceeds.

Typical failures are analyzed, and reconstruction methods are described for torsional cracking in slabs and shear failure caused by construction error. Failure due to inadequate mudsills under shoring is also described. The recurrence of cracking and failures of precast concrete elements is charged to concealment of embarrassing facts involving loss of money; recurrent failures, however, are chiefly the result of inadequate awareness of the dangers in providing end restraint to precast elements. Four case histories are presented, and these simplified recommendations are made: avoid brackets and notches where possible; do not weld both ends of precast elements; and avoid bearing on unconfined edges. In addition, seven basic rules for preventing construction failures are included.

A-162 Chand, S. 1981 (Aug). "Preventive Measures for Cracks in Buildings," Indian Concrete Journal, Vol 55, No. 8, pp 217-221, Bombay, India.

Factors responsible for cracks in various types of buildings are identified in this article. The major categories of factors influencing

cracking are soil and foundation movement, thermal movement, drying shrinkage, weathering and chemical action, design and quality control, and unforeseen and seismic forces. Specific preventive measures to effectively minimize cracking development are suggested for each category. These measures are presented in detail from the planning and design stages to actual construction.

A-163 Kelly, J. W. 1981 (Sep). "Cracks in Concrete," Concrete Construction, Vol 26, No. 9, pp 725-734 (reprinted from Apr 1964), Addison, IL.

In two articles, the author examines different kinds of cracks and causes of cracking as well as prevention and control of cracking in concrete. In the first article, kinds of cracks are classified according to depth, direction at the surface, and other considerations. Cracking in concrete is explained as a process involving the increase of tensile stress until it reaches tensile strength. The relationship between cracking and drying shrinkage is discussed, and the way each of the following affects cracking is explained: water; cement; shrinkage-compensating cement; aggregates; admixtures; bleeding; placing; curing; temperature; exposure; restraint. The causes of cracking in fresh and hardened concrete are enumerated.

The second article begins by discussing which cracks are objectionable and why, considering such factors as leakage, collection of material, and cracking as an indication of deterioration. A general guide for tolerable crack widths at the tensile face of reinforced concrete structures is given. After emphasizing that using prestressed concrete is an excellent way to prevent cracking, the author closes with 10 recommendations for crack prevention addressed to everyone concerned with concrete, from the architect to the field workman.

A-164 Fookes, P. G., Pollock, D. J., and Kay, E. A. 1981 (Sep). "Concrete in the Middle East (2) - Rates of Deterioration," Concrete, Vol 15, No. 9, pp 12-19, London, England.

Simple comparative observational techniques are applied to assess rates of deterioration of concrete in the Middle East. The higher deterioration rates are attributed to climate and environment, geology and materials, workmanship, and other factors. Rates of deterioration were empirically determined for 90 major and several hundred other concrete structures and plotted on a simple graph. Eight brief case histories with supplementary photos of deterioration defects are given. Aspects of concrete deterioration are provided in tabular form.

Four principal factors, apart from deleterious salts, that lead to particular problems are listed. Several changes in detailing and design philosophy are suggested. These include use of the lowest practical water-cement ratio for any reinforced or mass concrete use of high-quality mass concrete rather than reinforced concrete where possible in marine situations and 100-mm concrete cover to reinforcement in concrete subject to wetting and drying by saline water.

A-165 Schroeder, H. 1981 (Oct). "Stability of Foundations Under Frost Action" (in German), Bauplanung-Bautechnik, Vol 35, No. 10, pp 442-445, Berlin, Germany.

Two cases are considered: the base of the footing lying below or above the frost line of the soil. Formulas are given to determine the stability of the footing. Discussed are the influence of critical superimposed loads, perpendicular and tangential frost heave stresses, depth of frost penetration and surcharge, and thermal insulation to reduce frost action.

A-166 Kay, E. A., Fookes, P. G., and Pollock, D. J. 1981 (Nov). "Deterioration Related to Chloride Ingress," Concrete, Vol 15, No. 11, pp 22-28, London, England.

The last article in a three-part series concerned with the investigation of concrete and rates of deterioration of concrete structures in the Middle East covers the problem of chloride ingress. Case histories illustrating the three methods of ingress are discussed. Preliminary results are presented from tests to determine the effect of mix proportions and other characteristics of concrete on chloride penetration in hot marine conditions. Results of surface treatment trials are also included. General recommendations to overcome chloride related problems are provided. They include effective use of fibers or other noncorroding materials to replace conventional reinforcement, use of protective coatings to supplement production of a high standard concrete, and use of clean aggregates.

A-167 Prudon, T. 1981 (Nov). "Confronting Concrete Realities," Progressive Architecture, Vol 62, No. 11, pp 131-137, Stamford, CT.

Restoration and repair of reinforced concrete and cast stone structures built from 1900-1940 is a significant concern for architects, builders, and owners. Concrete materials of this age have reached a critical stage of their lifespan; a whole generation of buildings are beginning to require extensive repairs.

The history of concrete construction has always been closely related to developments and improvements in the cement, formwork, reinforcement, and admixtures technologies. The development of reinforced concrete construction has been more complicated as different materials have been tried and accepted. In the 1930's and 1940's, architects such as Frank Lloyd Wright helped explore and popularize the esthetic potential of concrete construction.

Weathering, failures, and deterioration, frequent problems in concrete, are the result of numerous factors, each of which must be analyzed before repair or restoration can proceed. Buildings built several decades ago were constructed according to different codes. This fact should not be considered a design flaw, but rather a factor to be accounted for in repair plans. For example, concrete cover specified at the turn of the century was probably substantially less than is

required today, when corrosion of reinforcement has become of more concern. In restoration work, the characteristics of the old and new concrete must be compatible to avoid premature failure. A study of materials available and used at the time of construction and a knowledge of previous quality standards is also required.

The most serious problem encountered in older concrete structures is corrosion of the embedded reinforcement or structural steel. Rust staining or cracking of exterior surfaces are indicative of this problem. Also of considerable importance, but difficult to establish, are the deterioration problems and failures inherent in the structural design and detailing. If design inadequacies can be established, accurate assessment of corrosion damage and its possible effects on structural strength can be made. Thermal exposure, weathering, and water runoff can also cause deterioration. Fortunately, only rarely is deterioration the result of structural failures.

The causes of deterioration and failure of historic concrete buildings are not always easy to identify, but satisfactory repairs can be made with readily available skills and materials. Thorough visual inspection to identify basic patterns of decay, accumulation of background design documents, and on-site structural tests form the evaluation approach used. Structural repairs can be made to reinforce the structure to accept greater loads or correct damage and inadequate structural repair. An increase in load-carrying ability is frequently accomplished by the insertion of a new frame of steel or concrete into the building. Cracks can be repaired with pressure injection of epoxides, shotcrete can be used to reline walls, and additional reinforcement can also be added.

A-168 Brown, P. W. 1981 (Nov). "Evaluation of the Sulfate Resistance of Cements in a Controlled Environment," Cement and Concrete Research, Vol 11, No. 5-6, pp 719-727, Elmsford, NY.

The maintenance of the pH of a sulfate solution, in which mortar specimens were immersed at a constant and predetermined value through controlled sulfuric acid additions, ensured that the sulfate ion concentration in solution remained invariant with time. The rates of sulfate attack of mortar specimens exposed to typical immersion and environmentally controlled conditions were compared. It was observed that environmental control significantly increased the rate of sulfate attack as measured either by strength loss or linear expansion. However, the strength changes and expansion observed occurred in a manner consistent with the severity of the test conditions imposed.

A-169 Kennerley, R. A. 1981 (Dec). "Efflorescent Deposits on Concrete," New Zealand Concrete Construction, Vol 25, pp 21-24, Wellington, New Zealand.

This article examines the nature and causes of efflorescence, defined as disfiguring deposits that sometimes form on the surface of cementitious products, concrete, or masonry walls. The deposits on concrete

consist of alkali metal or calcium salts that can be classified according to their solubility in water. Water in concrete acts as a solvent or vehicle for transporting soluble salts to the surface and promotes solution and crystallization. Curing prevents excess evaporation of excess internal water from concrete during the hardening period. Reducing the risk of efflorescence can be achieved by curing in humid air. Storage, concerned with effects of water external to the product, should be at a uniform temperature and humidity to have a uniform shade of concrete and prevent run-off and staining of products.

Major precautionary measures to minimize efflorescence are listed. Use of surface treatments and admixtures are briefly discussed. Two case studies of efflorescent deposits, one concerning soluble deposits and the other insoluble deposits, are treated.

A-170 Allen, R. T. L. 1981. "Concrete in Maritime Works," Cement and Concrete Association, Wexham Springs, England.

Fundamentally, maritime concrete construction is similar to construction on dry land, although greater care must be taken at every stage. Success is often linked to three main principles. First, allowances must be made for the inherently difficult working conditions by planning every step beforehand. Special attention must be given to the quality of materials and workmanship. Lastly, the work must be protected as much as possible during the concrete's vulnerable period.

The performance of concrete exposed to the sea is discussed, along with major causes of damage. The proportioning of materials for the concrete mix and suggestions for proper choice of aggregates are given. The limits of design for maritime structures, along with the most effective types of joint sealants to reduce maintenance requirements are suggested. Construction methods, both above and below water level, are explained. Proper repair procedures and discussion of effective repair materials are also included.

A-171 Lawrence, C. D. 1981. "Durability of Concrete: Molecular Transport Processes and Test Methods," Technical Report 554, Cement and Concrete Association, Wexham Springs, England.

The mechanisms of concrete deterioration in aggressive environments are reviewed, indicating the likely rate-controlling transport processes and estimating the speeds of deterioration. A discussion of test methods involving transport phenomena is given in light of requirements for predicting durability from basic material properties. Diffusion measurements employing gases are measurements shown to be both relevant to durability problems and easily carried out. The diffusion of water vapor from saturated specimens appears to be a rate determining step in many durability problems.

A-172 Vesikari, E. 1981. "Corrosion of Reinforcing Steels at Cracks in Concrete," Research Report 11, Technical Research Centre of Finland, Espoo.

The extent that reinforcements in concrete bridges were corroded at cracks and the greatest influences on corrosion of reinforcements were studied. Forty-eight road and railway bridges from 7 to 54 years old in different areas of Finland served as objects of the investigation.

The corrosion grade of reinforcing steels at cracks was visually estimated and the depth and width of a corroded area was measured. The factors chosen to explain corrosion were: age of a bridge, thickness of protective concrete cover, crack width, carbonation depth at cracked and uncracked concrete surfaces, the pH value of concrete in the vicinity of reinforcements, and the strength and chloride content of concrete.

The correlation of the corrosion grade with the pH and chloride content of concrete was clearly indicated. The corrosion grade was also shown to be dependent on the difference between the thickness of the protective concrete cover and depth of the carbonated zone at the crack. An equation to determine potentially dangerous crack sizes in bridge design is given.

A-173 Fagerlund, G. 1981. "Principles of Frost Resistance of Concrete" (in Swedish), Nordisk Betong, Vol 25, No. 2, pp 5-13, Stockholm, Sweden.

The critical spacing factor for freezing cement paste in pure water or in a 3-percent NaCl solution has been determined experimentally. Two methods, different in principle, give the same results. The critical spacing factor is almost independent of the water-cement ratio. If the air void distribution and the environmental characteristics are known, then the requisite air content can be calculated for each concrete. The importance of having a low water-cement ratio and a high air content is demonstrated by means of a service life analysis.

A-174 Shirley, D. E. 1981. "Construction Guide: Impurities in Concreting Aggregates," 2nd Edition, Publication No. 45.016, Cement and Concrete Association, Wexham Springs, England.

This guide lists minor constituents of natural and manufactured aggregates that are commonly considered undesirable. These are absorbent particles, alkali-reactive minerals, chalk, chlorides, clay, coal dust, iron compounds, mica, organic matter, shell, silt, sulfates, and sulfides. Each constituent is discussed separately, including type of aggregate it is found in, its effect, methods of estimating the amount present in the aggregate, and measures to counteract any adverse effects from its presence. The appendix suggests a way to estimate frequency of surface defects.

A-175 Ivanov, F. M. 1981. "Attack of Aggressive Fluids," Cement, Concrete, and Aggregates, Vol 3, No. 2, Winter 1981, pp 105-107, Philadelphia, PA.

This article deals with the present state of classification of aggressive fluids. The USSR codes on rating the corrosive attack of water as an environment are given. Methods of imparting higher corrosion resistance for concrete are briefly analyzed.

A-176 Johnson, S. M. 1981. "Deterioration, Maintenance, and Repair of Structures," reprinted ed., Robert E. Kriger Publishing Co., Inc., Melbourne, FL.

While design load safety factors are perfectly adequate to account for applied structural loads, inadvertent but repeated use of unsuitable details and/or practices can cause serious problems of maintenance in an otherwise structurally sound building. This text considers this frequently occurring problem and offers causes of defects and methods of repair.

Unsatisfactory details are repeated because designers and construction personnel do not know these details are troublesome or require corrective procedures. Design, construction, and maintenance work is often performed by separate departments; investigation of poor performance of a design or structure is limited. The author describes his experiences in identifying defects and in establishing liaison between the members of the construction team.

Three principal classes of construction - steel, concrete, and timber - are discussed, with data presented to show types and causes of deterioration and success of procedures to prevent or minimize their occurrence. Selection of proper materials, attention to design details, and insistence on proper construction practices are the basic principles emphasized. Detection and correction of defects is also discussed. Photographs show characteristics of several common forms of deterioration, and the author's experience relate proper identification, correction, and maintenance operations.

A-177 Harrison, W. H., and Teychenne, D. C. 1981. "Sulphate Resistance of Buried Concrete: Second Interim Report on Long-Term Investigation at Northwick Park," Building Research Establishment Report, Department of the Environment, Garston, Watford, England.

An investigation to assess the performance of various types of concrete exposed underground to the action of sulfate-bearing groundwater and to compare this with concrete cubes stored in controlled sulfate solutions is presented.

A-178 Monk, W. 1981. "Control of Blemishes in Concrete," Appearance Matters 3, Cement and Concrete Association, Wexham Springs, England.

This study aids in the identification of blemishes on the surface of

concrete structures so that their cause and prevention may be determined. Twenty-five photographs of different surface defects are provided. Each photo is accompanied by a short, physical description, its appropriate technical term, probable causes, and preventive measures. Pages from Visual Concrete: Design and Production, another publication in this series on concrete appearance, are given to assist in avoiding blemishes in the production of the concrete surface. A bibliography is provided for reference to more detailed discussions of surface defects. An appendix briefly discusses remedial measures.

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A-179 Zaman, M. S., Ridgway, P., and Ritchie, A. G. B. 1982 (Jan-Feb). "Prediction of Deterioration of Concrete Due to Freezing and Deicing Chemicals," ACI Journal, Proceedings, Vol 79, No. 1, pp 56-58, Detroit, MI.

This article presents a brief report on mechanical strength test results for cement paste specimens subjected to cycles of freezing and thawing in sodium chloride solutions. Also indicated is the importance of these tests in predicting the behavior of concrete in the presence of chloride based deicing chemicals under freeze-thaw conditions.

A-180 Mather, B. 1982 (Mar). "Concrete in Sea Water," Concrete International: Design & Construction, Vol 4, No. 3, pp 28-34, Detroit, MI.

Research on factors affecting durability of concrete in marine exposures has yielded data that permits practical measures to minimize the likelihood of damage. Further work is needed to fully elucidate the interacting roles of constituents of cement with the chloride and sulfate ions of seawater. Additional research is also needed to fully appreciate the mechanisms that may accelerate the corrosion of ferrous metal embedded in concrete exposed to the sea.

A-181 Schupack, M., and Suarez, M. G. 1982 (Mar-Apr). "Some Recent Corrosion Embrittlement Failures of Prestressing Systems in the United States," Journal, Prestressed Concrete Institute, Vol 27, No. 2, pp 38-55, Chicago, IL.

Recommendations are supplied to avoid corrosion embrittlement failure of prestressing steels. A limited survey was made to gather as much data as possible on incidents of prestressing steel corrosion that have occurred in the US during the past 5 years. From a near 100 responses to the survey, 50 structures were found with tendon corrosion. Of the 50 corrosion incidents reported, 10 cases of probable brittle failure related to stress corrosion or hydrogen embrittlement were cited.

A-182 Eaton, R. A. 1982 (Apr). "Potholes: The Problem and Solutions," The Military Engineer, Vol 74, No. 479, pp 160-162, Alexandria, VA.

This article analyzes causes of potholes and descriptions of preventative maintenance programs and patching procedures. A table comparing costs for different methods of repair is included.

A-183 Tuthill, L. H. 1982 (Apr). "Alkali-Silica Reaction - 40 Years Later," Concrete International: Design & Construction, Vol 4, No. 4, pp 32-36, Detroit, MI.

This article describes highlights of the discovery of and experience with alkali-silica reaction (ASR) since its identification 40 years ago. Special cases involving unusual materials are noted. Termination of significant ASR in three southwest arch dams, without diminishing the serviceability of interior concrete, is reported. Avoiding the problem by use of an acceptable, as well as economic aggregate, is discussed.

A-184 O'Neil, E. F. 1982 (Apr). "Durability of Post-Tensioned Concrete Beams Exposed to Severe Natural Weathering," Miscellaneous Paper SL-82-2, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

A study of the durability of post-tensioned concrete beams and of the types of end caps used to protect the anchorage systems from deterioration when subjected to severe environmental conditions was conducted. Twenty post-tensioned concrete beams, 254 by 406 mm (10 by 16 in.) in cross section and 2.44 m (8 ft) in length, were cast and placed at the mean tide elevation on the beach at Treat Island off the coast of Eastport, ME. The beams were subjected to wetting and drying cycles twice daily plus an average of 130 freezing and thawing cycles per winter for a period of 12 to 13 years.

During this exposure period, the beams were inspected annually to determine the condition of each end cap or plug, the joint between beam and cap or plug, and the beams themselves.

At the end of the exposure period, eight representative beams were returned to the laboratory for autopsy and analysis of the protective caps, the method of joint preparation, and the post-tensioning steel being protected.

The results of the durability investigation indicated, among other findings, that the end protective caps attached to the beams by reinforcing bars across the cap/beam joint experienced no cap failures; the epoxy concrete end caps provided the best protection to the end anchorages of all methods tested; and the post-tensioning wires in the beams experienced no structural damage over the exposure period provided they were encased in a flexible metal conduit and protected with portland-cement grout.

A-185 O'Neil, E. F. 1982 (Apr). "Durability of Reinforced Concrete Beams Exposed to Marine Environment," Miscellaneous Paper SL-82-1, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

A study was begun in 1950 to determine the effects of severe natural weathering on stressed, reinforced concrete beams of various compositions, and degrees of stress. The objectives of the study were to obtain information on the long-term weathering of air-entrained and nonair-entrained concrete beams containing steel of different compositions and types of deformation and having different levels of stress in the steel that would cause varying degrees of cracking of the concrete.

The beams were fabricated, cured, and loaded at the US Army Engineer Waterways Experiment Station (WES) in 1951, then shipped to Eastport, ME, and placed on the beach at the natural weathering exposure station on the south side of Treat Island, Cobscock Bay, Eastport, and Lubec. The beams were subjected twice daily to tidal cycles exposing them to wetting under considerable head and drying to surface dry conditions. In addition, during the winter months, the beams were subjected to cycles of freezing and thawing with each tide when the air temperature was at or below -2.2° C. The beams were inspected annually during the exposure period and evaluated by a team of inspectors to determine the degree of deterioration. Maximum crack widths were also measured annually beginning in 1956 and continuing until 1975, when the exposure period was concluded after 25 years of weathering.

At the end of the exposure period, 13 of the 82 beams still remained at the testing site. (By 1956, 60 of the beams, all fabricated from nonair-entraining concrete, had been destroyed by freezing and thawing.) Of the 13 beams remaining in 1975, 11 were returned to the laboratory for laboratory testing.

The results of the exposure study and the laboratory investigation indicated, among other findings, that stressing the steel to various levels of stress over the exposure period did not adversely reduce the moment carrying capacity of the beams even though rusting and spalling had occurred; corrosion to the steel could not be found at any flexural crack smaller than 0.40 mm; and sustained levels of stress to the reinforcing did not reduce the tensile properties of the steel to below acceptable standards.

A-186 "Thousands of U.K. Flats Condemned." 1982 (May). Engineering News-Record, Vol 208, No. 19, New York, NY.

This article briefly discusses reasons behind demolition orders for some United Kingdom public housing. The apartment buildings, built from precast concrete panels or system designs, have suffered from condensation, rotting wood window frames, crumbling cladding, and other problems since erection in the late 60's and early 70's. Frequent problems have occurred with a precast system marketed by a British company, usually resulting from poor details and shoddy workmanship, according to the British Government. The buildings are built from

precast panels bordered with joints of cast-in-place concrete. The precast panels on the exterior of the buildings contain an inner layer of polystyrene insulation and are leveled by screws and packed underneath with dry sand and cement.

A-187 Kasami, H., Izumi, I., Shinokaki, M., and Okuno, T. 1982 (May). "Pop-Out Formation on Concrete Surfaces Caused by Expansion of Aggregates" (in Japanese), Takenaka Technical Research Report, No. 27, pp 63-71, Tokyo, Japan.

Crater-shaped eruptions, or popouts, are often observed on concrete surfaces. These popouts are caused by internal pressure, created, for example, by hydration of dolomite clinker, freezing of water in porous aggregates, or alkali-aggregate reactions.

Popouts were observed on concrete surfaces a few years after construction. Their cause has never been reported and is not essentially different from alkali-aggregate reactions, etc. Through our investigations, we found that these popouts were caused by internal pressure, created by weathering of serpentinite aggregates in concrete. These popouts are not only a problem for concrete surfaces but also seriously affect the durability of concrete structures.

In this paper, the mineralogical mechanism of popout formation and the effect of popout on the mechanical properties of concrete are discussed. These results indicated that the internal pressure was created by the alteration of preexisting brucite during the weathering of serpentinite; these popout formations and the decrease of mechanical properties of concrete can be prevented by isolation from the atmosphere.

A-188 Jones, C. W., Miedema, D. G., and Watkins, J. S. 1982 (Jun). "Frost Action in Soil Foundations and Control of Surface Structure Heaving," Report REC-ERC-82-17, Bureau of Reclamation, Engineering and Research Center, Denver, CO.

This is a report on frost action in soil foundations that may influence the performance of irrigation structures. The report provides background information and serves as a general guide for design, construction, operation, and maintenance. It also includes information on the mechanics of frost action, field and laboratory investigations of potential frost problems, case histories of frost damage to hydraulic structures, and measures to control detrimental freezing to avoid damage. The structures mentioned include earth embankment dams with appurtenant structures, canals with linings, and various other concrete canal structures.

A-189 Fagerlund, G. 1982 (Jul). "Predicting the Service Life of Concrete Structures," Cementa AB, Danderyd, Sweden, Characterization and Performance Prediction of Cement and Concrete Conference, Henniker, NH,

Jul 25-30, 1982; Publication 82-15, pp 187-198, United Engineering Trustees Inc, New York, NY.

It is suggested that the qualitative but widely used concept 'durability' should be abandoned and be replaced by the quantitative concept 'service life'. If this is to be meaningful, however, reliable methods for service life prediction are needed. Such methods would enable us to achieve much more rational designs than we do today; consideration could also be given to such fundamental factors as the required service life, the consequences of failure due to lack of durability, and the cost of maintenance and repair.

A-190 St. John, D. A. 1982 (Sep). "Unusual Case of Ground Water Sulphate Attack on Concrete," Cement and Concrete Research, Vol 12, No. 5, pp 633-639, Elmsford, NY.

The attack by sodium sulfate on the concrete linings of three rail tunnels features a concentration of sodium sulfate by the evaporation of groundwater due to ventilation in the tunnels. Groundwater is drawn through the ballast and up the walls while undergoing continuous evaporation. When the solubilities of the salts naturally present in the groundwater are exceeded because of evaporation, they are deposited and, in the case of sodium sulfate, cause exfoliation of the concrete.

A-191 Mehta, P. K., and Gerwick, B. C., Jr. 1982 (Oct). "Cracking-Corrosion Interaction in Concrete Exposed to Marine Environment," Concrete International: Design & Construction, Vol 4, No. 10, pp 45-51, Detroit, MI.

Physical and chemical processes which lead to enlargement of the size and area of microcracks in concrete are classified. The electrochemical phenomenon responsible for corrosion of steel in concrete is reviewed. A cracking-corrosion model is proposed according to which significant corrosion of steel occurs when the permeability of concrete due to excessive microcracking becomes high enough to permit oxygen access to large areas of the reinforcement.

A-192 Deichsel, T. 1982 (Oct). "Efflorescence-Origins, Causes, Counter Measures" (in English and German), Betonwerk und Fertigteil-Technik, Vol 48, No. 10, pp 590-597, Wiesbaden, Germany.

Four different types of line efflorescence on concrete surfaces are distinguished. Because these blemishes are caused by a number of interacting influences, they present a complex and awkward problem.

A-193 "Fire Resistance of Reinforce Concrete Floor Slabs" (in Dutch). 1982 (Oct). Cement, Vol 34, No. 10, pp 642-646, Hertogenbosch, The Netherlands.

A summary of a research report into the fire behavior of reinforced concrete floor slabs, both freely supported and continuous, conducted at Gent State University, Belgium, is presented. A number of measures are proposed for enhancing fire resistance.

A-194 Murray, M. H., and Heiman, J. L. 1982 (Nov). "Discussion on Corrosion Problems in Reinforced Concrete Structures in Marine Environments," Transactions Institute of Engineering in Australia, Civil Engineering CE24, No. 4, pp 361-362.

The primary conclusion that there is no relationship between crack width and the extent of corrosion reinforcement in marine structures is questioned by Murray. It is pointed out that the field test results run counter to those obtained in the laboratory and that the impressed current method, used to obtain the laboratory results, and the construction of the test specimens both differ from conditions found with common structures. The author, in reply, acknowledges that, on theoretical grounds, the corrosion mechanism via impressed current method is considerably different from that occurring in a structure but draws attention to the marked similarity of corrosion attack in both laboratory and field tests. He discusses other arguments questioning his experimental approach and interpretation of results. In conclusion, the author suggests that the corrosion can readily occur in cracks only 0.1 mm wide is just as important, if not more so, than the lack of correlation between the amount of corrosion and crack width.

A-195 Monnier, T., and van Geest, J. M. 1982 (Nov). "Concrete Study - The Durability of the Concrete Structure" (in Dutch), Cement, Vol 34, No. 11, pp 774-781, Hertogenbosch, The Netherlands.

As part of the study of the durability of a storm flood barrier, emphasis was placed on the technological facets of the concrete. Topics discussed include the cooling of concrete, properties of young concrete with a view to prestressing, injecting cable sheaths, and others.

A-196 Malinowski, R. 1982 (Dec). "Durable Ancient Mortars and Concretes," Nordic Concrete Research No. 1, Chalmers University of Technology, Divivision of Building Materials, Goteborg, Sweden.

Data of previous investigations compiled with new tests and recent literature on engineering structures known for their unusual durability are presented from the Mediterranean mainly. The first chapter is related to surface protection by means of polishing plain and multiple layered mortar. The second chapter deals with structural lime mortar used in brick structures. The third is related to concrete in structures of high durability and the fourth to special engineering solutions of the antiquity. The composition and properties of the materials were studied in situ, in laboratory and in tests of simulation.

A-197 Sorensen, B., and Maahn, E. 1982 (Dec). "Penetration Rate of Chloride in Marine Concrete Structures," Nordic Concrete Research No. 1, Technical University of Denmark, Department of Metallurgy, Lyngby, Denmark.

Chloride penetration has been studied in some 15- to 20-year old concrete structures in the Danish Store Baelt area. The penetration follows an expression for diffusion in a semiinfinite system with constant

surface concentration. The surface concentration decreases to the original chloride content from about 15 m above water level. About 40 percent of total chloride is water soluble, but this percentage decreases with decreasing total chloride content. The critical condition for corrosion in the reinforcement is found to be about 0.06 wt percent chloride in the concrete but the corrosion attack is strongly dependent on the supply of oxygen.

A-198 Rand, C. V. 1982 (Dec). "Performance Studies of Bridges (Inspection and Maintenance)," Bridge and Structural Engineer, Vol 12, No. 4, pp 47-66, New Delhi, India.

This article discusses observations made of old masonry bridges and concrete bridges, uncovering some unknown information concerning the serviceability of bridges. Detailed performance studies of bridges highlighted that the in-service behavior of the structures, performance of materials, and correctness of design procedure are necessary to a good maintenance program.

A-199 LePatner, B. B., and Johnson, S. M. 1982. "Structural and Foundation Failures," McGraw-Hill, New York, NY.

Various practices that can cause dangerous and costly mistakes in the design or construction of a building are highlighted in an examination of 32 case histories of building projects that ended in litigation. For each case there is a narrative of events, a discussion of relevant technical problems, and a discussion of legal and contractual points.

Some of the cases involve the following: cracking of a posttensioned, multistory, rigid frame of a parking garage; cracking and distortion of masonry parapets of a building; structural failure of bearing seats and excessive deflection of a bridge; excessive settlement of foundations of a hospital; and bucking of columns, sag of ceiling, settlement of floor slab, and tilting of foundation walls in apartment buildings.

A-200 "Alkali Aggregate Reactions in Concrete." 1982. Digest, No. 258, Building Research Establishment, Garston, Watford, England.

This article concentrates on the alkali-silica reactions (ASR) of concrete in the United Kingdom. Siliceous aggregates form a calcium alkali silicate gel that imbibes water, producing a volume expansion that disrupts the concrete. Recognition of ASR is discussed, including external evidence to positive identification by microscopic examination. ASR's structural effects, its monitoring, and repair methods are briefly covered. Conditions necessary for ASR to occur and their avoidance are described. Use of cement replacement materials such as natural pozzolans, pulverized fuel ash, or granulated blast furnace slag to counteract ASR is discussed. Conditions needed for ASR to occur are concrete exposed to an external source of moisture, total cement alkali content of concrete mix exceeding 3 kg of equivalent Na_2O per m^3 or concrete exposed to an external source of alkali or alkali concentration by moisture migration, and a potentially reactive

aggregate. The similarities and differences between AST and alkali-carbonate reaction are mentioned.

1983

A-201 Gustaffero, A., Hillier, M. A., and Janney, J. R. 1983 (Jan-Feb). "Performance of Prestressed Concrete on the Illinois Tollway After 25 Years of Service," Journal of the Prestressed Concrete Institute, Vol 28, No. 1, pp 50-67, Chicago, IL.

The paper presents an overview of the performance of the precast prestressed concrete elements and structures on the Illinois State Toll Highway after 25 years of service. The condition of the bridge girders, stay-in-place deck panels, bearings, and bridge piers, together with any evidence of corrosion and freeze-thaw damage are discussed.

A-202 Saeki, N., et al. 1983 (Feb). "Resistance to Frost of Coastal Concrete to Using Blended Cement" (in Japanese), Cement and Concrete, No. 432, pp 2-9, Tokyo, Japan.

An investigation carried out in Hokkaido (the northern island of Japan), on coastal structures using blended cement proved that the majority of frost damage in these structures consists of peeling off (or scaling) of the concrete surface. The article presents the conditions in which the damage occurs, its development, and characteristics. The external (environment, freezing, and thawing) and internal (aggregates, cement variety, unit-cement quality, water-cement ratio) factors exerting an influence on concrete frost damage are examined. A summary of the factors exerting an influence on concrete frost damage are examined.

A-203 Beckett, D. 1983 (Feb). "Influence of Carbonation and Chlorides on Concrete Durability," Concrete, Vol 17, No. 2, pp 16-18, Leatherhead, England.

This article discusses how the hydration and carbonation process may hinder the durability of concrete and aid in corrosion. The most important influences of carbonation are shrinkage and neutralization of alkaline conditions of the hydrated cement paste. Corrosion is related to carbonation and chloride ion content. Carbonation reduces durability as the concrete cover is penetrated. Chlorides, found in admixtures, water and aggregates in marine environments, and penetration of the hardened concrete by exposure to deicing salts increase corrosion potential of reinforcement. Chlorides reduce the alkalinity of concrete, increase the flow of corrosion currents, and penetrate the passivating iron oxide film on the steel surface.

Recommendations and use of protective coverings are also briefly discussed.

A-204 Beeby, A. W. 1983 (Feb). "Cracking, Cover, and Corrosion of Reinforcement, Concrete International: Design & Construction, Vol 5, No. 2, Detroit, MI.

A study of design recommendations in various countries for the avoidance of reinforcement corrosion suggests that no real consensus exists on the levels of cover, concrete quality, and permissible crack width which should be specified. This paper attempts to assess the relative importance of these factors by reference to published data from exposure tests carried out in many countries. It is concluded that the width of cracks has far less importance in assuring durability than has generally been supposed and that the important parameters are the amount of cover and the quality of concrete. The possibility of a more rational design approach to corrosion control is discussed, but it is concluded that much of the information necessary to implement this remains to be established.

A-205 DeSitter, W. R. 1983 (Mar). "Even Concrete Calls for Attention," (in Dutch), Cement, Vol 35, No. 3, pp 188-193, Hertogenbosch, The Netherlands.

This paper was presented at the study day on repairs to concrete constructions. Subjects discussed in depth include the development of damage in time, the circumstances promoting corrosion consequent upon carbonation of concrete and the penetration by chlorides; further subjects involve the influence of coatings, the damage-criterion, the influence of crack formation, as well as the inspection of concrete constructions.

A-206 Buchhardt, F., et al. 1983 (Mar). "Structural Investigation of the Berlin Congress Hall Collapse," Concrete International: Design & Construction, Vol 6, No. 3, pp 63-68, Detroit, MI.

The sudden collapse of the southern arch of the Berlin Congress Hall roof prompted an investigation of the building's structural behavior. The report presented is part of an expert's report on the failure investigation covering structural defects, defects of the roof covering, defects of the prestressing cables and sheaths, and defects of the anchorage connections.

A-207 Hobbs, D. W. 1983 (Mar). "Possible Influence of Small Additions of pfa, gbfs, and Limestone Flour Upon Expansion Caused by the Alkali-Silica Reaction," Magazine of Concrete Research, Vol 35, No. 122, pp 55-58, Wexham Springs, England.

This paper presents experimental results which show that replacing 5 percent by weight of portland cement by four pulverized fuel ashes, a ground granulated blast furnace slag, or limestone flour has little effect on the expansion of mortar bars tested at their critical alkali-reactive silica ratio.

A-208 Randtke, S. J. (Ed.). 1983 (Apr). Proceedings - Twenty-Fifth Annual Public Water Supply Engineers Conference, 26-27 Apr 1983, Engineering for Water Supply in Today's Economy," University of Illinois at Urbana-Champaign, Department of Civil Engineering, Urbana, IL.

This conference proceedings contains 11 papers. Various topics discussed are: deteriorating infrastructure; water quality enhancement; low energy destratifier; concrete structure useful life extension; production maintenance; cost effectiveness; existing plant upgrading; improved pumping; transmission/distribution facilities; rehabilitation/expansion; water supply management objectives; water storage effective use; future funding; and human resource training.

A-209 "Concrete in Aggressive Environments." 1983 (Apr). New Zealand Concrete Construction, Vol 27, Porirua, New Zealand.

This article considers concrete under chemical attack. Situations where problems could arise are identified and discussed. A typical carbonic attack was observed inside two cleaning water storage tanks. Two solutions were considered; a cascade system to allow aeration to remove dissolved carbon dioxide was chosen.

A-210 Paul, D. 1983 (Apr). "Weathering of Hardened Concrete - Causes and Suggested Remedies," Indian Concrete Journal, Vol 57, No. 4, pp 97-99, Bombay, India.

Cement concrete behaves like an artificial calcareous rock and is vulnerable to weathering resulting in a shortened life span of the structure. Damage to concrete due to weathering has been studied in simulated laboratory conditions on over 540 concrete specimens. Experimental results confirmed that the concrete suffers damages and consequently loses its compressive strength to the extent of 30 to 40 percent. A richer concrete with lower water-cement ratio and replacement of 20 percent cement by weight with fly ash is shown to enhance the resistance to weathering. Based on the data obtained, it is recommended that fly ash be added to concrete hydraulic structures like canal linings, spillways, and dams.

A-211 Deloye, F. X., Maire, G., and Buisson, M. J. 1983 (Mar-Apr). "Use of Exudates as Primary Indicators of the Deterioration of Concrete and Masonry in Highway Structures" (in French), Bulletin de Liaison des Laboratoires des Ponts et Chaussees, No. 124, pp 25-30, Paris, France.

The presence of exudates (stalactites, concretions, efflorescences) on a structure results from the circulation of water inside the material (concrete or masonry). After reviewing the mechanism of formation of stalactites, some 10 characteristic examples are given showing the variety of causes of deterioration detected through exudates. A distinction is made between: (1) Exclusively calcareous exudates, separating the case where the limestone can originate only from the dissolution of the binder from that where it may originate either from the dissolution of the binder or from the dissolution of the aggregates, or

both, (2) Mainly, but not exclusively, calcareous exudates with other constituents making it possible to detect various mechanisms of deterioration such as alkali-aggregate reaction, sulfate attack, or alkaline carbonization of aluminates. (3) Slightly calcareous or noncalcareous exudates, which reflect very varied deteriorations such as the formation of rust from leaching of the soil or corrosion of reinforcing rods, sulfate aggressions, or attacks by various substances used on the structure (for example, chemical fluxes, weed-killers).

A-212 Poitevin, P., and Regourd, M. 1983 (Mar-Apr). "Durability of Concrete; the Case of Reactive Aggregates" (in French), Annales Institut Technique du Batiment et des Travaux Publics, No. 413, pp 109-143, Paris, France.

Describes deterioration of concrete structures that has been attributed to either the use of aggregates polluted by various elements (clay, chlorides, gypsum, etc.) or of aggregates that are weathered or reactive to alkalies. In particular, the mechanism of deterioration by alkali-aggregate reaction is examined by surveying investigations already performed. Preventive measures to be considered are then presented.

A-213 Dartsch, B. 1983 (May). "Durability and Building Preservation" (in German), Beton, Vol 33, No. 5, pp 170-174, Dusseldorf, Germany.

Some 240 experts attended the Federal Ministry of Research and Technology (BMFT) state-of-the-art seminar to discuss the durability and preservation of structures. Twenty-four lectures emphasized the need for building research and pointed out the priorities of this forum in the fields of damage to prestressed concrete structures, corrosion in concrete buildings, and newly developed special concretes are reported.

A-214 Allen, R. T. L., and Forrester, J. A. 1983. "The Investigation and Repair of Damaged Reinforced Concrete Structures," Corrosion of Reinforcement in Concrete Construction, London, 13-15 Jun 1983, pp 223-234, Society of Chemical Industry, London, England.

Deterioration of concrete structures may, in general, be divided into three stages. The first consists of changes in appearance, such as discoloration with local blemishes and staining; the second stage affects surface texture and is marked by scaling and cracking with, sometimes, a general break-up of the concrete surface; and the third stage of deterioration is a disruption with major spalling of concrete away from the reinforcement, which may eventually lead to failure of the structure. These stages of deterioration may be caused by various influences as described. The causes of corrosion of reinforcement and the remedy of the resulting damage are discussed.

A-215 Aziz, M. A., and Mansur, M. A. 1983 (Jun). "Deterioration of Marine Concrete Structures with Special Emphasis on Corrosion of Steel and Its Remedies," Corrosion of Reinforcement in Concrete Construction, London, 13-15 Jun 1983, pp 91-99, Ellis Horwood, London, England.

Concrete, both conventionally reinforced and prestressed, is being used extensively in the construction of various types of structures in marine environment. Long-term performance of marine concrete structures requires a careful procedure to be followed in both design and construction stages. Selection of materials, mix design, proper detailing of reinforcement, appropriate construction technique, and a strict control program are the essential parameters to produce a durable marine concrete structure. This paper presents the various factors affecting the durability of marine concrete structures and the mechanism of deterioration of concrete and corrosion of steel reinforcement by various aggressive sea salts. Results of laboratory and field investigations of some aspects of concrete deterioration are also reported. Preventive measures to be adopted in the design and construction stages are presented in an orderly form.

A-216 Popovics, S., Simeonov, Y., Bozhinov, G., and Barovskii, N. 1983. "Durability of Reinforced Concrete in Sea Water," Corrosion of Reinforcement in Concrete Construction, London, 13-15 Jun 1983, pp 19-38, Ellis Horwood, London, England.

This paper presents the state of the art on the durability of reinforced concrete in marine environment. Specifically the following two topics are discussed: (1) The corrosion mechanism of steel embedded in concrete in marine environment, and (2) Durability of reinforced concrete structures in sea water. The role of concrete in the protection of reinforcement is emphasized in this report and the importance of improvement of the properties of this concrete is demonstrated. A sizable list of references completes the paper.

A-217 Neville, A. 1983 (Jun). "Corrosion of Reinforcement," Concrete, Vol 17, No. 6, pp 48-50, London, England.

The problem of corrosion is reviewed by identifying conditions necessary for corrosion. Electro-chemical, chloride corrosion, and electrochemical corrosion in the presence of chlorides is discussed. Reliable information concerning minimum oxygen and water requirements is still not available.

A-218 Gjelsvik, T. 1983 (May-Jun). "Apparatus for Accelerated Weathering of Building Materials and Components," Materials and Structures, Research and Testing, Vol 16, No. 93, pp 209-211, Paris, France.

Natural weathering of building materials and components is a result of the combined influences of a number of aging factors. Climates differ greatly from place to place and from one year to another. Durability consequently depends on time and place.

Accelerated artificial weathering is a still more complex matter. When the individual aging factors act in combination, the results can be different from when they act alone. Size and shape of samples are also important. It is desirable to be able to accelerate the individual aging factors to the same extent, but this should not be overemphasized as it is the final result that counts.

A special apparatus for accelerated weathering of building materials and components has been designed and built at the Trondheim Branch of the Norwegian Building Research Institute. This equipment is unique in that it can take samples up to 1 m^2, a striking contrast to those commercially available. The results are promising when compared with practical experiences in Scandinavia. A modified version for samples up to 4 m^2 was completed in 1979 and is now running satisfactorily.

There seems to be general agreement about the factors that influence the natural weathering or aging of building materials and components. Only the most important factors are addressed.

A-219 Bionda, R. 1983 (May-Jun). "Gardiner--Toronto Expressway Is Heavily Damaged," Corrosion Control, Vol 1, No. 1, pp 32-35.

The damage in Toronto's Gardiner Expressway caused by the corrosion of reinforcing bars in the concrete is discussed. The mechanism of rebar corrosion in the presence of chloride ions from deicing salts and its effect on concrete structures are outlined. Some design flaws and repair measures are presented. Guidelines for future expressway design and construction are recommended to control the problem.

A-220 Forsyth, B., and Stahl, F. L. 1983 (Jul). "Throgs Neck Bridge: Why Did Its Deck Deteriorate?" Civil Engineering, Vol 53, No. 7, pp 50-52, American Society of Civil Engineers, Philadelphia, PA.

This article presents a case study of the deterioration of approach spans of a viaduct indicating that significant secondary tensile and fatigue stresses can exist in reinforced concrete roadway slabs designed in accordance with all applicable standards when slabs are supported by cantilever brackets. The principal cause for the distress was found to be secondary tensile and fatigue stresses resulting from repetitive deflection of the floor/beam cantilever brackets under live load. Contributing factors included insufficient distribution reinforcement, chloride-ion contamination of the concrete, and general wearing of the riding surface. Present AASHTO specifications are inadequate to compensate for these special stress conditions so that the designer must make the appropriate allowances.

A-221 Abdun-Nur, E. A. 1983 (Jul). "Cracking of Concrete - Who Cares?" Concrete International: Design & Construction, Vol 5, No. 7, Detroit, MI.

Concrete cracks because it is weak in tension and lacks ductility. Some of the major mechanisms that develop the excess tension in

concrete and cause it to crack are enumerated. Good concrete practices in mix proportioning, proper ingredients, and accepted procedures that have proven themselves in mixing, transportation, placing, vibrating, curing, and protection are the best defenses against cracking.

In addition to these practices, the four major engineering contributions to make concrete resist cracking are reinforced concrete, prestressed concrete, fiber reinforced concrete, and expansive cement. These minimize cracking but do not completely eliminate it.

Good concrete practices, quality assurance, quality control, and these four technologies as they apply to particular situations should be used, as cracking not only is unsightly but permits aggressive environments to penetrate the concrete and in some cases results in extensive damage, and expensive maintenance to say the least. Who Cares? the answer is everybody should care.

A-222 Ahlvin, R. G. 1983 (Jul-Aug). "Spalling on the Wrong Side," The Military Engineer, Vol 75, No. 488, pp 346-347, Alexandria, VA.

The observation that substantially more severe spalling appears in the passing lane than in the traveled lane of continuously reinforced concrete pavement highways is presented. This phenomena remains unexplained.

A-223 Buck, A. D. 1983 (Aug). "Alkali Reactivity of Strained Quartz as a Constituent of Concrete Aggregate," Miscellaneous Paper SL-83-13, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

Some strained quartz may cause deleterious alkali-silica reaction if present as a constituent of concrete aggregate in sufficient amounts. The criterion for reactive strained quartz is suggested to be more than 20 percent strained quartz with an average undulatory extinction angle greater than 15 deg. Length changes of mortar bars containing such strained quartz will be 0.025 and 0.040 percent or more at 6 and 12 months, respectively, when stored at a temperature of 60° C (140° F). Revisions to applicable ASTM standards may be appropriate.

A-224 Boqi, C., Dinghai, H., Hengquan, G., and Yinghao Z. 1983 (Sep). "Ten-Year Field Exposure Tests on the Endurance of Reinforced Concrete in Harbor Works," Cement and Concrete Research, Vol 13, No. 5, pp 603-610, Elmsford, NY.

The paper summarizes a 10-year field exposure test made at reinforced concrete observation stations in Zhanjiang, Shanghai, and Tianjin, China. Through the exposure tests at the sites, detailed studies were made and various factors causing corrosion of reinforcements in the reinforced concrete structures for harbor works are discussed.

A-225 "Minimising the Risk of Alkali-Silica Reaction." 1983 (Sep). Cement and Concrete Association, Guidance Notes, Wexham Springs, England.

These guidance notes are based on the best information available at the present time and give only the basic, essential information on the circumstances under which damage due to alkali-silica reaction could occur and how to avoid or minimize such damage in new concrete construction. These notes apply to materials, conditions, and practice in the United Kingdom. They will not necessarily apply in other countries.

A-226 Dauvergne, P., and Tache, G. 1983 (Oct). "Corrosion of Rebars" (in French), Travaux, No. 581, pp 75-77, Paris, France.

The progressive instability of concrete, the process of corrosion, dissolution of the steel, corrosion by pitting and cracking, and fatigue corrosion caused by hydrogen is discussed. Corrosion factors due to materials, to the composition and application of concrete, to aging, and to fissuring are also discussed.

A-227 Ducrot, B. 1983 (Oct). "Repair of Concrete" (in French), Travaux, No. 581, pp 95-98, Paris, France.

This article discusses the three phases in the deterioration of concrete and its repairs. The first phase involves fine cracking, efflorescence, and traces of rust. The second phase includes clearly defined cracks, crumbling, and strong traces of rust. The third phase involves severe effects upon the structure.

A-228 Holm, T. A. 1983 (Sep-Oct). "Three Decades of Durability," Military Engineer, Vol 75, No. 489, pp 413-416, Alexandria, VA.

A multilevel, holistic approach to durability of concrete bridge decks that considers macro, micro, and chemical level variables is advocated as the best approach. Information from laboratory tests could be integrated with the experience gained from existing structures. Satisfactory freeze-thaw results may prove to be inaccurate if structural/environmental interaction develops a different microcracking response within the structure. The most reliable insight may be provided by close examination of full-scale test specimens.

A-229 Agrawal, K. S., and Sircar, A. 1983 (Dec). "Failure and Remedial Measures of a Storm Water Pump House," Indian Concrete Journal, Vol 57, No. 12, pp 309-312, 329, Bombay, India.

This article discusses structural difficulties of a storm water pump house in a factory compound in India. On inspection, it was discovered that extensive fracturing had occurred in the reinforced concrete walls, floor, and superstructure walls. The causes are explored, and photographs are included.

A-230 Anderson, R. B. 1983. "Acid and Sulphate Distributions in Groundwater of the Melbourne Area, with Respect to Their Potential for Concrete Corrosion," International Conference on Groundwater and Man; Groundwater and the Environment, Sydney, Australia, 5-9 Dec 1983; Australian Water Resources Council Conference Series 8, Vol 2, pp 1-10.

The concentrations of acidity and sulfate in groundwater and the rates of groundwater movement are principal criteria used to classify the aggressiveness of groundwaters to exposed concrete structures. In the Melbourne area, the broad distributions of these chemical parameters, in groundwater samples from boreholes, are evaluated in terms of variations in geology, climate, and landforms.

A-231 Gerwick, B. C., Jr. 1983 (Dec). "Oil Rigs Designed to Combat Artic Ice," Civil Engineering, pp 38-41, American Society of Civil Engineers, New York, NY.

Extending exploration to the open sea off Alaska's north slope will require structures designed to withstand forces never before encountered in oil drilling operations. The culprit is the great Artic polar pack, 1,500 miles in diameter, that rotates clockwise carrying with it massive features such as multiyear ridges and embedded ice island fragments. The multiyear ice floes present the most severe problems. Spun off from the central polar pack, floes with masses of 4 million tons or more, contain embedded ridges 65 to 100 ft deep. Lateral forces on typical structures may reach 50,000 to 200,000 tons, depending on location and the structure's configuration and style. Materials must be chosen carefully for use in this extremely harsh environment, where temperatures go to -50° F and the cold saline water is rich in oxygen. Concrete must resist freeze-thaw attack and ice abrasion at the waterline. Intensive research is being carried out on lightweight concrete made from high quality expanded shale aggregates and incorporating finely ground pozzolans such as condensed silica fumes.

A-232 Holden, W. R., Page, C. L., and Short, N. R. 1983. "The Influence of Chlorides and Sulphates on Durability," Corrosion of Reinforcement in Concrete Construction, London, 13-15 Jun 1983, pp 143-150, Ellis Horwood, London.

The use of poorly prepared aggregates, contaminated with mixtures of salts containing chloride and sulphate ions, presents risks of corrosion of reinforcement in concrete. There is an urgent need to assess these risks, particularly with regard to the durability of reinforced concrete structures in the Middle Eastern Gulf regions where salt-contaminated aggregates proliferate. In this paper, techniques of pore solution expression and analysis are used to quantify the extent to which chlorides and sulphates react with different cement to form insoluble products when various dosages of salts are included in the mix materials. The influence of cement composition is examined for a range of cements produced in Britain. Kinetics of chloride ion diffusion in different types of cement matrix are also considered. The importance of the above factors in relation to the mechanism of

chloride-induced pitting of reinforcing steel is examined and implications regarding corrosion risks are discussed.

A-233 Cady, P. D., and Weyers, R. E. 1983. "Chloride Penetration and the Deterioration of Concrete Bridge Decks," Cement, Concrete, and Aggregates, Vol 5, No. 2, pp 81-87, Philadelphia, PA.

Rapid deterioration of the nation's bridges is a widely recognized problem. A major contributor to this problem is bridge deck deterioration caused by chloride-induced corrosion of reinforcement. Chlorides are derived primarily from the application of roadway deicing salts. This paper synthesizes empirical data from previous studies with the diffusion theory in developing a predictive model for chloride influsion of bridge decks. The model includes the effects of subsidence cracking over the reinforcement. Primary input data consist only of average reinforcement cover. This is easily obtainable with existing instrumentation. The model is intended to serve as a useful, rational means of providing information for life-cycle costing in bridge deck rehabilitation planning studies.

A-234 Slater, J. E. 1983. "Corrosion of Metals in Association with Concrete," Special Technical Publication 818, American Society for Testing Materials, Philadelphia, PA.

This article considers deterioration of reinforced concrete decks in the snow belt from deicers and deterioration of marine structures where reinforcing steel is contacted by chlorine ion. First, the magnitude of the problem is addressed, focusing on the nature of the problem, historical perspective, economic viewpoint, and nature and type of structure affected. Next, mechanisms of corrosion of reinforcing steel are covered, including the properties of concrete and the specific aspects of steel corrosion in concrete that are dissimilar to other types of corrosion. Factors influencing the rate of steel corrosion in concrete, methods of measuring deterioration, and methods of protecting against deterioration are also discussed. The manual concludes with an assessment of current standards and suggestions for further research.

A-235 Crane, A. P. 1983. "Corrosion of Reinforcement in Concrete Construction," Ellis Horwood, London, England.

Corrosion of steel reinforcement in concrete construction is a worldwide problem which can, on the small scale, cause disfigurement. On the large scale it may lead to structural catastrophe. This volume is a compilation of papers presented at a meeting on corrosion of reinforcement in concrete construction. Among the topics included are evaluations of past failures, the role of cement composition and the control of concrete permeability, design criteria, the condition and nature of the reinforcing bar material, mechanistic studies, monitoring techniques, and methods of repair.

A-236 Ratinov, V. B., and Rozental, N. K. 1983. "Corrosion Inhibitors for Steel Reinforcement in Concrete" (in Russian), Beton i Zhelezobeton, No. 8, pp 5-7, Moscow, USSR.

Applications of corrosion inhibitors are analyzed. The most effective inhibitors were selected according to the substance (seawater, salt solutions, and some aggressive gases) or according to the concrete (cellular, gypsum, slag portland cement, etc.). Their amounts and economic effects are presented. Results on long-term tests are also examined.

A-237 Wilkins, N. J. M., and Lawrence, P. F. 1983. "The Corrosion of Steel Reinforcements in Concrete Immersed in Seawater," Corrosion of Reinforcement in Concrete Construction, London, 13-15 Jun 1983, pp 119-141, Ellis Horwood, London, England.

Good quality concrete can provide embedded steel with long-term protection against the marine environment. This is particularly true of concrete fully immersed in seawater when the cathodic reaction (ultimately oxygen reduction) is severely restricted; such a situation is indicated by very negative potentials in the range --800 to --1100 mV with reference to silver/silver chloride. The steel is then actively corroding, but the corrosion is spread over the largest possible area of the reinforcement and the actual corrosion rates, limited by the rate of oxygen reduction, are extremely small. In conditions where cathodic oxygen is more readily available, such as in concrete at or near the tideline or possibly in concrete exposed to air on one side as is a hollow immersed concrete structure, potentials in the range + 50 to -300 mV are observed. In these circumstances, the corrosion of bare steel or steel embedded in a highly porous or cracked concrete can be accelerated by galvanic coupling to a cathode of reinforcing steel in sound concrete. Local corrosion damage will depend on the relative sizes of corroding and cathodic areas. Corrosion of embedded steel is not necessarily associated with chloride penetration and cracks extending to the steel surface may not result in significant corrosion. The extent of corrosion damage depends on a number of factors including crack geometry, void content of the concrete, relative areas of cracked and sound concrete, and the precise chemical and physical properties of the concrete mix and its continuing long-term reactions with the seawater. Other factors such as seawater flow or turbulence, tidal range, and marine fouling may also have some influence. In anaerobic conditions, corrosion by sulphate-reducing bacteria has been observed on steel in highly porous concrete. This work has been undertaken as part of the Concrete-in-the-Oceans program funded by the Department of Energy and the Offshore Industries, coordinated by CIRIA/UEG.

A-238 Virmani, Y. P., Clear, K. C., and Pasko, T. J., Jr. 1983 (Sep). "Time-To-Corrosion of Reinforcing Steel in Concrete Slabs - Volume 5," Report No. FHWA/RD-83/012, US Department of Transportation, Federal Highway Administration, Washington, DC.

Thirty-one relatively large reinforced concrete slabs were fabricated

in 1980 using either nonspecification epoxy-coated reinforcing steel or calcium nitrite admixture with black (uncoated) steel. Their performance is compared with slabs containing uncoated steel in concrete without admixtures. The slabs were placed in two lifts: the bottom lift consisted of a bottom mat of reinforcing steel in chloride-free concrete; the top lift consisted of the top-mat reinforcing bars in concrete contaminated with various quantities of sodium chloride. All the electrical connections between the reinforcing mats were made exterior to the slabs so the corrosion current flow could be monitored. A worst-case type of research design was used by specifying poor-quality concrete, nonspecification epoxy-coated reinforcing bars and good electrical coupling between the reinforcing bar mats.

Findings of the study indicate that both epoxy-coated reinforcing steel and calcium nitrite can provide more than an order of magnitude reduction in the corrosion rate, and thus should provide long-term protection against corrosion-induced damage on properly engineered and constructed structures in severe salt environments.

A-239 Copier, W. J. 1983. "The Spalling of Normal Weight and Lightweight Concrete Exposed to Fire," Fire Safety of Concrete Structures, Publication SP-80, American Concrete Institute, Detroit, MI.

Spalling of concrete exposed to fire is understood to be the explosive detachment of large or small pieces of concrete from the concrete surface subjected to heating. It was known from literature that spalling is very much related to the moisture content of concrete. In addition to several tests done in an earlier stage, 25 fire tests were carried out on both beams and platelike elements to investigate the influence of the moisture content. In these tests, parameters other than the moisture content were incorporated like gravel as coarse aggregate and several kinds of light-weight coarse aggregate as well; the compressive stress; the compressive strength; the thickness; reinforcement and one- or two-sided heating. In addition, the moisture content of concrete that could be expected in buildings in course of time was investigated both by tests and calculations. It can be concluded that a high moisture content can give rise to severe spalling only if, in addition, one or more other unfavorable working factors are present at the same time. When a low moisture content (7 percent v/v) can be expected in centrally heated buildings, about 5 years after completion, the risk of spalling diminishes.

1984

A-240 Subba Rao, V. V. 1984 (Jan). "Guidelines for Foundations Under Aggressive Environments," CRI, Technology Digest.

Concrete has excellent resistance to weathering. Therefore, concrete foundations and structures built with proper controls on material and workmanship have resulted in durable structures under normal environments, requiring practically very little maintenance for several decades. However, corrosion of concrete and reinforcement is likely to

occur when such structures are constantly exposed to aggressive surroundings, such as obtaining in aggressive groundwaters and soils, in chemical industries, marine environments, etc., if not given special attention. This digest lays down guidelines for foundations under such aggressive environments.

A-241 Smith, J. R. 1984 (Jan). "Architectural Concrete," Concrete International: Design & Construction, Vol 6, No. 1, Detroit, MI.

Through a discussion of variations in architectural concrete finishes, specifications and shop drawings, sample panels, and mockups, the author provides guidance on what to expect in the way of surface defects, the necessity of accepting variations, and principles to follow in achieving good results.

A-242 Kenney, A. R. 1984 (Jan). "Problems and Surface Blemishes in Architectural Cast-in-Place Concrete," Concrete International: Design & Construction, Vol 6, No. 1, Detroit, MI.

This article offers a look at some of the things that can happen when working with architectural concrete - and their causes.

A-243 Kawamura, M., and Hasaba, S. 1984 (Feb). "Mechanisms of Alkali-Silica Reaction--A Review," Concrete Journal, Vol 22, No. 2, pp 6-15, Tokyo, Japan.

Recent discoveries of concrete structures deteriorated by alkali-silica reactions require immediate and accurate information concerning the phenomenon of this reaction. Emphasis should be placed on the expansive characteristics of alkali-(calcium)-silica gels and a new concept of processes of chemical and physical reaction in alkali-silica distress in concrete. Further research on the mechanisms of alkali-silica reaction is necessary since revealing the reaction mechanisms directly leads to a possibility of more accurately predicting the future behavior of affected concrete structures.

A-244 Rasheeduzzafar, Dakhill, F. H., and Al-Gahtani, A. S. 1984 (Jan-Feb). "Deterioration of Concrete Structures in the Environment of the Middle East," Journal, American Concrete Institute, Vol 81, No. 1, pp 13-20, Detroit, MI.

Adverse geomorphic and climatic conditions as well as defective construction practices control concrete performance in the Arabian Gulf area. Condition surveys on structures located in Eastern Saudi Arabia show an alarming degree of deterioration within the short span of 10 to 15 years. Data show that this deterioration is attributable in decreasing order of importance to corrosion of reinforcement, sulfate attack, and environmental cracking. The mechanisms of these causal factors are discussed with respect to the environmental conditions of the Gulf coast.

A-245 Treadway, K. W. S., and Page, C. L. 1984 (Mar). "Durability of Steel in Concrete," Concrete Plant and Production, Vol 2, No. 3, pp 113-114, Amersham, England.

In a joint research program, the Building Research Establishment and Aston University are studying the basic processes of corrosion in reinforced concrete. This will provide essential knowledge for predicting long-term durability and performance of reinforced concrete and for the assessment of repair. Mechanisms of protection and corrosion of steel in concrete are discussed.

A-246 Saeki, N., Ayuta, K., and Maekawa, S. 1984 (Mar). "Scaling Damage of Coastal Concrete Structures in Hokkaido," Transactions of the Japan Society of Civil Engineers, Vol 14, pp 398-399.

The scaling damage due to freezing and thawing occurs often at the coastal concrete structures in Hokkaido, the cold northern district in Japan. A survey of about 200 coastal concrete structures was carried out to seize the state of constructions and to observe the condition of the extent and severity of frost damage. The main factors affecting the damage are considered to be the properties of aggregate, the kind and content of cement, the water-cement ratio, the influence of seawater, the number of freeze-thaw cycles, etc.

A-247 Wiebenga, J. G. 1984 (Apr). "Durability of 64 Concrete Constructions On-Shore and Off-Shore" (in Dutch), Cement, Vol 36, No. 4, pp 215-218, Hertogenbosch, The Netherlands.

An extensive research program was carried out on the durability of offshore and onshore constructions in the Netherlands. Sixty-four hydraulic constructions were inspected for damage, including the locks, piers, quay walls, and the like between 3 and 63 years old. To complete the investigation, laboratory tests were carried out on five bored test cylinders from one of the structures. The data obtained showed that these structures have, as a rule, high durability. Among other facts, it was demonstrated that the carbonization depth is low whereas reinforcement corrosion was observed only in objects with a long exposure time and with a relatively sparse concrete cover. No visible corrosion could be found in structures younger than 30 years.

A-248 Lawrence, C. D. 1984 (Sep). "Transport of Oxygen Through Concrete," Conference on Chemistry and Chemically-related Properties of Cement; Proceedings, Basic Science Section of the British Ceramic Society London, England, Apr 12-13, 1984, No. 35, pp 277-293, Cement and Concrete Association and British Ceramic Society, Stoke-on-Trent, England.

This paper presents steel results from a research program aimed at quantifying the factors that control the service life of reinforced concrete. Of the various durability problems identified, the most important is the corrosion of the reinforcement steel. The diffusion of species, especially gaseous oxygen and carbon dioxide, through the concrete to the steel plays a controlling role. The paper describes a

technique for measuring the diffusion rate of oxygen and investigates the effect of concrete mix composition and curing procedure. (20 refs.)

A-249 "Lightning and Concrete: An Explosive Pair." 1984 (Apr). Concrete Construction, Vol 29, No. 4, pp 413-414, Addison, IL.

This article briefly describes a series of experiments conducted to determine the extent of damage lightning and electricity can cause to concrete. Damage results resembled explosions, taking place along the path of the simulated lightning discharge.

A-250 Plum, D. R., and Hammersley, G. P. 1984 (May). "Concrete Attack in An Industrial Environment," Concrete, Vol 18, No. 5, pp 8-11, London, England.

Concrete deterioration and its subsequent repair has been a much discussed topic of recent years. Greater problems are encountered when reinforced concrete is used in an aggressive environment, and many industrial processes give such possibilities. Where deterioration of the concrete and/or reinforcement occurs, it is likely to be severe to the point of loss of structural adequacy. Identification of the causes, and subsequent protection, can often be more difficult due to the presence of potentially aggressive substances.

This article identifies the aggressive substances as mineral acids, some organic acids, solutions of sulfates, solutions of ammonium compounds, chlorides, sugars, nitrates, phenols, and in addition, any alkalis should be considered where strong crystal growth is likely. Objectives for comprehensive investigation are also examined, and the characteristics of chemical attack, the effects of aggressive solutions on concrete, are classified in five different types and explained. Finally, the effects of chemical attack on concrete are examined, and it is concluded that concrete is far from indestructible in an aggressive chemical environment, and protection should be introduced at the design stage.

A-251 Potyondy, J. G. 1984. "Designer's and Contractor's Responsibility in Crack Control Through Correct Construction Procedures," Proceedings, 1984 Annual Conference - Canadian Society for Civil Engineering, Halifax NS, Canada, May 23-25, 1984, Vol 1, pp 359-378, Canadian Society for Civil Engineering, Montreal, Quebec, Canada.

Cracking is a common phenomenon in reinforced concrete structures because of the limited ability of concrete to take up tension. However, cracks in concrete are objectionable because they reduce the structure's durability, increase its permeability, reduce its strength, and are unsightly. In recent years, building codes introduced minimum requirements for crack control. These requirements are related to flexural cracking of the completed structure, (crack width and crack spacing) but very limited guidance is provided for the control of other

types of cracks. The undesired crack developments during the construction phase or thereafter may be influenced by errors at the design stage, by the type of materials used, workmanship, after-placing treatment, curing, and early use of the structure. These undesired crack developments can result in a definite loss of performance of the structure, causing accelerated deterioration, loss in usefulness and making the building unserviceable for its original use.

A-252 Locher, F. W., Rechenberg, W., and Sprung, S. 1984 (May). "Concrete After a 20-year Action of Lime-Solving Carbonic Acid," Beton, Vol 34, No. 5, pp 193-198, Dusseldorf, West Germany.

Water with a content of more than 60 mg/l CO_2 is very strongly aggressive to concrete. For determination of limit values of such corrosive action, long-term testing was carried out on samples of concrete that had been immersed in water containing more than 100 mg/l of carbonic acid.

After 20 years, dense concrete with quartz aggregate showed a maximum erosion depth of 6 mm. Chemical resistance was primarily a function of concrete density; cement type and quantity was shown to be largely noninfluential. Limestone-aggregate concretes were noticeably less durable than concretes with quartz aggregates. The study concludes that dense concretes with acid-resistant aggregates will resist corrosion in water of up to 100 mg/l carbonic acid concentration.

A-253 Buenfeld, N. R., and Newman, J. B. 1984 (Jun). "Permeability of Concrete in a Marine Environment," Magazine of Concrete Research, Vol 36, No. 127, pp 67-80, Wexham Springs, England.

Permeability is a fundamental property governing the durability of concrete in the marine environment. Only recently has it been appreciated that some concretes exhibit a significant reduction in permeability on immersion in seawater. To investigate this phenomenon further, a resistivity technique has been developed and used to monitor the changes in permeability of five mortars and one concrete on exposure to seawater. All mixes studied showed a fall in permeability (increase in resistance) on immersion in seawater. Indeed, 25 mm thick specimens of the two most permeable mortars showed a fall equivalent to over 20 mm of additional thickness after only 10 weeks. This increase is due to the formation of an aragonite-brucite layer on the surface of the mortar plus a more widespread progressive constriction of the cement paste pore system. This effect also has considerable influence on the absorption capacity of concrete after a period of drying, which is important in the tidal and splash zones.

A-254 "Further Reports On the Deterioration of Prefab Houses." 1984 (Jul). Concrete Plant and Production, Vol 2, No. 7, pp 277-278, Amersham, England.

This article summarizes the findings of investigations into the deterioration of prefabricated reinforced concrete houses in Great Britain.

The research confirms that all British prefabricated reinforced concrete houses built before 1960 are deteriorating as a result of carbonation of concrete and, in certain locations, the presence of high levels of chloride leading to corrosion of the steel reinforcement and the consequent cracking of the concrete. However, no structurally unsafe conditions were found in the majority of the deteriorated houses.

A-255 "Identifying Non-Durable Aggregates for Concrete Paving." 1987 (Jul). The Construction Specifier, Vol 37, No. 7, pp 24-25, Alexandria, VA.

Coarse aggregates in portland-cement concrete are suspected to be one of the main causes of D-cracking. While the cracks can appear in different forms, usual deterioration originates in the lower level of a pavement slab and is viewed at the surface as fine, closely spaced cracks parallel and adjacent to longitudinal or transverse joints or intermediate full-depth cracks. Tests have been concluded on sedimentary rock sources to identify beds which may cause D-cracking. ASTM Test Method 666 is a lengthy but reliable test used to find the durability of coarse aggregates. This test data is based on freezing and thawing results of the aggregates. State aggregate acceptance criteria differ, and a more rapid means of testing concrete aggregates is desired. Alternate testing methods such as the Pore Index Test or the "expected durability factor" test have been successfully incorporated.

(Reprinted from the Winter 1984 issue of RETS Digest, published by the National Crushed Stone Association.)

A-256 Kohne, J. H. 1984 (Aug). "Inventory of Damage Outside Concrete Surfaces in Housing Built During the Period 1950-1980," Cement, Vol 36, No. 8, pp 484-487, Hertogenbosch, The Netherlands.

An investigation into the extent of damage caused by reinforcement corrosion and the influence of environmental conditions on concrete durability was made and a report submitted. The report demonstrated a working hypothesis for estimating costs of current and future repairs. The design of the research and the working method applied in the study are discussed.

A-257 Cox, D. 1984 (Aug). "Fire Endurance of G.R.C. Panels," Constructional Review, Vol 56, No. 3, pp 54-57, Sydney, Australia.

Results of preliminary testing for fire resistance of glass reinforced concrete (GRC) panels are presented. Six composite panels were fabricated for thermal insulation testing of various types of core fillings. Tests indicated that the glass reinforced concrete panels, though weighing only one-quarter to one-fifth as much as precast concrete panels of comparable size, had equal or superior fire resistance. Details of the fabrication of the six core fillings used in the tests are given, and photographs and tables illustrating the test results are presented.

A-258 Vassie, P. R. W. 1984 (Aug). "Reinforcement Corrosion and the Durability of Concrete Bridges," Proceedings, Institution of Civil Engineers (London), Part I, Design and Construction, Vol 76, pp 713-723.

Corrosion can arise in most parts of a bridge substructure or superstructure and usually results from the use of deicing salts. Substructure corrosion is often associated with leaking joints, faulty drainage, or salt spray from traffic. General corrosion is found on substructures and although this is a relatively slow process, producing only small reductions in bar cross section, it causes substantial disruption of the concrete cover. Localized corrosion has occurred on unwaterproofed decks and is much more rapid than general corrosion; it leads to substantial local reductions in bar cross section. This form of corrosion is not easy to visually detect because it is not always associated with concrete disruption or rust staining, and, in any event, the deck is covered with asphalt surfacing.

Several site investigation tests are available. When used together they can usually locate corroding reinforcement, determine its type and causes, and estimate its rate, thus providing the information required to specify repairs. The threshold concentration of chlorides in concrete bridges has not proved a reliable basis for predicting corrosion. Likely explanations are that chloride contamination is associated with relatively high concentrations of the more damaging free chloride ion. Localized anodes also sometimes protect the surrounding steel from effects of high chloride levels. The repair of chloride-contaminated bridges is difficult. Repair of corroding areas is generally effective, but the development of anodes in the concrete adjacent to the repair can lead to further damage. Cathodic protection appears to be the most promising method of overcoming this problem, although further development is needed before it can be applied effectively.

A-259 Van Der Meid, R. G. 1984 (Aug). "Testing for Salt Damage," Civil Engineering, Vol 54, No. 8, pp 46-47, Sear-Brown Associates, Rochester, NY.

Rochester, NY, is typical of many cities where liberal sprinklings of salt help melt ice during the long winters - and also help destroy concrete structures. Two examples: Deicing salts applied to a street trickled down to ruin the basement wall of a 56 year old bank, a national landmark occupied by the Rochester Community Savings Bank. Salt also contributed to the corrosive atmosphere that, because of design and construction defects, deteriorated a parking structure only 14 years old. Both projects required extensive investigation before repairs could be recommended.

A-260 Stark, D. 1984 (Jul-Aug). "Determination of Permissible Chloride Levels in Prestressed Concrete," Journal, Prestressed Concrete Institute, Vol 29, No. 4, pp 106-119, Chicago, IL.

A laboratory investigation to determine chloride concentrations and exposure conditions required to induce corrosion of prestressed tendons

in concrete beams is described. Variables included source and concentration of chloride ion, wetting and drying, C_3A content of the cement, water-cement ratio of the concrete, stress level in the steel, and concrete curing method.

Performance was evaluated by electrical potential measurements, visual examination of tendons, and measurement of chloride contents. Recommendations are made for permissible chloride levels in prestressed concrete as they are affected by exposure conditions.

A-261 Roper, H. 1984. "Durability of Concrete Marine Structures," Marine Corrosion and Fouling, Vol 1, Marine Corrosion, Sixth International Congress, Athens, Greece, 5-8 Sep 1984, pp 145-164, National Technical University of Athens.

The durability problems of reinforced and prestressed concrete marine structures are considered. Degradation processes include chemical attack, physical erosion, freeze-thaw damage, and fatigue effects on the concrete and corrosion and fatigue of the reinforcement. Methods to overcome or minimize these phenomena are discussed.

A-262 Lachaud, R., and Salomon, M. 1984 (Oct). "Concrete Deterioration," Annales, Institut Technique du Batiment et des Travaux Publics, No. 224. pp 21-64, Paris, France.

After a brief survey of the main components in concrete, the factors influencing its deterioration are reviewed. The following points are then examined: (1) the internal factors of deterioration which are preexistent in the concrete and consequently linked to the cement and the aggregate (aggregate alkali-reaction, for example); and (2) the external factors of deterioration due to the environment (presence of sulfate, for example). The deterioration mechanisms are analyzed in both cases. A comparative study of the principal regulations in force (France, Great Britain, Germany, and USA) regarding problems of concrete deterioration are presented, and a certain number of steps for prevention are proposed.

A-263 Uchikawa, H. 1984 (Oct). "Review On the Test Methods for Potential Alkali Reactivity of Concrete Aggregates" (in Japanese), Concrete Journal, Vol 22, No. 10, pp 12-23, Tokyo, Japan.

This article reviews various test methods and means of estimating alkali-aggregate reactions. Individual test methods in current use are not completely accurate and it may be necessary to combine several methods to prevent concrete deterioration. Individual factors must be established to determine a reliable test method. These include analysis of reaction and expansion mechanisms, identifying reactive aggregates and determining their allowable content limit, eliminating aggregate expansion caused by other reactions, verifying and theoretically clarifying worst conditions, a, ' selecting scale factors and testing conditions to correspond to concrete deterioration in the environment.

A-264 Ramaswamy, H. S., and Jain, Y. K. 1984 (Oct). "Investigation of the Durability of Concrete Sewer Pipes," Indian Concrete Journal, Vol 58, No. 10, pp 258-260, Bombay, India.

The strength and durability of concrete has a lot to do with the proper selection of good raw materials. However, there are instances where deterioration of concrete and concrete structures has been observed despite care being taken to ensure selection of durable materials. The possible explanation for this could be that there are factors other than quality of materials that contribute to deterioration. The paper highlights factors responsible for the lack of durability in concrete pipes exposed to aggressive environments such as those carrying sewage. The extent of deterioration developed over a period of time and studied progressively under a scanning electron microscope is presented.

A-265 "Design Life of Buildings." 1984. Conference on Design Life of Buildings, London, Nov 26-27, 1984, Thomas Telford, London, England.

This symposium proceedings contains 21 papers. The topics covered include: building durability and design life; factors affecting concrete structure durability; prestressed concrete member durability; building degradation causes; blast resisting structure design; temporary structure service life; building material long-term behavior; glass fiber reinforced panel performance; brick and block masonry durability; steel structure surface treatment; research, durability and design life interrelationships; corrosion - resisting alloy research; timber structure design.

A-266 Locke, C. E. 1984. "Corrosion of Steel in Portland Cement Concrete: Fundamental Studies," Symposium on Corrosion Effect of Stray Currents and the Techniques for Evaluating Corrosion of Rebars in Concrete, Williamsburg, VA, 28 Nov 1984, American Society for Testing Materials Committee G-1 on Corrosion of Metals, Philadelphia, PA.

Corrosion of steel in portland cement concrete occurs when the outside influences change the composition of the pore solution. This paper provides an overview of the information available from the literature and work done in the University of Oklahoma laboratories on this corrosion problem so important to the transportation system in the United States.

Steel is passive in the high pH environment present in portland-cement pore solution. Until recently, this pore solution was thought to be saturated calcium hydroxide, but now some work has shown it is more like potassium and sodium hydroxides. The work using presses to express pore solutions with subsequent analysis is described.

Chloride ions can penetrate the passive film, cause the steel potential to shift, and result in corrosion. The nature of the chloride ion affects the severity of the corrosion problem. Chloride ion, which diffuses into hardened concrete, will initiate corrosion at a smaller amount than that required to initiate corrosion with chloride ion mixed

in the concrete. In addition, the cation will affect the amount of chloride required for corrosion problems. Calcium chloride seems to be more aggressive than sodium chloride. These results will be compared to pore solution analyses, which indicate the chloride binding capacity of the portland cement changes with the type chloride ion also.

Some data on the effect of portland cement analysis on the corrosion behavior will also be given.

This paper shows that the pore solution composition can be used to explain the corrosion behavior of steel in concrete. Better understanding of these facts can lead to development of better corrosion control measures for this very costly problem.

A-267 Rothman, P. S., and Price, R. E. 1984. "Detection and Considerations of Corrosion Problems of Prestressed Concrete Cylinder Pipe," Symposium on Corrosion Effect of Stray Current and the Techniques for Evaluating Corrosion of Rebars in Concrete, Williamsburg, VA, 28 Nov 1984, American Society for Testing Materials Committee G-1 on Corrosion of Metals, Philadelphia, PA.

Prestressed concrete cylinder pipe (PCCP) is constructed by circumferentially winding a high-strength steel wire, under tension, around a concrete core containing a sheet steel cylinder, which serves as a watertight membrane. The service life of such pipe is generally determined by the ability of this steel prestressing wire to retain its integrity under tension. Corrosion of the steel wire results in pitting, embrittlement, or the dissolution of the iron with a corresponding reduction in cross-sectional area. The result is degradation of the physical strength of the high tensile wire and possible failure of the prestressed concrete cylinder pipe through this mechanism. Pipe affected by this failure mode does not develop leaks as in the case of the steel pipe, but bursts catastrophically. Failure is usually attributed to "wire breaks," not specifically to corrosion.

For concrete cylinder pipe, the components of the joint are susceptible to stray current corrosion if component low resistance continuity does not exist. This condition can be responsible for failure of the steel prestressing wires if they are not electrically continuous with the other components of the pipe (steel cylinder, bell ring, spigot ring, fittings, etc.).

This paper presents the potential corrosion problems and causes associated with the metallic components of prestressed concrete cylinder pipe. The difficulties in detecting these problems, because of materials and fabrication practices are discussed, as well as methods that have been used successfully to detect corrosion in buried lines (pipe-to-soil potential profiles, cell-to-cell potential profiles).

The results of a new typical studies are presented as a suggested approach to the investigation and analysis of potential problems involving both galvanic and electrolytic (stray current) corrosion.

A-268 Kasami, H., et al. 1984 (Dec). "Carbonation of Concrete and Corrosion of Reinforcing Bars in RC Buildings," Cement and Concrete, No. 454, pp 29-39, Tokyo, Japan.

An investigation carried out on 44 reinforced concrete buildings (the oldest erected in 1925) allowed collection of a large number of data relative to concrete compressive strength, concrete carbonation, covering depth, and corrosion of reinforcing bars (the carbonation depth was measured on 2,449 places, and the covering depth and corrosion on 1,541 places).

The article presents a statistical analysis of the results obtained, concerning in particular: the carbonation speed; the dispersion of data relative to carbonation depth; the carbonation ratio; the influence exerted on the corrosion of reinforcement by the finishing materials, etc. In addition, the authors, taking these results as a basis, propose a way of determining reliable plans relative to the covering depth of reinforcement. They also give a method of estimating the probability of reinforcement corrosion and explain how to evaluate buildings by durability by using these two methods.

A-269 Kivekas, L. 1984 (Dec). "Durability of Concrete in Arctic Offshore Structures," Nordic Concrete Research, No. 3, pp. 129-139, Technical Research Center of Finland, Concrete & Silicate Lab, Espoo, Finland.

Concrete is a suitable material for arctic offshore oil and gas drilling and production platforms. In the splash and tidal zone of these structures concrete is subjected to severe frost-salt attack, chemical attack of seawater and ice abrasion. In the test series a method for accelerated testing of the arctic freeze-thaw durability in seawater was developed. High-strength superplasticized concretes were tested. The test was found to be very severe; the more entrained air the concretes included and the higher their protective pore ratio, the better was their durability.

A-270 Beckett, D., Sir Frederick Snow & Partners. 1984 (Nov-Dec). "Concrete Durability," Consulting Engineer, Vol 48, No. 10, pp 15-60, 20, London, England.

Defects arising in buildings constructed in the past 20 years are the primary cause for concern. These defects arise from a number of causes, one of which is the premature lack of durability of in situ and precast concrete structures. This article surveys the factors which can lead to lack of durability and focuses attention on the necessity for designing concrete structures for strength and durability. It discusses cement properties and their influence on durability, hydration, factors contributing to corrosion of reinforcements, corrosion protection, and design considerations.

A-271 Bealey, M. 1984 (Dec). "Pipe Durability Investigations," Concrete Pipe News, Vol 36, No. 6, pp 9-14, Vienna, VA.

Results of a 1983 literature search of works published since 1925 on the durability of pipeline materials are listed. Seven comprehensive reports are highlighted and their conclusions reprinted. Bibliographic information is given for 83 state culvert surveys and reports, and 48 miscellaneous pipeline surveys and reports.

A-272 West, T. R., and Shakoor, A. 1984. "Influence of Petrography of Argillaceous Carbonates on their Frost Resistance in Concrete," Cement, Concrete, and Aggregates, Vol 6, No. 2, Winter 1984, pp 84-89, Philadelphia. PA.

Argillaceous carbonate rocks, when used as coarse aggregate, have been found to cause severe pitting and popouts in several Indiana highways within one winter after construction. These rocks were studied in detail petrographically to determine texture, structure, mineral composition, and, in particular, the amount, type, and mode of distribution of argillaceous material.

Results of petrographic examination are compared with other test data including specific gravity, absorption-adsorption values, pore characteristics, and loss in freeze-thaw resistance. This comparison suggests a close relationship between petrographic characteristics and freeze-thaw resistance of argillaceous carbonates. A comparison of petrographic information with field performance shows that those rocks containing more than 20-percent silt and clay distributed uniformly throughout the rock mass result in pitting and popouts while those in which silt and clay are concentrated as streaks and laminations are not necessarily unsound. This is contrary to several previous investigations concluding that laminated carbonates should be considered nondurable without specific concern for their total argillaceous content.

A-273 (Deleted)

A-274 Libby, J. R. 1984. "Precast Concrete Weathers Fire Damage," Concrete International: Design & Construction, Vol 6, No. 11, Detroit, MI.

Following a fire in a building constructed with reinforced concrete masonry bearing walls, a municipal building inspection department ordered that all panels with spalled areas must be replaced. The loading testing of all panels without spalling was also required. As a result, load tests on four panels were conducted and, despite the intensity of the blaze, no structural remedial work was needed for the masonry walls and precast floor panels.

A-275 Sayward, J. M. 1984. "Salt Action on Concrete," Special Report 84-25, US Army Cold Regions Research and Engineering Laboratory, Hanover, NH.

Serious deterioration of concrete bridges by deicing salts is generally ascribed to depassivation and corrosion of reinforcing steel, as growth

of corrosion causes spalling. Here simple evaporative tests simulated the salt weathering that slowly crumbles rocks in nature, where crystals growing from pore water fed from below stress the matrix just as do ice crystals in frost-heaving soil. Like needle ice (surface frost action in soil), the salt columns exuded from concrete also lifted tiny particles, signifying crumbling. Microcracks developed in 1 to 3 years of after-test dry storage. In a 4-month simpler repeat test with salt, such cracks developed in all six concretes tested (five dolomitic, one siliceous). The siliceous concrete developed visible cracks in 3-year storage and a visible stone chip in the short repeat test, both with NaCl. The siliceous concrete also cracked badly within 1 week with strong $CaCl_2$ and deteriorated completely in 3-year storage. It also cracked badly with dilute $CaCl_2$ or $Ca(No_3)_2$ in a few weeks to a year of after-test dry storage. The small or nil exudation in tests with seawater may signify internal reaction plugging pores with insoluble $Mg(OH)_2$. This suggests a hypothetical means of control by addition of MG++ to deicers or concrete. Present results suggest that neither corrosion of steel nor the Cl-ion are requisite in salt action on concrete but that salt-caused microcracks may facilitate access of salt for cracking and also of CO_2, oxygen, water, and salt for ultimate corrosion effects.

A-276 Rehm, G., Frey, R., and Funk, D. 1984. "Influence of Defective Mortar-Injection On the Corrosion of Prestressing Steel," Deutsher Ausschub Fur Stahlbeton, Bulletin No. 353, pp 57-79, Berlin, Germany.

In constructions of prestressing steel, some mortar-injection defects usually exist. The corrosion effects of prestressing steels in such defects are investigated. The results indicate that for intensive corrosion in such defects periodic moistening and drying is a consequence of variations in environment and temperature. A negative influence of the hydrogen being created by the corrosion itself demands prestressing steel of special hydrogen sensitiveness. If the prestressing steel in the injection defect is covered with some alkali mortar, no corrosion occurs.

A-277 Wesche, K., Neroth, G., and Weber, J. W. 1984. "Penetration of Chlorides from Burning PVC into Reinforced Concrete Structures," Deutscher Ausschuss fur Stahlbeton, Bulletin No. 352, pp 81-101, Berlin, Germany.

Fumes of hydrochloric acid escape by the thermal decomposition of PVC, which can cause corrosion of the reinforcement of concrete. Laboratory investigations showed that during the fire the fumes penetrate only a few millimetres in the concrete (if the concrete is not thermally destroyed). The chloride ions diffuse into the interior of the concrete, but the diffusion velocity depends on the humidity. Investigations and restoration methods of chloride-contaminated concretes are shown and eight fire cases are described.

A-278 Rostam, S. 1984. "Durability of Concrete Structures," ed. by Danish Concrete Association, Copenhagen, Denmark.

Reports on the international workshop Durability of Concrete Structures, where participation was by invitation only, document the discussion of professionals and researchers from 18 different countries. A comprehensive and updated presentation of the actual durability problems encountered in practice is presented including possible ways of handling these problems in both short- and long-term perspective. The report treats both specific problems experienced with existing structures and general problems associated with the design and construction of new concrete structures as well as discussing the important aspects of their actual service life. The objectives of the workshop were to establish the state of the art, identify short-term needs, formulate relevant performance criteria, bridge the communication gap between material science and engineering descriptions, identify relevant national and international activities, and coordinate and cooperate activities between and within the international associations involved.

A-279 Crumpton, C. F., Koontz, G. M., and Smith, B. J. 1984. "For Want of Air, a Drainage System was Nearly Lost," Symposium on Durability of Culverts and Storm Drains, Transportation Research Record 1001, Transportation Research Board National Research Council, Washington, DC.

The omission of entrained air from a concrete pipe end section in 1972 set up a chain of events that could have been much more destructive. Freezing and thawing, which were aided and abetted by salty meltwater from deicing salts running over the exposed invert of the end section, caused the pipe to scale. By the end of 10 winters the scaling had worked completely through the pipe invert, allowing runoff water to erode beneath the end section and the adjacent concrete ditch liner. The end section and a large portion of the ditch liner were lost. Minor slides and soil slumping at the toe of the fill began. The damaged end section and portions of the ditch liner were removed and replaced in 1983. Had corrective action not been taken, a much larger portion of the drainage system and the fill could have been lost. To paraphrase Ben Franklin in Poor Richard's Almanac of 1758: For want of air, an invert was lost; for want of an invert, an end section was lost; for want of an end section, a ditch liner was lost, being undercut and destroyed by uncontrolled runoff, all for want of care about entrained air.

A-280 Bealey, M. 1984. "Precast Concrete Pipe Durability: State of the Art," Symposium on Durability of Culverts and Storm Drains, Transportation Research Record 1001, Transportation Research Board National Research Council, Washington, DC.

In this paper, the performance of precast concrete pipe is reviewed, and state-of-the-art information concerning the durability of buried precast concrete pipe is presented. The properties of precast concrete pipe, and other factors that influence durability, are discussed. The

performance of precast concrete pipe in specific aggressive environments is evaluated. The service life of precast concrete pipe in most installation environments is virtually unlimited. Aggressive environments are readily identifiable in the design stage, and precautions are available to eliminate any concerns with the use of precast concrete pipe.

A-281 Hurd, J. O. 1984. "Field Performance of Protective Linings for Concrete and Corrugated Steel Pipe Culverts," Symposium on Durability of Culverts and Storm Drains, Transportation Research Record 1001, Transportation Research Board National Research Council, Washington, DC.

In this paper, information is provided regarding the durability of protective linings for concrete pipe and galvanized corrugated steel pipe (6 by 2-in. and 2.67 by 0.5-in. corrugations) used for culverts at corrosive and abrasive sites in Ohio. The performances of epoxy-coated concrete pipe, polymeric-coated corrugated steel pipe, and asbestos-bonded bituminous-coated-and-paved corrugated steel pipe have been monitored for the past 10 years. Observations and conclusions made to date are reported. All three materials have provided satisfactory protection of base pipe material at study sites, except for polymeric coating at abrasive sites. The performance of other types of less frequently used protective linings are discussed to a limited extent.

1985

A-282 "Cracking in Concrete Structures - Why Concrete Structures Crack and What to do About It." 1985 (Jan). Concrete International: Design & Construction, Vol 7, No. 1, pp 26-30, Detroit, MI.

The cracking of concrete is not necessarily a cause for placing blame on the designer, builder, or supplier. What really matters is the type of structure and the nature of the cracking. Cracks that are acceptable for building structures may not be acceptable for water-retaining structures. Cracking of concrete can never be totally eliminated, but the practitioner can be aware of the causes, evaluation, and methods of repair. This article discusses these subjects in terms of cracking of unhardened concrete, cracking of hardened concrete, inspection, nondestructive testing, repair materials and methods, and other related subjects.

A-283 Watanabe, A., Idemitsu, T., and Takayama, S. 1985 (Jan). "Corrosion of Steel in Concrete Under the Influence of Chloride," Journal, Society of Materials Science, Vol 34, No. 376, pp 26-32, Kyoto, Japan.

The Japan Society of Civil Engineers has recommended the allowable chloride content of fine aggregate in reinforced concrete and prestressed concrete members to be 0.1 and 0.03 percent by weight, respectively. In Kyushu, about 90 percent of the fine aggregate used for concrete works are sea sand. However, the relationship between the salt content of concrete and corrosion of reinforcing bars and prestressed concrete wire has not been clearly known and the basic concept

for the recommended salt content is not firmly established yet. Under these circumstances, the authors have conducted experimental studies of reinforcing bars and prestressed concrete wire.

Although the experiments are still being conducted, results thus far are as follows:

1. Measured values of salt content in the specimens placed on land were reduced to about one-half of the designed amount, but cases in sea and on the coast reached up to 1 to 2 percent near the surface. It is thought that the phenomenon for the latter cases was caused by infiltration of chloride ions.

2. Though the prestressed concrete wires were covered with rich mix concretes, their rusting was remarkable compared with reinforcing bars. When the salt content of concrete was 0.5-1.0 percent, the percentage of rusting weight of steel became remarkable. Every effort should be made to keep the salt content as low as possible when placing concrete.

A-284 Webster, R. P., and Kukacka, L. E. 1985 (Feb). "Effects of Acid Deposition on the Properties of Portland Cement Concrete State-of-Knowledge," Report EPA/600/3-85/011, Brookhaven National Laboratories, Upton, NY.

Presented in this report are the results of a program conducted to determine the state-of-the-art knowledge pertaining to the effects of acid deposition on the properties of portland cement concrete structures. Information was collected from a computerized literature survey, interviews, and replies to mail and telephone inquiries addressed to cement and concrete researchers and to governmental agencies and private firms active in the maintenance and restoration of concrete structures.

A-285 Knoefel, D., and Boettger, K. G. 1985 (Feb). "On the Behavior of Cement-Bound Building Materials in An SO_2 Enriched Atmosphere," Betonwerk und Fertigteil-Technik, Vol 51, No. 2, pp 107-114, Wiesbaden, Germany.

The development of high-quality concretes made it possible during the past decades for building parts to be reduced in size and, to some extent, the concrete coverage above reinforcement diminished. As a result, damages on concrete structures are known to have occurred in certain cases in connection with the inevitable fluctuations in concrete composition and particularly while building works were in progress. The influence of the atmosphere was in many cases the chief factor to blame. The atmosphere conditions, because of its CO_2 and SO_2 contents, a carbonation and sulphation of the concrete.

A-286 Gau, Y., and Cornet, I. 1985 (Feb). "Penetration of Hardened Concrete by Seawater Chlorides with and without Impressed Current," Corrosion 41, Vol 2, pp 93-100.

Chloride ions in sufficient concentration have been known to shift the potential of steel in concrete in an active direction. Therefore, the rate of chloride ion penetration of concrete structures is of interest to corrosion engineers. The results of a laboratory investigation into the rate of seawater chloride penetration of various hardened concrete mixes with and without impressed current conditions are reported. The effects of current densities and duration of exposure were evaluated. Diffusion models predicting the chloride concentration in concrete structures with and without impressed current are proposed.

A-287 Pailliere, A. M., Raverdy, M., and Millet, J. C. 1985 (Jan-Feb). "Influence of Cement on the Deterioration of Concrete in a Marine Environment" (in French), Bulletin de Liaison des Laboratoires des Ponts et Chaussees, No. 135, pp 5-10, Paris, France.

Laboratory research work carried out with an accelerated swelling test has allowed study of the influence of a number of factors inherent in cement nature influencing the durability of concrete exposed to seawater. The importance of SO_3 contents is predominant during the first 2 years and gradually lessens to be taken over by C_3A content. The cement granularity factor is above all intervening in the case of cements when $C_3A>10$ percent and when the SO_3 content is high; it can be observed that the thinner the cement, the more it resists sulfate attack. The granularity influence is quite pronounced in the case of cements with 20 percent slag. The addition of fly ashes and calcareous or siliceous fillers tends to improve or reduce the swelling phenomenon.

A-288 Shayan, A. 1985 (Mar). "Warping of Precast, White Concrete Panels," Cement and Concrete Research, Vol 15, No. 2, pp 245-252, Elmsford, NY.

Severe warping occurred of decorative, precast, white concrete panels fixed to the frames of some buildings in Perth, Western Australia. Measurements of cyclic shrinkage and expansion, and petrographic, XRD, and SEM examinations showed that the concrete expanded irreversibly due to cracking and subsequent healing. This behavior is attributed to the lack of sand and excess of cement in the mix design. Inclusion of sand in the mix eliminated the problem. In laboratory experiments, concrete made with white cement and ordinary portland cement behaved similarly and indicated that the warping was not due to the use of white cement.

A-289 Thomas Telford. 1985 (May). "Improvement of Concrete Durability, Proceedings of the Seminar 'How to Make Today's Concrete Durable for Tomorrow'," Conference on Improvement of Concrete Durability, London, England.

This conference proceedings contains five papers. Topics discussed are requirements for durable concrete; the use of pulverized fuel ash to

produce durable concrete; use of ground granulated blast furnace slag to produce durable concrete; practical considerations in producing durable concrete; maintenance of buildings and structures - the problem, some causes and remedies.

A-290 Rao, D. S. P., and Aggarwal, P. 1985 (May). "Carbonation and Corrosion in Concrete Structures," Journal, Indian Concrete, Vol 59, No. 5, pp 130-132, 138, Structural Engineering Research Center, Roorkee, India.

Durability of a concrete structure depends, among other factors, upon the quality of concrete and the protection it accords to the steel. Carbonation of concrete, which leads to the corrosion of the steel, reduces the useful life of the structure, besides causing maintenance problems. The factors that influence these phenomena are discussed in the article. Preventive measures to reduce the deleterious effects of carbonation and corrosion are also highlighted.

A-291 Browne, R. D. 1985. "Practical Considerations in Producing Durable Concrete," Conference on Improvement of Concrete Durability, Proceedings of the Seminar 'How to Make Today's Concrete Durable for Tomorrow', London, May 8, 1985; pp 97-130, Thomas Telford, London, England.

The problem of concrete durability is discussed in terms of the mechanisms by which deterioration due to environmental attack occurs. The major controlling factors are discussed. Curves for chloride and carbonation ingress are presented in terms of depth of penetration over time. These can be used to predict the life of structures or to estimate life expectancy from code cover and strength requirements. A check list gives the ways in which durable concrete in the cover zone can be achieved in practice.

A-292 Roper, H. 1985. "State of the Art of Practical Prevention and Control of Corrosion in Concrete Structures," 4th Conference on Asian-Pacific Corrosion Control, Material Conservation and Corrosion Control, Tokyo, May 26-31, 1985, Vol 2, pp 716-722.

The two main conditions under which rapid corrosion of steel is known to occur in concrete are developed when carbonation of the concrete has led to a reduction of pH or when the depassivating chloride ion is present. To enhance long-term durability over and above the usual procedures followed in the case of most civil engineering works is the objective. Some procedures available for enhancement of some aspects of durability are briefly outlined.

A-293 Sakugawa, T., Sakuta, M., and Kishitani, K. 1985. "Durability of Reinforced Concrete Structures in Marine Environment," Conference on Ocean Space Utilization '85, Proceedings of the International Symposium, Tokyo, Jun 1985; Vol 2, pp 455-461, Springer-Verlag, Tokyo, Japan, and New York, NY.

The corrosion of reinforced steel is the most critical problem to affect the durability of reinforced concrete in marine environment. The corrosion of reinforced steels is affected by the content of salt (use of beach sand and the penetration of chloride) in concrete. In particular, structures built in the coastal zone suffered heavy damage due to the penetration sea-salt particles. The relation of the sea-salt particles and the penetration of chloride into concrete occurs when the sea-salt particles volume is greater than 0.12mg/dm^2/day; the penetration of chloride volume tends to increase suddenly.

A-294 Dewar, J. D. 1985 (Jun). "Testing Concrete for Durability," Concrete, Vol 19, No. 6, pp 40-41, London, England.

Surveys broad issues relevant to durability testing of concrete. Topics discussed include concrete mobility (permeability, sedimentation, and stress and strain concentrations), variations in structures, and discrepancies between "real" concrete and cube specimens.

A-295 Kashino, N. 1985 (Jun). "Some Aspects of the Classifications of Pollution by Sea Water Aerosol for Reinforced Concrete Buildings," Ministry of Construction, Tsukuba, Japan, Conference on Ocean Space Utilization '85, Proceedings of the International Symposium, Tokyo, Jun 1985, Vol 2, pp 447-454, Springer-Verlag, Tokyo, Japan, and New York, NY.

Classification of reinforced concrete buildings standing along seashores was done based on investigations of actual conditions regarding the distributions of seawater aerosol in the atmosphere measured by the distance from the shoreline and the quantity of penetration of the aerosol into concrete. According to the classification, parts of reinforced concrete structures standing up to 200 m from the shoreline directly facing the sea are subjected to salt damage without fail so that it is necessary for some kind of countermeasure to be taken. In case of 1 km from the shoreline, it is necessary for damage being sustained.

A-296 Ramos, J. M., and De Pinho, J. S. 1985 (Jun). "Delayed Effects Observed in Concrete Dams," Fifteenth International Congress on Large Dams," 24-28 Jun 1985, Lausanne-Suisse, Lausanne, Switzerland.

The analysis of long-term behavior of concrete dams, in most cases, reveals the existence of important nonelastic effects, which however can to some extent be due to the rheology of the material forming the superstructure, i.e., the concrete. The rheologic behavior of concrete is predicted from results of laboratory tests as well as from data on concrete composition and results of << in situ >> tests. A methodology is presented to quantify the amount of the nonelastic effects observed

that can be justified on account of concrete rheology. Delayed displacements observed in a large dam are interpreted following this methodology.

A-297 Kamata, H. 1985. "Mechanism of Frost Damage, and Tests of Resistance to this Phenomenon" (in Japanese), Cement and Concrete, No. 461, pp 34-41, Tokyo, Japan.

The fourth part of a series of articles relative to the resistance to freezing and thawing, this report deals more particularly with the following items: 1) water pressure theory and part played by air bubbles; 2) interpretation taking into consideration the influence exerted by the pores' diameter on the freezing temperature and evaluation of the importance of the factors allowing prevention of frost damage; 3) other mechanisms involving frost damage in concrete, including Collin's theory, osmotic pressure theory, and scaling; and 4) tests for estimating the resistance of concrete to frost, including ASTM C 666 and JIS; testing method of the America Development Board; Power's testing method (ASTM C 671); RILEM limit degree of water-saturation method; one-size freezing tests; and scaling tests (ASTM C 672).

A-298 El-Sayed, H. A. 1985 (Jul). "Case Study of An Early Failure of a Concrete Construction Due to Reinforcement Corrosion," Durability of Building Materials, Vol 3, No. 1, pp 23-24, Amsterdam, The Netherlands.

This report investigates the factors responsible for the early failure of the reinforced concrete in the Central Hospital, Kafr El-Sheikh Governorate in Egypt. Concrete analysis revealed the presence of high sulfate and chloride content. The sulfate content has been found to be characteristic of a blast furnace slag cement. Testing for carbonation indicated that the concrete has been converted to a carbonated one. Microscopic inspection showed that the reinforcing steel suffered from intense pitting attack. The investigation disclosed that cracking and spalling of the concrete was the result of dense corrosion products formed in the vicinity of reinforcing steel, exerting excessive internal pressures sufficient to crack the concrete with an attendant loss in the strength of the structure.

A-299 Dewar, J. D. 1985 (Jul). "Testing Concrete for Durability: Part 2," Concrete, Vol 19, No. 7, pp 19-21, London, England.

Before choosing an existing method or designing a new one for testing concrete for durability, first priority must be given to establishing the purpose of the test, the parameter to be measured, and the place of testing. Methods designed for one purpose may be inadequate for another. Examples of different purposes relating to durability are provided, and where and how the durability test is to be used is discussed. As durability testing can cover the whole range of standard, nonstandard, and ad-hoc tests, the differences between them are also discussed.

A-300 Fukushi, I. 1985 (Jul). "Evaluation of Concrete Carbonation-Carbonation and RC Buildings' Durability" (in Japanese), Cement and Concrete, No. 461, pp 8-16, Tokyo, Japan.

Detailed explanations are given on the following points: 1) mechanism and speed of carbonation; 2) factors exerting an influence on the speed of carbonation, including concentration of carbonic acid gas, environment, water-cement ratio, unit-cement quantity, varieties of cement, admixtures, and additives, and finishing materials; 3) relations between carbonation of concrete and corrosion of steel reinforcement; and 4) corrosion of steel reinforcement and durability of reinforced concrete buildings. In this last paragraph, the authors analyze each stage of the progress of carbonation (from t_1, time when carbonation reaches the surface of steel reinforcement, to t_2, corresponding to the corrosion of reinforcement and the production of cracks in concrete, and t_3, time when the resistance of reinforced concrete members reaches its limits).

A-301 Babaei, K. 1985. "Bridge Deck Program Development," Report WA-RD-73.1, Federal Highway Administration, and Washington State Department of Transportation, Olympia, Washington.

The report identifies, classifies, and addresses WSDOT's needs and questions regarding concrete bridge deck deterioration. Included is a state-of-the-art assessment regarding any major areas of concern to the statewide bridge deck program. Recommendations are made to WSDOT regarding future bridge deck research. A proposed work plan is developed for high priority research items as directed by the WSDOT.

A-302 Frey, R., and Rehm, G. 1985. "Corrosion of Badly Extruded Reinforced Steels After Storage Periods of Several Years" (in German), Report IRB-T-1530, Institut fuer Bautechnik, Berlin, Germany.

Due to faulty extrusion of reinforcing steels with mortar, there are faults which are particularly sensitive to corrosion. Based on assessment, nearly one-half the faults in reinforced concrete structures fail due to such faults. Only experiments can show how corrosion of badly extruded reinforcement occurs in practice. The aim of suitable investigations was therefore to clear these faults and corrosion conditions. This is a report on the occurrence of corrosion pitting (mechanism of the anodic and cathodic part reactions and formation of corrosion pitting), on carrying out the experiment (samples, reinforcing steel, and its storage methods of investigation), and on the results (steel surfaces free of mortar and coated with mortar, carbonation of faults). The interpretation of the results was related to wetting and drying of steel surfaces at faults, the formation of condensed water, transport of oxygen, and speed of corrosion.

A-303 Erlin, B., and Hime, W. G. 1985 (Sep). "Chloride-Induced Corrosion," Concrete International: Design & Construction, Vol 7, No. 9, pp 23-25, Detroit, MI.

Based on a study of many structures that have suffered from damage due to chloride-induced corrosion of reinforced steel, it appears that even the more stringent limits on chloride now being proposed may be too lenient. Furthermore, only determinations of total chloride may provide a basis for reasonable assurance against future corrosion.

A-304 Atkinson, A., Goult, D. J., and Hearne, J. A. 1985. "Assessment of the Long-Term Durability of Concrete in Radioactive Waste Repositories,"Conference on Scientific Basis for Nuclear Waste Management TX, Stockholm, Sweden, Sep 9-11, 1985, Materials Research Society Symposia Proceedings, Vol 50, pp 239-246, Materials Research Society, Pittsburgh, PA.

A preliminary assessment of the long-term durability of concrete in a repository sited in clay is presented. The assessment is based on recorded experience of concrete structures and both field and laboratory studies. It is also supported by results of the examination of a concrete sample which had been buried in clay for 43 years. The engineering lifetime of a 1-m-thick reinforced concrete slab, with one face in contact with clay, and the way in which pH in the repository as a whole is likely to vary with time have both been estimated from available data. The estimates indicate that engineering lifetimes of about 10^3 years are expected (providing that sulfate-resisting cement is used) and that pH is likely to remain above 10.5 for about 10^6 years.

A-305 Mukai, T. 1985 (Sep). "Effects of Finishing on Buildings' Durability" (in Japanese), Cement and Concrete, No, 463, pp 2-7, Tokyo, Japan.

After an introduction on the development of finishing materials from an historical point of view, the lowering of durability in recently constructed reinforced concrete buildings and the role to be played by finishing materials in the improvement of durability of new buildings and already constructed buildings are described. The only technical details provided are two tables analyzing the main factors of deterioration of reinforced concrete buildings and the processes of deterioration and the differences in the progress of concrete carbonation according to the finishing material used.

A-306 Rasheeduzzafar, Gahtani, A. S., and Dakhil, F. H. 1985 (Sep). "Corrosion of Reinforcement in Concrete Structures in the Middle East," Concrete International: Design & Construction, Vol 7, No. 9, pp 48-55, Detroit, MI.

After only 10 to 15 years of service, many reinforced concrete structures in the aggressive environment of the areas surrounding the Arabian Gulf are showing an alarming degree of deterioration. Condition surveys indicate that corrosion of the reinforcement is the most prevalent form of this deterioration. This article presents a study

based on data collected from 20 reinforced concrete structures, all from 22 to 27 years in service and located in Eastern Saudi Arabia. The study included an analysis of 108 cores to determine the influence of chloride content, cover of the reinforcement, and other factors that could lead to corrosion.

A-307 Papworth, F., and Grace, W. 1985. "Designing for Concrete Durability in Marine Environs," Concrete 85 Conference on The Performance of Concrete and Masonry Structures, Brisbane, Australia, Oct 23-25, 1985, National Conference Publication - Institution of Engineers, Australia, No. 85-17, pp 104-110, Institution of Engineers, Australia, Barton.

This paper discusses mechanisms of concrete deterioration in marine environments and describes a concrete mix selection method which, in conjunction with appropriate detailing will greatly improve the durability of reinforced concrete. The paper also discusses the influence of environment on corrosion rate and outlines a method for designing concrete for durability in nonchloride environments.

A-308 Roper, H., Kirkby, G. A., and Baweja, D. 1985. "Durability - A Quantitative Approach," Concrete 85 Conference on The Performance of Concrete and Masonry Structures, Brisbane, Australia, Oct 23-25, 1985, National Conference Publication - Institution of Engineers, Australia, No. 85-17, pp 32-35, Institution of Engineers, Australia, Barton.

Durability of concrete structures is, despite considerable interest, as yet ill-defined. Methods of classification and quantification of durability of concrete members have recently been outlined in a series of co-authored papers. The application of such methods to structures is outlined. The accumulation of data requires the use of a computer, and methods of transferring data from photographic or television images to storage is discussed. The data is then available for computations, which relate types of deterioration effects to reinforcement and other details. Statistical procedures are introduced to systematize the data, and to permit comparisons to be made between structural members, within the same structure or between structures. The approach should, if successfully applied, allow better measurements of durability to be made, and hence improve techniques of predicting performance, making comparisons between materials and systems, assessing repair procedures, and estimating repair costs.

A-309 Dhir, R. K., Jones, M. R., and Munday, J. G. L. 1985 (Oct). "Practical Approach to Studying Carbonation of Concrete," Concrete, Vol 19, No. 10, pp 32-34, London, England.

This article describes the design and development of a curing system to allow the practical study of the carbonation of concrete, obtaining data in the short term by accelerating the process. The system is suitable to study portland-cement concretes, including those containing hydraulic binders, lightweight aggregate, and admixtures. Variables were humidity, temperature, and air circulation in a curing atmosphere of CO_2 enriched air. The system allows for a rapid assessment, for

mixes with various constituents, of what is essentially a long-term durability problem.

A-310 Marecos, J. 1985 (Sep-Oct). "Research and Following of Concrete Structures," Materials and Structures, Research and Testing, Vol 18, No. 107, pp 349-352, RILEM, Paris, France.

The importance and interest of applied research for improving knowledge of the long-term structural behavior of concrete structures is increasingly being recognized as a growing number of relatively new concrete structures have been found to present pathological problems that endanger their safety, serviceability, and durability.

A-311 Lukas, W. 1985 (Nov). "Relationship Between Chloride Content in Concrete and Corrosion in Untensioned Reinforcement on Austrian Bridges and Concrete Road Surfacings," Betonwerk und Fertigteil-Technik, Vol 51, No. 11, pp 730-734, Wiesbaden, Germany.

In all of the investigated cases (concrete road surfacings, bridge edges, bridge supports), a distinct correlation between the concentration of chloride in concrete without cracks and evidence of corrosion was established. This value is relatively high for the investigated concrete structures and varies between 1.8 and 2.2 percent, chloride ion content as related to the cement.

A-312 Smith, M. A. 1985 (Dec). "Effect of Phenol Upon Concrete," Magazine of Concrete Research, Vol 37, No. 133, pp 234-237, Wexham Springs, England.

Phenols are common contaminants of sites used for coal carbonization. Phenol itself (C_6H_5OH) is reported to be detrimental to concrete, but no quantitative data are available. This paper describes results of up to 2 years of a test series carried out on 100-mm cubes immersed in phenol solutions of various concentrations.

Concentrations of phenol as low as 0.2 percent by volume are shown to have an adverse effect on the development of compressive strength, and concentrations as low as 0.1 percent may be detrimental.

A-313 Uomoto, T., Tsuji, K., and Kakizawa, T. 1985. "Deterioration Mechanism of Concrete Structures Caused by Corrosion of Reinforcing Bars," Transactions, Japan Concrete Institute, Vol 6, pp 163-170, Japan Concrete Institute, Tokyo, Japan.

Concrete structures located in marine environment are apt to suffer severe deterioration by corrosion of reinforcing bars. The main cause of the deterioration is the chloride ions supplied from seawater. To maintain the concrete structure during its service life, measures to prevent deterioration and deterioration mechanism must be clarified.

A-314 Nagano, H., and Naito, T. 1985. "Application of Diffusion Theory to Chloride Penetration into Concrete Located in Splashing Zones," Transactions, Japan Concrete Institute, Vol 7, pp 157-164, Japan Concrete Institute, Tokyo, Japan.

The diffusion theory is applied to analyze the mechanism of chloride ion penetration into concrete located in splashing zones. The concrete member is considered semi-infinite, so that the analytical exact solution for one-half space is used. The condition of chloride environment is classified into three types, and an analytical solution is obtained for each type. A method to evaluate the effect of coating for concrete damaged by chloride is also proposed by introducing the repairing effect factor. The chemical analysis of the actual concrete structures is also conducted. From the results of the chemical analysis, it is confirmed that the present method based on the diffusion theory gives an accurate distribution of chloride ion concentration, and that the classification of chloride environment is also reasonable.

A-315 Matousek, M., and Drochytka, R. 1985. "Effect of Carbon and Sulphur Dioxide on Service Life of Concrete" (in Czechoslovakian), Stavivo/Building Materials, No. 10, pp 394-398, Prague, Czechoslovakia.

The text is adapted from a lecture held at a special seminar. Results of research in the silicates branch of the seventh 5-Year Plan at the Chemical Technological University in Prague.

The corrosion on concrete due to atmospheric carbon dioxide takes place in four steps in conjunction with special kinetics depending on the moisture present. The decisive process is the diffusion of the carbon dioxide, owing to its very low speed. A number of physical and chemical methods are necessary to determine the degree to which the concrete has been attacked by carbon dioxide. Various plots of dependences among the individual criteria have been proposed to evaluate carbonation. In the process of sulphur dioxide action on concrete there are not only the cement hydration products that decompose, but also the $CaCO_3$ formed by earlier carbonation. The final product of the reaction of sulphur dioxide and concrete is calcium sulphate dihydrate which severely attacks the initial structure. An important intermediate product of the mentioned reactions is calcium sulphite hemihydrate.

A-316 Bhatty, M. S. Y. 1985. "Mechanism of Pozzolanic Reactions and Control of Alkali-Aggregate Expansion," Cement, Concrete, and Aggregates, Vol 7, No. 2, pp 69-77, American Society for Testing and Materials, Philadelphia, PA.

The mechanism of pozzolanic reactions and their control of expansion caused by alkali-aggregate reaction was investigated. Mixtures of tricalcium silicate, opal, sodium hydroxide, and water having calcium oxide to silica mole ratios from 1.07 to 3.0 were prepared and reacted from 7 days to 4 years before filtering. The solids (precipitates) were studied by X-ray diffraction to determine the phases present, and the alkali content of filtrates was obtained by chemical analysis.

Results suggest that pozzolans reduce or eliminate alkali-aggregate expansion by producing additional calcium silicate hydrate and low-lime calcium silicate hydrate. These hydrates can retain additional alkali, thus reducing the amount of alkali available for reaction with reactive aggregate. To control alkali-aggregate expansion by the addition of a pozzolan, such as fly ash, results indicate that adding about 30 percent low-lime fly ash is required. However, this amount could be reduced to a level as low as 20 percent (cement basis) if the concrete retains reactive siliceous aggregate.

A-317 Gorchakov, G. I., et al. 1985. "Durability of Light Concretes and Structures Made of Industrial Wastes" (in Russian), Beton i Zhelezobeton, No. 7, pp 13-14, Moscow, USSR.

Durability of reinforced concrete structures made of concretes based on porous aggregates, including industrial wastes, is composed of many factors: concrete resistance, reinforcement, and corrosion resistance. To reduce corrosion caused by free CaO, MgO, and other physicochemical properties of industries wastes (metallurgical slags, slurry, ashes, phosphorous slags, or silica wastes), the cement-aggregate ratio must be determined and studied with accuracy.

A-318 Miettunen, A. 1985. "Corrosion-Resistant Concrete" (in Finnish), Betonituote, Vol 55, No. 1, pp 32-36, Helsinki, Finland.

Due to difficult environmental conditions, corrosion has recently occurred in concrete, the material traditionally regarded as almost eternal. The mechanisms of freezing-thawing corrosion, reinforcement corrosion, and chemical corrosion and the methods for preventing them are described and discussed in detail. By proper methods, corrosion resistant concrete can be produced for aggressive conditions as well.

1986

A-319 Page, C. L., Short, N. R., and Holden, W. R. 1986 (Jan). "Influence of Different Cements on Chloride-Induced Corrosion of Reinforcing Steel," Cement and Concrete Research, Vol 16, No. 1, pp. 79-86, Elmsford, NY.

Corrosion of embedded steel in concrete may occur as a result of the depassivating effects of chloride ions. Two important parameters governing the risk of chloride-induced corrosion in cement matrices of varied compositions are believed to be the relative concentrations of chloride and hydroxyl ions in the pore electrolyte and the diffusivities of chloride ions. Measurements of these parameters for cement pastes of constant water/cement ratio and fixed total chloride content have been used to rank a series of portland cements, slag blended cements, and fly-ash blended cements in terms of their expected levels of corrosion protection. The validity of the predicted rank orders has been independently assessed by electrochemical monitoring of the corrosion rates of embedded steel electrodes by means of the method of linear polarization.

A-320 Millet, J. C. 1986 (Feb). "Weathering of Concrete in Chambon Dam" (in French), Travaux, No. 607, pp 52-54, Paris, France.

This paper deals with studies conducted on the problems raised by the weathering of the concrete materials in the Chambon Dam and endeavors to derive a philosophy for subsequent investigations.

A-321 Adkins, D. F. 1986 (Feb). "Laboratory Duplication of Surface Scaling," Concrete International: Design & Construction, Vol 8, No. 2, pp 35-39, Detroit, MI.

This article presents a new laboratory procedure which closely mimics the deterioration of concrete in the field under moderate to severe freeze-thaw conditions. This research investigated the process that occurred and resulted in surface scaling of saturated concrete slabs subjected to complete freezing and partial thawing in such a manner that the bottoms remained frozen while the upper portion of the slabs was thawed and refrozen from the top downward. Freezing and thawing in this manner is believed to have concentrated ice into lenses below the surface of the concrete, and in turn, failure was caused by the surface spalling off in sheets, or in some cases causing popouts. The availability of this procedure should help resolve the differences between conflicting theories on deterioration and provide insight into the relative importance of the factors and combination of factors which cause scaling.

A-322 Robison, R. 1986 (Mar). "Parking Problem." Civil Engineering, Vol 56, No. 3, pp 68-71, New York, NY.

Parking garages are the most vulnerable structures of all. Unlike other buildings, they must bear an extraordinary range of atmospheric conditions. Unlike bridge decks, parking decks are not rinsed off by rain. And they seem to be low on an owner's list of spending priorities for design, construction, and maintenance. Whether freestanding and open or enclosed within another building, parking garages must, above all else, be defended against corrosion. This article discusses the problem, what is being done to overcome it, corrosion protection requirements, materials, and other aspects of the subject.

A-323 Lemoine, L., and Raharinaivo, A. 1986 (Mar-Apr). "Reinforced Concrete Structures in Contact with Sea Water and Subjected to Fatigue and Corrosion" (in French), Bulletin de Liaison des Laboratoires des Ponts et Chaussees, No. 142, pp 69-75, Paris, France.

Reinforced concrete structures in a marine medium are subjected to mechanical stresses due to the action of waves and currents. These stresses, in combination with mechanisms of corrosion, give rise to phenomena of fatigue and corrosion which can shorten the life of the structure. To study these phenomena, experimental studies have been developed on concrete beams, making it possible to keep track of the evolution of mechanisms of deterioration of the concrete. The deflection and the width of cracks are measured over a period of time. The

appearance of corrosion is noted by means of measurements of electrode potential (potential mapping) and by other electromechanical methods such as impedance diagrams.

A-324 "Cure for Sick Structures?" 1986 (May). International Construction, Vol 25, No. 5, pp 25, 27, 30, Surrey, England.

Repair and refurbishment of deteriorated concrete structures is one of the few growth areas of construction. Under normal circumstances reinforced concrete is a highly durable material. Properly designed and properly placed, it can and has produced handsome structures which have stood the ravages of time. But recently, and particularly in the last 10-15 years, there has been growing concern at the increase in the number of buildings showing signs of distress within a comparatively short time of completion. One of the most common and most dangerous types of deterioration is corrosion of the reinforcement on which the strength and integrity of the structure depends.

A-325 Harsh, S. and Darwin, D. 1986 (May). "Traffic-Induced Vibrations and Bridge Deck Repairs," Concrete International: Design & Construction, Vol 8, No. 5, Detroit, MI.

Traffic-induced vibrations appear to have no detrimental effects on concrete-steel bond strength or compressive strength in full-depth bridge deck repairs, so long as low-slump concrete is used. This conclusion is based on the results of experiments using vibrations that match values obtained from field measurements. Variations in concrete cover, reinforcing bar sizes, and slump were investigated.

A-326 Rogers, C. A. 1986. "Evaluation of the Potential for Expansion and Cracking of Concrete Caused by the Alkali-Carbonate Reaction," Cement, Concrete, and Aggregates, Vol 8, No. 1, pp 13-23, Philadelphia, PA.

Alkali-carbonate reactive rock was inadvertently used in the Cornwall and Ottawa areas of Ontario between 1978 and 1982. Excessive expansion and cracking caused by this reaction resulted in the need to replace concrete within 3 years of construction. This reaction of dolomitic limestone with the alkalies from cement is well known in the Midland-Kingston areas of Ontario but had not been expected in the Cornwall and Ottawa areas. In an effort to prevent further occurrences of this reaction, 17 quarries in the Gull River Formation were studied.

Aggregate durability tests, chemical analysis, and concrete prism expansion tests were conducted on 26 bulk aggregate samples. Concrete prism expansion tests were conducted at alkali contents of 1.25 and 3.0 percent sodium oxide (Na_2O) equivalent. Results showed that the current Canadian Standards Association specifications are inadequate for recognizing some alkali-carbonate reactive aggregates. This was due to the occurrence of delayed expansive aggregate.

It is recommended that the concrete prism expansion test be conducted using cement with an alkali content of 1.25 percent Na_2O. Those

aggregates that exceed 0.025 percent expansion at 1 year should not be used in highway structures exposed to deicing salt. A rapid chemical screening test is proposed. The determination of the calcium oxide to magnesium oxide ratio and alumina content of insoluble residue can be used to screen potentially alkali-carbonate expansive rocks from those that are nonexpansive.

A-327 Vernon, P. 1986 (Jun). "Stray-Current Corrosion Control in Metros," Proceedings, Institution of Civil Engineers, Part 1, Vol 80, pp 641-650, London, England.

This paper briefly reviews some corrosion mechanisms of steel reinforcement in concrete, indicates the extent to which designs to control such corrosion in metro railways are emerging, and presents modeling and installation experience to further develop this design.

A-328 Isecke, B. 1986 (Jun). "Corrosion Behavior of Stressed and Prestressed Reinforcement in Concrete Structural Elements" (in German), Werkstoffe und Korrosion, Vol 37, No. 6, pp 322-330, Berlin, Germany.

In steel reinforced or prestressed concrete structures corrosion protection of the reinforcement is resulting from the high alkalinity of the concrete environment which guarantees passivity of the steel surface. The long-time efficiency of the corrosion protection is a function of the design of the structure and influence from the properties of the used concrete materials as well as the environmental conditions of the structure. Essential factors preventing corrosion are given by a good quality and thickness of the concrete covering, a proper curing of the concrete, and position of the reinforcement which avoids cracks and defects in the concrete covering. Passivity of the reinforcement can be destroyed by carbonization of the concrete or a sufficiently high amount of chlorides in the concrete.

A-329 Rozental, N. K., and Suasnabar, K. H. 1986 (Jul). "Concrete Carbonation in Tropical Climate Conditions" (in Russian), Beton i Zhelezobeton, No. 7, pp 11-13, Moscow, USSR.

The article discusses the effects of the tropical climate in Cuba on the reinforced concrete structures. The carbonation of concrete depends on the physico-chemical and mechanical properties of the concrete. The higher quality of cements and concrete reduces carbonation of concrete remarkably and protects the reinforcement steel from corrosion. The porous, low quality concrete is very vulnerable to the effects of humidity, temperature, and chlorides.

A-330 Schneider, U., Nagele, E., and Dumat, F. 1986 (Jul). "Stress Corrosion Initiated Cracking of Concrete," Cement and Concrete Research, Vol 16, No. 4, pp 535-544, Elmsford, NY.

The simultaneous action of corrosive media and mechanical stresses on concrete leads to stress corrosion cracking phenomena. The flexural strength of mortar specimens in sulfate-solutions has depended

significantly on the external load being applied during the sulfate-solution exposure of the specimens. Low stresses cause a relatively higher specific decrease of flexural strength than higher stresses. The effects observed are of fundamental importance with respect to the evaluation of the durability of concrete structures subjected to corrosive media.

A-331 Raharinaivo, A., and Genin, J. M. 1986 (Jul-Aug). "Corrosion of Concrete Reinforcements in the Presence of Chlorides" (in French), Bulletin de Liaison de Laboratoires des Pontes et Chaussees, No. 144, pp 59-64, Paris, France.

This study attempts to give scientific justification to certain empirical results in the field of the corrosion of reinforcing steel in a concrete containing chlorides. First, it appears that the products of steel corrosion are of different natures and structures, depending on whether the chloride content is above or below a characteristic value. Second, the penetration of chlorides in a concrete can, in cases that most frequently occur, be described by a simple Fick's law of diffusion. When the cement has a high tricalcium aluminate content and the concrete has a low porosity, this Fick's law does not apply.

A-332 Novokshchenov, V. 1986 (Aug). "Cracking in Hot Climates," Concrete International: Design & Construction, Vol 8, No. 8, pp 27-33, Detroit, MI.

Several classes of concrete cracking were encountered on major projects in Saudi Arabia and Egypt; the causes and methods employed to prevent, evaluate, and repair cracks varies among projects. In addition to severe weather conditions, poor control of concrete operations, lack of experience, and local regulations contributed to concrete failure due to cracking. In most instances, cracking can be prevented by adhering to such good concreting practices as proper assessment of concrete service conditions prior to construction, careful evaluation of concrete materials (especially chemical admixtures), adequate consolidation, and proper curing.

A-333 Pfeifer, D. W., Landgren, J. R., and Perenchio, W. F. 1986 (Jul-Aug). "Concrete, Chlorides, Cover and Corrosion," Journal, Prestressed Concrete Institute, Vol 31, No. 4, pp 42-53, Chicago, IL.

Results show the very significant effect of water/cement ratio on salt intrusion, which can be much greater than the effect on compressive strength. These results help explain the typically observed greater corrosion resistance of precast concrete, which is usually made with lower water-cement ratio.

A-334 Hime, W. G., Erlin, B., and McOrmond, R. R. 1986 (Summer). "Concrete Deterioration Through Leaching with Soil-Purified Water," Cement, Concrete, and Aggregates, Vol 8, No. 1, pp 50-51, Addison, IL.

An unusual variety of concrete deterioration was encountered. Distress

was due to concrete exposure, during a decade of service, to poorly drained calcium-absorptive acidic soil, and groundwater having a negative Langlier saturation index. Calcium loss was due to a mechanism like ion-exchange or chromatographic phenomena. Deterioration resulted in the essential depletion of calcium of the portland-cement paste, which left relatively pure silica gel. Attack was accelerated because the concrete was very porous in areas, a result of the manufacturing process used to make the concrete conduit.

Steps to prolong concrete service life in similar environments include use of dense and low-permeable concrete, limestone aggregate, and limestone fill. This type of aggressive environment can be identified in the field by use of kits that measure calcium-absorption characteristics of soils, and pH.

A-335 Fookes, P. G., Simm, J. D., and Barr, J. M. 1986. "Marine Concrete Performance In Different Climatic Environments," Marine Concrete, Papers for the International Conference on Concrete in the Marine Environment, London, Sep 22-24, 1986, pp 115-130, Concrete Society, London, England.

Well-made marine concrete structures may last many years, but other concrete structures have suffered rapid deterioration. This paper focuses on the influence of the climate in the marine environment on the deterioration process. World climatic variations are described and four types categorized, and research and current understanding of the deterioration processes are reviewed. Case histories of marine concrete structures in each climatic region are given. Conclusions are drawn from these case histories, and from a general experience of concretes, regarding the likely occurrence in different climates of various types of marine concrete defects and their likely rates of development.

A-336 Normand, R. 1986. "Review of the Performance of Concrete Coastal Structures in the Gulf Area," Marine Concrete, Papers for the International Conference on Concrete in the Marine Environment, London, Sep 22-24, 1986, pp 101-113, Concrete Society, London, England.

The paper reviews the performance of certain concrete coastal structures mainly located in the Gulf area, based largely on experience and by reference to various published sources of information. The structures are broadly described as coastal but it should be appreciated that a wide range of harsh exposure conditions has been covered and their performance viewed in this light. While it is now widely recognized that the Gulf coastal area is an aggressive location for concrete structures, it is also fair to say that problems of concrete deterioration are far more widespread elsewhere in the world including western Europe and the United Kingdom than was envisaged even as recently as 10 years ago.

A-337 Pritchard, B. 1986 (Sep). "Road Salt Corrosion in UK Concrete Bridges: Part 1," Construction Repairs & Maintenance, Vol 2, No. 5, pp 13-16, London, England.

Deicing salt-generated corrosion severely damages concrete bridges, requiring considerably increased expenditure on future maintenance. In this first part of a two-part article, the corrosion problem is identified in examples of typical salt attack zones in bridges and current methods of detection.

A-338 Bonzel, J., Krell, J., and Siebel, E. 1986 (Sep). "Alkali Reaction in Concrete," Beton, Vol 36, No. 9, pp 345-348, Dusseldorf, West Germany.

Alkali damage, arising from the use of alkali reactive North German concrete aggregate, can be avoided by strictly following the guideline "Preventive measures against damaging alkali reaction in concrete," as over 10 years of experience have shown. The guide sets a limit for all types of concrete on the Na_2O equivalent in cement and also limits the cement content to 500 kg/m^3, when aggregate containing high level of alkali is used. The high level of cement content is, however, usually already greatly reduced for economic reasons. The following report examines to what extent on top of this the alkali reactive process can be altered and damage avoided, as a result of the composition of the concrete, particularly the water-cement ratio, the strength of the cement, and the insertion of air voids. Furthermore, tests were carried out over long periods on damp storage and external alkali insertion. The interrelation that was discovered corroborates the stipulations laid down in the guideline, which tend to be more conservative.

A-339 Raharinaivo, A., et al. 1986 (Sep-Oct). "Influence of the Deterioration of Concrete on the Rusting of Reinforcements" (in French), Bulletin de Liaison de Laboratoires des Pontes et Chaussees, No. 145, pp 31-36, Paris, France.

Research has been conducted on the effect of the geometry of cracks in concrete on the extent of reinforcement corrosion. The deterioration of the concrete is due either to carbonation or the penetration of chloride. Experiments were carried out on samples of reinforced mortar and reinforced concrete, using CPA55 cement.

The condition of the reinforcements was assessed nondestructively by electrode potential methods and at the end of the tests by visual examination. The results show in particular that steel reinforcements may rust even if the concrete is not completely carbonated (pH > 9.1) when the chloride content is fairly high. The diffusivity of the chloride ions was measured in sound cracked concrete. This makes it possible to estimate the chloride content of the concrete and hence to predict the possibility of rusting of the reinforcements.

A-340 Kettle, R. J., and Sadegzadeh, M. 1986 (Nov). "Recent Research Developments in Abrasion Resistance," Concrete, Vol 20, No. 11, pp 29-31, London, England.

For many years research has been undertaken to investigate various aspects of the abrasion resistance of concrete, but such work has been almost entirely laboratory based and the findings are not directly applicable to concrete floors in typical industrial environments. To overcome some of these shortcomings, a specific research program was designed and performed. This report summarizes the laboratory and on-site research.

A-341 Vinayaka, M. R. 1986 (Nov). "Durability of Concrete: Resistance to Chloride, Sulphate and Acid Attack," Indian Concrete Journal, Vol 60, No. 11, pp 292-295, 300, Bombay, India.

The test of any concrete lies in its fulfilling the requirements of serviceability and durability. The causes of deterioration of concrete are provided with an examination of some important aspects relevant to durability, particularly its resistance to chloride, sulfate, and acid attack.

A-342 Chandra, S., and Berntsson L. 1988 (Nov-Dec). "Deterioration of Concrete in Swimming Pools in the South of Sweden," ACI Materials Journal, Vol 85, No. 6, Detroit, MI.

Concrete placed in the back lining of the glazed tiles in swimming pools made 15 years ago in the south of Sweden has been damaged. The concrete looked porous, tests showed that the strength of the concrete was not very high, and its cement content was rather low. A systematic analysis of the concrete is done here. Alkali-silica reaction is reported to be the major cause of swimming pool deterioration. Besides the alkali-silica reaction, tests showed the influence of sulfates forming ettringite and gypsum, leaching of pyrites, and disintegration of feldspar as is shown by petrographical analysis. Thus, deterioration has occurred as a combined effect.

A-343 Hobbs, D. W. 1986 (Dec). "Alkali-Silica Reaction in Concrete," Structural Engineer, Vol 64A, No. 12, pp 381-383, London, England.

Specifications are currently being developed to minimize the risk of cracking due to alkali-silica reaction at a time when there are widespread misunderstandings of the reaction, its diagnosis, and its effects on structural performance. These topics are discussed.

A-344 Prudencio, W. J. 1986 (Dec). "Durability of Reinforced Concrete Structures" (in Spanish), Revista IMCYC, Vol 24, No. 187, pp 17-24, Mexico.

Topics related to the durability of reinforced concrete structures and the consequences thereof are discussed. In addition, concrete deterioration and steel reinforcement corrosion are highlighted.

A-345 Raharinaivo, A., et. al. 1986 (Dec). "Relationship Between Concrete Deterioration and Reinforcing-Steel Corrosion," Durability of Building Materials, Vol 4, No. 2, pp 97-112, Amsterdam, The Netherlands.

This article reports investigation of the influence of crack geometry in concrete on reinforcement corrosion. Tests were carried out on parallelepipeds of mortar and of concrete. The cement used in both cases was plain portland cement. The specimens had cracks ranging from 0.05 to 2.5 mm for a sample thickness of 20 mm.

The deterioration in the concrete specimens was due either to carbonation or to chloride penetration. By measuring the electrode potential of the reinforcement, making a visual examination of these steels, and by measuring the carbonated cover depths and the chloride contents, it was possible to draw the following conclusions: cracks increase the apparent diffusivity of chloride, even if their openings are small (about 0.1 mm for a cover thickness of 20 mm); under experimental conditions, steel corrosion was found only in the vicinity of cracks, but the rusted lengths were larger than the carbonated cover thickness.

A-346 de Alencar Naas, I. 1986. "Agricultural Structure Problems in Tropical Countries," AMA, Agricultural Mechanization in Asia, Africa and Latin America, Vol 17, No. 3, Summer 1986, pp 67-71.

The most important construction materials anywhere in the world are concrete, steel, masonry, and wood. In respect to tropical countries, there is a considerable reduction of durability in most of these materials, usually because of high temperatures and high humidities. These climatic conditions are excellent for developing bacteria and fungi that attack the material and cause a progressive deterioration. At other times it is only the climate that affects the structure. This paper discusses the problems involved and studies conducted for concrete, concrete masonry, steel, and wood structures.

A-347 Hawes, F. 1986. Weathering of Concrete Buildings, Cement and Concrete Association, Wexham Springs, England.

This is the sixth publication in the series Appearance Matters. It deals with the effects of natural forces, such as rain and sunlight, and unnatural forces, such as pollution, on well-made concrete. Areas discussed include characteristics of concrete, external factors, the visible effects of weathering, prediction, and control.

A-348 Andrade, C. 1986. "Effect of Fly Ash in Concrete on the Corrosion of Steel Reinforcement," Fly Ash, Silica Fume, Slag, and Natural Pozzolans in Concrete, SP-91, pp 609-620, American Concrete Institute, Detroit, MI.

The substitution in the concrete fabrication with ordinary portland cement by blended materials may affect the excellent protective properties of the concrete, vis-a-vis the steel reinforcements. Although the

blended materials produce the favorable effect of increasing the concrete impermeability and density, they decrease the alkalinity.

In the present paper, the results of the addition of two ashes (with low- and high-calcium and sulfate content) to the mortar mixtures and the concrete are presented.

To evaluate the possible corrosion, polarization resistance and impedance measurement techniques have been used. The specimens were held about 2 months in a chamber with 90 to 100 percent relative humidity. The results show that the protective properties of the concrete, vis-a-vis the steel bars, are not altered by the blended materials, while in mortars some portion of them may induce localized corrosion.

A-349 Gebler, S. H., and Klieger, P. 1986. "Effect of Fly Ash on the Durability of Air-Entrained Concrete," Fly Ash, Silica Fume, Slag, and Natural Pozzolans in Concrete, SP-91, pp 483-526, American Concrete Institute, Detroit, MI.

Concretes containing fly ash were evaluated to establish the effect of the fly ash on freeze-thaw resistance, resistance to deicer scaling, and chloride ion penetration. The effects of low temperature curing and moisture availability during curing were also evaluated. These tests indicated that the freeze-thaw resistance of air-entrained concrete was reduced by the use of certain fly ashes when cured at low temperature. For other conditions there was no significant influence of fly ash. Deicer scaling resistance tests showed that air-entrained concrete without fly ash generally performed somewhat better than concrete with fly ash generally performed somewhat better than concrete with fly ash, regardless of the type of curing provided. Air-entrained concretes made with some fly ashes were as resistant to chloride ion penetration as air-entrained concrete without fly ash. The class of fly ash did not significantly influence the degree of chloride ion penetration.

A-350 Saeki, N., Fujita, Y., and Takada, N. 1986. "Surface Layer Strength of Concrete as a Measure of Scale Resistance," Fly Ash, Silica Fume, Slag, and Natural Pozzolans in Concrete, SP-91, pp 563-590, American Concrete Institute, Detroit, MI.

The properties of the surface layer of concrete may be closely related to the causes of scaling and play an important role in the durability of concrete. To obtain the mechanical properties of the surface layer, which are affected by such factors as type of cement, curing and atmospheric conditions, etc., some tests were carried out on model specimens with penny-shaped cracks or truncated steel cores (pullout test).

The ratio of the surface layer to splitting tensile strength was found to be approximately proportional to the thickness of the layer. The surface layer strength is influenced by curing conditions and is related to the degree of scaling and frost damage.

A-351 Rehsi, S. S. 1986 (May). "Corrosion of Concrete in Fertilizer Industry and Its Prevention," Workshop on Corrosion of Materials in Fertilizers and Chemical Industries, CBRI Roorkee; pp 25-26.

Surface protective coating on concrete in aggressive environment have not proved to be longer lasting. Therefore, this paper stressed the need of rendering concrete itself resistant to aggressive agents. Taking into account the fact that hydration products of portland cement produce a large quantity of Ca $(OH)_2$ which is vulnerable to aggressive agent, it was considered necessary to use cement which does not liberate lime on hydration and has minerological composition different from that of portland cement.

The two cements tried were (i) supersulphated cement as per IS: 9606-1973 and (ii) high alumina cement. Granite stone slab was also tried for its resistance.

A-352 Sidney, D. 1986. "Chloride Concentrations in Concrete Pore Solutions Resulting from Calcium and Sodium Chloride Admixtures," Cement, Concrete, and Aggregates, Vol 8 No. 2, pp 97-102, Addison, IL.

The damages occurring due to corrosion of steel in concrete structures are well known. Problems developed when a sufficient concentration of chloride ions develops in the pore solution of the concrete surrounding the steel or when the carbonation front working its way inward from the surface of the concrete reaches the vicinity of the steel. Occurrences traceable to chloride-related depassivation are more prevalent. The present paper deals with chemical admixtures in concrete. Calcium chloride has been incorporated as an accelerator of concrete setting and strength gain. In spite of the fact that nonchloride based accelerator are available, their effectiveness on both weight basis and cost basis lags far behind that of calcium (and other) chloride based formulations.

A-353 Lindley, R. 1986. "Maintenance Concrete," Proceedings, SSPC Industrial Maintenance Painting Conference, Heathrow, Paper 7.

Conditions causing corrosion of reinforcing metal in concrete are described, i.e. carbonation, chloride ions, and alkali aggregate reaction. Requirements of coatings for concrete are discussed together with laboratory test methods and some case laboratories.

A-354 Kishitani, K., et al. 1986. "Study on Salt Permeation into Reinforced Concrete," Journal of Research of the Onoda Cement Company, No. 114, pp 22-30.

The salt permeation problem in reinforced concrete structures was studied, concentrating mainly on the estimation of reasonability of Fick's diffusion equation as its model function. The data of salt content in concrete was obtained from the research papers in the past and was analyzed by Fick's equation in this research.

The value of diffusion coefficient calculated there showed the large variation of 10^{-2} to 10^{2} cm^2/year. From this fact, the Fick's equation in further research will be reexamined and thus improved as a salt permeation model function for reinforced concrete structures with material and environmental factors.

1987

A-355 Weyers, R. E., and Cady, P. D. 1987 (Jan). "Deterioration of Concrete Bridge Decks from Corrosion of Reinforcing Steel," Concrete International: Design & Construction, Vol 9, No. 1 pp 15-20, Detroit, MI.

Twenty-two bridge decks were examined to determine the extent of deterioration of the concrete resulting from corrosion of the reinforcing steel. Visual inspection indicated that about 40 percent of the decks containing bare reinforcing steel were in the initial stage of deterioration, but none of the decks containing epoxy-coated reinforcing steel were deteriorating because of corrosion of the steel.

An in-depth study of four of the decks revealed more extensive deterioration of those containing bare steel but no deterioration in those containing epoxy-coated steel. The in-depth study also indicated that the diffusion of chloride ions through concrete bridge decks obeys Fick's law, and an effective diffusion constant exists that can be used for planning maintenance and rehabilitation.

A-356 Evans, A. R., and Smith, D. G. E. 1987 (Jan). "Deterioration and Life Expectancy of Concrete Structures in A Middle East Town," Concrete, Vol 21, No. 1, pp 34-37, Scott Wilson Kirkpatrick & Partners, London, England.

In the second of a short series of articles on concrete in a remote Middle East coastal town, the results of a survey of concrete structures are presented. Observations are made on concrete practice in the town, which is shown to be related to the rate of deterioration occurring. It is evident that better practice would lead to considerably more durable structures. A noticeable feature of reinforced concrete buildings was corrosion of reinforcement and spalling of cover concrete. Balcony slabs were present on many buildings and often were heavily loaded by high parapet walls. Such slabs were particularly prone to deterioration and they exhibited alarming deflections.

A-357 Bhaskara Rao, M. V., and Maheshwari, R. K. 1987 (Jan). "Review of the Investigation and Evaluation of Corrosion in Concrete Structures," Indian Highways, Vol 15, No. 1, pp 22-33, Central Road Research Institute, New Delhi, India.

Corrosion of the reinforcement in concrete structures is a complex process which is electro-chemical in nature. It may be defined as a process in which iron of the steel is transformed from its metallic state to its natural ore(s) under the action of environment. A necessary condition for initiating corrosion is the creation of a galvanic

cell comprising two electrodes an electrical circuit. Steel corrosion causes distress due to the cracking and spalling of concrete and may result in the failure of a structure. Some topics discussed are the following: corrosion as an electro-chemical phenomenon; methods of prevention; the monitoring of corrosion; and some case studies.

A-358 Rossetti, A. 1987 (Feb). "Durability: from Theory to Practice. Norms and Controls," Industria Italiana del Cemento, No. 2, pp 137-144.

During the last 10 years, the most frequent subject of discussion in the field of materials technology for civil construction has been the durability of structures. In particular, for reinforced concrete, the causes of deterioration, especially in aggressive environments, have been carefully examined to pursue methods of prevention and of reinstatement. A series of specifications for the durability of public works have been prepared as well as an UNI regulation aiming at the same target. A picture of the activity carried out in this field is herewith featured, underlining the necessity for the technical regulations concerning the application of Law No. 1086, to include durability among the design requisites of reinforced concrete structures.

A-359 Harrison, W. H. 1987 (Feb). "Durability of Concrete in Acidic Soils and Waters," Concrete, Vol 21, No. 2, pp 18-24, London, England.

Concrete in the ground is vulnerable to attack by acids and sulfates present in groundwaters. The action of acids on concrete is to dissolve the cement and, in the case of limestone aggregate, the aggregate too. Codes of practice vary throughout the world with their recommendations for the protection of buried concrete against attack by acid. A feature that is common throughout is the paramount importance attached to the production of a high quality, dense, impervious, and well-compacted concrete. This quality can be achieved in different ways appropriate to the type of concrete. Some of the relevant factors are discussed in this article and recommendations are suggested.

A-360 Leonhardt, F. 1987 (Feb). "Cracks and Crack Control at Concrete Structures," IABSE Proceedings No. P-109/87, pp 25-44, International Association for Bridge and Structural Engineering, Zurich, Switzerland.

Cracks are almost unavoidable in large concrete structures. Their causes and meaning for the serviceability and durability of the structures are tested in the paper. Simple rules for the design and sizing of reinforcement or prestressing are given to keep the crack width within admissible limits.

A-361 "BRE Study of Carbonation in Structural Quality Concrete." 1987 (Feb). Concrete Plant and Production, Vol 5, No. 2, pp 59-60, Amersham, England.

This article summarizes the main points and presents the conclusions from a recently published Building Research Establishment Report (BRE).

BRE found that the rate of carbonation in the structures surveyed was very variable and sensitive to the quality of concrete achieved in practice. The quality achieved depends on mixing, compaction, curing, and the materials specified--all of which need to be of a sufficiently high standard to produce concrete that is adequately resistant to carbonation. The prestressed concrete structures using higher strength concrete produced under the strictest conditions had both the lowest levels of carbonation and the least variability; normally reinforced precast components showed higher depths of carbonation for any given age of building and greater variability.

A-362 Al-Tayyib, A. J., and Khan, M. S. 1987 (Feb). "Concrete Deterioration Problems in the Arabian Gulf--A Review," Durability of Building Materials, Vol 4, No. 3, pp 287-298, Amersham, England.

According to research at the University of Petroleum and Minerals (UPM) in Dhahran, Saudi Arabia, and in some other Gulf States, countries in the Arabian Gulf with its hot and arid climate, salt-contaminated environment, and available low-quality raw materials experience various concrete deterioration problems on a much larger scale than countries with temperate climate conditions. This paper reviews some of the research studies conducted at UPM on concrete deterioration problems related to concrete constituents, environmental factors, and concrete properties. The objective of the paper is to bring into focus some aspects of concrete durability that may be helpful in alleviating various deterioration problems encountered in the Arabian Gulf region. Aspects requiring further investigation are also included.

A-363 Buck, A. D., and Mather, K. 1987 (Feb). "Methods for Controlling Effects of Alkali-Silica Reaction in Concrete," Technical Report SL-87-6, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

This research project concerned methods of minimizing the effects of alkali-silica reaction in concrete. Ten pozzolans were tested to determine how they could most effectively be used to maximize reduction of expansion due to alkali-silica reaction when the pessimum amounts of opal or of reactive glassy igneous rock were used as aggregate with cements of several levels of alkali content. Three of these pozzolans (fly ash AD-505, fly ash AD-509, and natural pozzolan AD-518) were selected for further work and were used at selected levels of cement replacement with pessimum amounts of opal, glassy igneous rock, and an estimated pessimum for chert with each of two high-alkali cements. In general, use of these pozzolans at their optimum levels was an effective procedure as expansions of several tenths of a percent were usually reduced to a few hundredths. It was also found that some fly ashes when used at about 30 percent cement replacement level actually caused more expansion, especially with low-alkali cement. This is believed to be due to the additional water-soluble alkali provided by the fly ash to the system. Work was done with different mineral fractions of a reactie granite gneiss plus the whole rock to identify the reactive constituent; it was concluded that the reactivity of the granite gneiss was due to strained quartz as a constituent mineral. Work

with combinations of silica fume and calcium hydroxide with water showed the reactivity of the fume and identified a well crystallized calcium silicate (CSH-I) as the reaction product.

A-364 (Deleted)

A-365 Kong, H. L., and Orbison, J. G. 1987 (Mar-Apr). "Concrete Deterioration Due to Acid Precipitation," ACI Materials Journal, Vol 84, No. 2, pp 110-116, Detroit, MI.

An accelerated laboratory test program was conducted to evaluate the response of portland-cement concrete cylinders to simulated acid precipitation solutions. A total of 140 specimens were placed in acidic solutions with pH levels ranging from 2 to 5 for a period of 3 months. The response of the specimens, made using Type I portland cement and having design compressive strengths of 3,000 psi (20.7 MN/m^2) to 9,000 psi (62.1 MN/m^2), was evaluated through visual examination, weight changes, and compressive strength changes. The results indicate that specimen deterioration, as evidenced by material loss as well as discoloration, increases with decreasing pH levels of the solutions, and with increasing design compressive strength.

A-366 Buck, A. D., Burkes, J. P., and Ahlvin, J. C. 1987 (Apr). "Frost Resistance of High-Strength Concrete," Miscellaneous Paper SL-87-1, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

High-strength concrete made with crushed granite as coarse aggregate, but without air entrainment, showed an average durability factor of 95 after 300 cycles of freezing and thawing in the laboratory. Determination of air content by American Society for Testing and Materials (ASTM) Designation: C 457 showed the unexpectedly good results were not the effect of protection afforded by air entrainment. Petrographic examination confirmed lack of damage on a microscopical scale. It was concluded that self desiccation and low permeability associated with an 0.24 water-cementitious solids ratio (W/S) prevented development of critical saturation so that the concrete behaved during testing as if it were not critically saturated and thus was not damaged by freezing. Similar concrete at the same W/S with crushed limestone as coarse aggregate showed a durability factor of 17. It is presumed that this is brought about by the lack of frost resistance of the limestone itself since in air-entrained concrete the specimens with granite coarse aggregate gave an average durability of 92, while those with limestone coarse aggregate gave an average durability of only 55.

A-367 Nischer, P. 1987 (May). "Improving the Durability of Structures Concrete-Technological Influencing Factors," Betonwerk und Fertigteil-Technik, Vol 53, No. 5, pp 341-351, Wiesbaden, Germany.

There has been a decline in the durability of concrete structures in consequence of using mixes with lower cement content and of applying rapid construction techniques. The relevant standards have already taken account of this situation in that they have, besides laying down

requirements for the grade (strength class) of the concrete, introduced equally rated requirements as to, for example, corrosion protection of reinforcement or frost resistance. To build durable structures, it is necessary always to comply with the upper permissible limits for the water-cement ratio required in the standards regardless of what strength is to be attained. It has emerged that these other properties depend to an even much greater extent on adequate curing than the strength of the concrete does.

A-368 Mangat, P. S., and Gurusamy, K. 1987 (May). "Chloride Diffusion in Steel Fibre Reinforced Marine Concrete," Cement and Concrete Research, Vol 17, No. 3, pp 385-396, Elmsford, NY.

Paper presents some results from a continuing research program on the marine durability of steel fiber reinforced concrete. A mix of proportions by weight of 1:1.5:0.86 with a water-cement ratio of 0.4 was reinforced with three types of steel fibers. The cement content of the mix was 590 kg/m^3. Uncracked prism specimens were cured under marine splash and tidal zone exposure in the laboratory and at Aberdeen beach. In one batch of prism specimens, flexural cracks of width ranging between 0.7 and 1.08 mm were induced prior to marine exposure. Chloride diffusion characteristics in uncracked and precracked concrete were determined at up to 2,000 cycles of marine exposure (1,250 days).

The results show that Cl concentrations are significantly greater in laboratory cured specimens relative to those cured on the beach. Most of the Cl penetration occurs within 150 tidal cycles of exposure at the beach. Cl concentrations increase with increasing crack widths, although the influence of small crack widths of $\leq$ 0.2 mm is marginal.

A-369 "College Found Defective." 1987 (May). Engineering News-Record, Vol 218, No. 22, New York.

A 13-year-old college complex in Singapore will be demolished due to structural defects making the building unsafe, following an examination that showed concrete in several parts of the building's frame required constant monitoring for continued use. The inspection was in response to the collapse of the New World Hotel last year, which killed 33 people. College functions have been moved to another of the school's buildings.

The concrete in the complex's main building was permeable and had been weakened by carbon dioxide. Steel reinforcing bars had corroded also. Construction practices in Singapore have come under increased scrutiny since the fatal hotel collapse.

A-370 Duda, A. 1987 (May). "Aspects of the Sulfate Resistance of Steelwork Slag Cements," Cement and Concrete Research, Vol 17, No. 3, pp 373-384, Elmsford, NY.

Cement mixes were prepared by intergrinding portland-cement clinker (PC), granulated blast furnace slag (BF), and two LD slags (LDI,

LDII) in varying proportions. On water-cured cement mortar and paste specimens, the compressive strength, pore size distribution, and $Ca(OH)_2$ content were determined. Corresponding specimens were exposed to sulfate attack ($CaSO_4$, $MgSO_4$, Na_2SO_4), and the expansion and the variation of compressive strength were monitored.

The results show all BF-LD-PC and BF-LD cements to be "sulfate" resistant which correlates well with their decreased capillary pore volume and low $Ca(OH)_2$ contents. X-ray analysis of SO_4 bearing phases indicate no clear correlation between ettringite contents and observed degree of sulfate corrosion. Besides, the chemical/mineralogical composition of the LD slags exerts a distinct influence on their hydraulic properties.

A-371 Ho, D. W. S., and Lewis, R. K. 1987 (May). "Carbonation of Concrete and Its Prediction," Cement and Concrete Research, Vol 17, No. 3, pp 489-504, Elmsford, NY.

This paper presents results on carbonation of concrete incorporating various constituents including chemical admixtures and fly ash. Both long- and short-term test results are discussed. For concrete with limited initial curing, it was found that the water-cement (not water-binder) ratio was the most reliable parameter in predicting the resistance of concretes to carbonation.

A-372 Crumpton, C. F., and Jayaprakash, G. P. 1987 (Jun). "Invasive Salt Tough Foe, Study Finds," Roads and Bridges, Vol 25, No. 6, pp 68 and 70, Des Plaines, IL.

Researchers used an electron microscope to examine salt penetration in concrete and found a strong relationship between bar depth and the area of spalls and delamination. Salt corrosion of the reinforcing steel was causing concrete deterioration. Freeze-thaw susceptible aggregates also contributed to the deterioration.

A-373 Libby, J. R. 1987 (Jun). "Three Chloride-Related Failures in Concrete Structures," Concrete International: Design & Construction, Vol 9, No. 6, Detroit, MI.

This article describes the failure of three reinforced concrete structures in marine air environments due to the effects of high chloride-ion contents. In two cases, zinc-coated embedments were also involved in the failures. Repair methods are indicated.

A-374 Sadegzadeh, M., Page, C. L., and Kettle, R. J. 1987 (Jul). "Surface Microstructure and Abrasion Resistance of Concrete," Cement and Concrete Research, Vol 17, No. 4, pp 581-590, Elmsford, NY.

The influence of several surface finishing techniques on the abrasion resistance of concrete specimens of various mix compositions has been measured by means of a rolling-wheel apparatus. Microstructural features of the cement matrix components of the exposed surfaces have been

studied by mercury intrusion porosimetry and microhardness determinations. The results indicate that different methods of surface finishing produce substantially different microstructural characteristics within a surface zone of a few millimeters of maximum thickness. For the systems investigated, it was found that the abrasion resistance was determined largely by the pore structure of this surface zone.

A-375 Poston, R. W., Carrasquillo, R. L., and Breen, J. E. 1987 (Jul-Aug). "Durability of Post-Tensioned Bridge Decks," ACI Materials Journal, Vol 84, No. 4, pp 315-326, Detroit, MI.

The results are reported from the durability phase of a research study to investigate the use of prestressing as a method of improving durability of bridge decks. This durability phase used an accelerated experimental investigation of conventionally reinforced and post-tensioned concrete exposure specimens to determine resistance to an aggressive deicing salt exposure.

The accelerated test results show that prestressing reduces the ingress of chlorides at crack locations but not to levels below the generally accepted chloride corrosion threshold, even for surface crack widths as small as 0.002 in. (0.05 mm). The main benefit of prestressing is to eliminate or to control greatly cracking so as to restrict chloride and oxygen penetration. The test results also clearly show that, in cracked concrete, concrete quality and cover had little effect on chloride penetration during the relatively short time period of the accelerated testing.

A-376 Ozturan, T., and Kocataskin, F. 1987 (Aug). "Abrasion Resistance of Concrete as a Two-Phase Composite Material," International Journal of Cement Composites and Lightweight Concrete, Vol 9, No. 3, pp 169-176, Harlow, Essex, England.

Concrete is treated as a two-phase composite material to investigate its resistance to abrasion. A relation based on the mixtures rule is considered; this predicts the abrasion resistance of concrete from the abrasion resistances and volume fractions of the mortar and coarse aggregate phases. Evaluation of the results of tests on composites with coarse aggregate volume fractions ranging from 0 to 0.40 showed good agreement to this relation. The effects of aggregate type and water-cement ratio on abrasion properties of the constituent phases of the composite are discussed. The relations between the abrasion depth of concrete with length of slide have indicated good aggregate to the theory of abrasion offered for metals. Correlations with some other mechanical properties of concrete have also been demonstrated.

A-377 Hope, B. B., and Ip, A. K. C. 1987 (Jul-Aug). "Chloride Corrosion Threshold in Concrete," ACI Materials Journal, Vol 84, No. 4, pp 306-314, Detroit, MI.

The effects of chloride in concrete containing admixed calcium chloride dihydrate and chloride-bearing aggregates on microcell corrosion were

studied. Concrete slabs, each containing three electrically isolated steel rods, were subject to various outdoor and indoor exposure conditions. Corrosion of the rods was examined by the linear polarization and AC impedance techniques, visual inspection, and gravimetric mass loss method. Chloride and pH measurements for the concretes were also conducted.

Corrosion of the steel increased with increasing admixed chloride content. The chloride corrosion threshold limit was between about 0.2 and 0.4 percent calcium chloride dihydrate by mass of cement (0.014 and 0.022 percent soluble chloride ion by mass of concrete) depending on the test method. Chloride in the chloride aggregates used for this investigation did not appear to be available to any significant degree for the corrosion process. Electrical resistivities of the concretes increased with increasing admixed chloride content, and pH of the concretes was in a range from about 12 to 12.5, regardless of the chloride content and aggregate type.

A-378 Carrasquillo, R. L., and Snow, P. G. 1987 (Jul-Aug). "Effect of Fly Ash on Alkali-Aggregate Reaction in Concrete," ACI Materials Journal, Vol 84, No. 4, Detroit, MI.

The main objective of the work described herein was to identify the most relevant components of fly ash, cement, and concrete aggregates affecting the alkali-aggregate reaction in concrete. For this purpose, over 108 mortar mixtures were made using both Class C and Class F fly ashes having available alkali contents ranging from 0.57 percent to 4.35 percent, two Type I cements and one Type IP cement, and several sources of aggregates classified as reactive and nonreactive as per ASTM C 227. Testing consisted of mortar-bar tests conducted according to ASTM C 227. Test results are based on the average of at least eight specimens exposure tested for at least 6 months.

The main variable affecting alkali-aggregate reaction in concrete is the amount of alkalies in the cement. Clearly, the replacement of a portion of cement with fly ash is an effective measure to control the expansion in concrete due to alkali-aggregate reaction for any aggregate or cement used. However, the effectiveness of a fly ash in reducing alkali-aggregate reaction damage in concrete was dependent on the available alkali content of the fly ash, cement replacement percentage, and cement alkali content. For mixtures that exhibit a pessimum limit, the lower the alkali content of the cement, the higher the pessimum limit. The available alkalies in the fly ash seem to be a factor affecting the alkali-aggregate reaction in concrete. Calcium- oxide content of a fly ash seems to have a negligible effect on the alkali-aggregate reaction in concrete.

A-379 Saricimen, H., et al. 1987 (Oct). "Case Study of Deterioration of Concrete in Sewage Environment in an Arabian Gulf Country," Durability of Building Materials, Vol 5, No. 2, pp 145-154, Amsterdam, The Netherlands.

This paper describes the investigations carried out to diagnose concrete deterioration in a sewage lift station in an Arabian Gulf country. The typical environmental conditions are high humidity (RH: 100 percent), high atmospheric, and sewage temperature (more than 30° C). In such a situation, sewage becomes an ideal environment for anaerobic bacterial activity and hydrogen sulfide generation. Hydrogen sulfide released from the sewage is absorbed by the moisture film on the unsubmerged sewer structures, where it is converted to sulfuric acid in the presence of aerobic bacteria, Thiobacilli. The severe deterioration of concrete observed on the unsubmerged portion of the lift station was thus caused by sulfuric acid attack.

A-380 Hover, K. C. 1987 (Oct). "Closing the Gaps: How to Make Concrete Less Permeable and More Durable," Concrete Construction, Vol 32, No. 10, pp 857-860, Addison, IL.

This article discusses permeability versus durability of concrete. Water-cement ratio, curing, and admixtures are cited as major factors influencing permeability and durability, and permeability is proposed as a possible quality-control parameter.

A-381 Hope, B. B., and Ip, A. K. C. 1987 (Nov-Dec). "Corrosion of Steel in Concrete Made with Slag Cement," ACI Materials Journal, Vol 84, No. 6, pp 525-531, Detroit, MI.

The effect of slag cement on corrosion of steel in concrete was investigated. Reinforced concrete slabs containing different proportions of slag and portland cement were subjected to various cycles of wetting and drying by soaking in an air-saturated 3.5 percent sodium chloride solution and drying in laboratory air. Corrosion of steel was examined electrochemically and visually. Concrete electrical resistivity and chloride measurements were conducted.

Corrosion of the steel rods in the concretes decreased with increase in slag content except during the first 7 days after casting. This was accompanied by a corresponding higher concrete electrical resistivity and lower chloride diffusion rate. The electrical resistivities of concretes made with slag cement appeared to be more sensitive to a change in storage condition than that of portland-cement concretes.

A-382 Keifer, O., Jr. 1987. "Major Damage to Concrete and Reinforcing Steel by N_2O_4 and Concentrated Nitric Acid," Concrete Durability--Katharine and Bryant Mather International Conference, SP-100, pp 1549-1574, American Concrete Institute, Detroit, MI.

This article describes the effect on concrete and reinforcing steel in a structure that was subjected to attack by pure nitrogen tetroxide

(N_2O_4), subsequently converted to nitric acid by dilution with water. Although N_2O_4 without any combined water is relatively inert in its reaction with steel, with the addition of only a little water it becomes fuming nitric acid and with the total dilution encountered here, the end product was a strong nitric acid with a concentration of about 18 percent. During the first 24 hours and during the initial application of water, the material was fuming violently. As the water was added, the temperature rose to an estimated 400° F.

After the diluted liquid was pumped out of the structure and washdown had taken place, the bottom of the structure was inspected. Initial visual observation indicated quite significant damage to concrete and reinforcing bars, plus major damage to attached steel accessories, all in the area below the final liquid level reached after dilution with the water. Further investigation by an inspection team using light hand tools (rock hammers, chisels, etc.) showed that the damage to the concrete, while widespread, was generally shallow with only isolated areas being damaged to any great depth. A few areas showed narrow zones of deterioration to a depth of 12 in. However, it was found that there was major damage to reinforcing steel that was quite extensive and deep with major areas showing complete disappearance of considerable lengths of No. 14 and No. 18 reinforcing bars. Surprisingly, in many of these areas, the remaining concrete showed perfect impressions of the missing reinforcing bars with no significant damage to the concrete surface making up the impression. Very little evidence of rust was present and it is assumed that, rather than ferric oxide (common rust) being formed, soluble iron oxide and soluble iron nitrate were formed and washed away.

A-383 Menzies, J. B., Moore, J. F. A., and Currie, R. J. 1987. "Durability of Structural Concrete in Modern Buildings in the United Kingdom," Concrete Durability--Katharine and Bryant Mather International Conference, SP-100, pp 143-168, American Concrete Institute, Detroit, MI.

Concrete is ubiquitous in building and civil engineering construction. Most of it is still performing satisfactorily and some has successfully reached a considerable age. However, instances of deterioration arising from corrosion of embedded steel following carbonation of the cover come to light increasingly, particularly in the United Kingdom among the forms of concrete structures constructed during the post-war building booms. For a proportion of these structures, deterioration of some concrete is advancing more rapidly than hoped or expected.

This paper examines information on rates and depths of carbonation obtained from extensive field investigations by the Building Research Establishment of reinforced and prestressed concrete in these populations of modern buildings. The data are compared with those derived from laboratory specimens and from field studies elsewhere. A consistent view of the performance with respect to carbonation of different grades of concrete emerges. The rate of carbonation in the buildings was widely variable and sensitive to the achieved quality of the concrete. The implications for existing structures are given. The need

for a substantial increase in the quality of the cover in reinforced concrete in future building construction is discussed in relation to the longevity required and the means of achieving it.

A-384 Hudec, P. P. 1987. "Deterioration of Aggregates--The Underlying Causes," Concrete Durability--Katharine and Bryant Mather International Conference, SP-100, pp 1325-1342, American Concrete Institute, Detroit, MI.

Freezing and thawing cycles in northern latitudes have resulted in the breakdown of some aggregates and concrete. Deicing salts have accelerated the problem. However, freezing of water cannot be the principal cause of deterioration, since in the fine-grained aggregates and cement paste the pores are too small to allow freezing. Yet these materials deteriorate the most. Deicing salts likewise lower the freezing point and the number of freeze-thaw cycles yet cause increased breakdown. The same materials susceptible to freeze-thaw breakdown also deteriorate significantly under repeated wetting-drying cycles. Laboratory experiments show these materials to expand on wetting and contract on drying. NaCl solution causes significantly greater expansion. Ice formation in the pores, therefore, is not the primary cause of breakdown.

The answer may be found in the nature of the water in the small pores--water affected by the capillary and surface forces of the pore material. The pore water has lower vapor pressure, which prevents it from freezing, but which results in osmotic pressure differential, causing expansion. Deicing salt cations are preferentially adsorbed and concentrated on pore surfaces, further increasing the osmotic potential, expansion, and breakdown.

A-385 Sri Ravindrarajah, R., and Ong, K. C. G. 1987. "Corrosion of Steel in Concrete in Relation to Bar Diameter and Cover Thickness," Concrete Durability--Katharine and Bryant Mather International Conference, SP-100, pp 1667-1678, American Concrete Institute, Detroit, MI.

One of the most common forms of deterioration of reinforced concrete structures is associated with the corrosion of reinforcement. The corrosion of the embedded steel bars is mainly due to the ingress of oxygen, water, carbon dioxide, chlorides, and other harmful salts toward the steel. The rate of corrosion depends on the quality of the cover concrete, cover thickness, and bar diameter. This paper discusses the results of an experimental investigation into the corrosion of steel bars in mortar with the use of an accelerated corrosion technique. It has been concluded that the cover/bar diameter ratio plays a significant role in determining the corrosion intensity of steel exposed to a given environment. In addition, an increase in the area of the exposed surface of the corrosion specimens directly decreases the corrosion resistance of steel in concrete.

A-386 de Wind, G., and Stroeven, P. 1987. "Chloride Penetration into Offshore Concrete and Corrosion Risks," Concrete Durability--Katharine and

Bryant Mather International Conference, SP-100, pp 1679-1690, American Concrete Institute, Detroit, MI.

The oxygen flux through concrete saturated with water has been calculated by means of the theoretically determined diffusion constant. Presuming oxygen diffusion to be the rate-controlling step, it is concluded, based on this flux, that the corrosion of reinforcement in the underwater zone is negligible. This holds also if the chloride concentration at the surface of the embedded steel exceeds the 0.4 percent by weight of cement level. The calculations are confirmed by analyses carried out on a 35-year-old concrete sea structure that is, until now, the most extensively examined one.

In the splash zone of the structure, the chloride concentrations at the surfaces of the reinforcements far exceed the 0.4 percent level. In this zone there is corrosion only in places where depth of cover or quality of concrete are inadequate. Calculation of the oxygen fluxes with the help of diffusion coefficients, taken from the literature, shows that the corrosive attack would be too severe even at a relative humidity of 90 percent. This indicates that the durability of offshore concretes in the splash zone is controlled by a thin layer of material saturated with water.

A-387 Sakuta, M., et al. 1987. "Measures to Restrain Rate of Carbonation in Concrete," Concrete Durability--Katharine and Bryant Mather International Conference, SP-100, pp 1963-1979, American Concrete Institute, Detroit, MI.

In an ordinary atmospheric environment corrosion of reinforcing steel in a concrete structure can occur when carbon dioxide permeates the concrete and the protective film of the steel is destroyed. Thus, the rate of carbonation in concrete can be a significant factor in influencing the durability of the concrete structure. Various means to restrain the rate of carbonation were investigated, and the addition of amino alcohol and glycol ether derivatives to concrete was effective for this purpose. The former appears to absorb carbon dioxide provided from the surface of the concrete, and the latter appears to reduce the total volume of air voids in the concrete and the size of each void, in effect making the concrete less permeable. It may be concluded from the tests described in this paper that even when the previously mentioned two derivatives are used together in concrete they demonstrate an effectiveness without any harmful side effects.

A-388 Sawan, J. S. 1987. "Cracking Due to Frost Action in Portland Cement Concrete Pavements--A Literature Survey," Concrete Durability--Katharine and Bryant Mather International Conference, SP-100, pp 781-804, American Concrete Institute, Detroit, MI.

A comprehensive review of the literature about durability (D-) cracking due to frost action in portland-cement concrete pavements is developed. D-cracking is defined and described and the mechanisms causing the phenomenon are discussed. The idea that D-cracking is moisture

oriented is established. It is affected by freezing temperatures that cause enough volumetric change in the moisture that exists in the cement-aggregate matrix and initiates a durability line crack in the concrete. Factors such as physical characteristics of aggregates and mortar, geographic location, maximum size of coarse aggregates, source of aggregates, and use of deicing agents are found to be among the main factors that affect the development of durability cracking.

Tests to indicate frost resistance in aggregate are also reviewed. These tests are of two general types: weathering tests such as unconfined and confined freeze-thaw tests, and measurements of a physical property correlated with performance such as porosity, pore size, and absorption tests. The use of petrographic analysis is an absolute necessity to identify frost-susceptible aggregates. Other tests such as ASTM "Test for Resistance of Concrete to Rapid Freezing and Thawing" (C 666), ASTM "Test for Critical Dilation of Concrete Specimens Subjected to Freezing" (C 671), the PCA method, the Iowa Pore Index Test, and particularly ASTM "Evaluation of Frost Resistance of Coarse Aggregates in Air-entrained Concrete by Critical Dilation Procedures" (C 682) are also considered satisfactory methods to predict field durability performance of concrete aggregates. Researchers such as Axon et al., Iyer et al., and Thompson and Dempsey developed some pertinent tests that could be used in this area as well.

A-389 Kivekas, L., and Lei[illegible], M. 1987. "Durability of Concrete Under Arctic Offshore Conditions," Concrete Durability--Katharine and Bryant Mather International Conference, SP-100, pp 935-946, American Concrete Institute, Detroit, MI.

Concrete is a suitable material for arctic offshore oil and gas drilling and for production platforms. In the splash and tidal zone of these structures concrete is subjected to severe frost-salt attack, chemical attack of seawater, and ice abrasion. In the test series, a method for accelerated testing of arctic freeze-thaw durability in seawater was developed. High-strength, air-entrained, superplasticized concretes made with blended cement were tested. The test was found to be very severe.

A-390 Newman, K. 1987. "Labcrete, Realcrete, and Hypocrete--Where We Can Expect the Next Major Durability Problems," Concrete Durability--Katharine and Bryant Mather International Conference, SP-100, pp 1259-1284, American Concrete Institute, Detroit, MI.

This paper attempts to draw lessons from major failures in the past 2 decades in the United Kingdom and gives a personal view why we still have problems in concrete today. Definitions are given to labcrete, realcrete, and hypocrete, and an examination is made of recent difficulties in the United Kingdom involving high-alumina cement, corrosion of reinforcing steel, alkali-silica reaction, and the definition of criteria for durability.

A prediction is then made why and where further deterioration of concrete structures can be expected in the next 10 to 20 years. Finally, proposals are made for overcoming durability problems in the longer term. Above all, there is a need to integrate our knowledge and understanding of the mechanisms of deterioration with concrete design, materials methods of construction, and use.

A-391 Regourd, M., et al. 1987. "Durability of An Arctic Concrete," Concrete Durability--Katharine and Bryant Mather International Conference, SP-100, pp 919-935, American Concrete Institute, Detroit, MI.

The use of unconventional aggregates, which includes several sulfide minerals, in making concrete in the Canadian Arctic aroused the interest of the authors to investigate the durability of such a concrete subjected to a very cold environment. Compressive strength measurements on concrete samples 3 and 9 years old, cored in a dock, show that the concrete is still very strong--at least 28 MPa (4,000 psi). A close examination of the aggregates and concrete microstructure suggests the concrete is durable. The presence of these aggregates does not give rise to any deleterious effect. The concrete is found to be a dense one. Only a superficial layer of a few millimeters thick has been transformed by carbonation. This zone, enriched in potassium, does not contain any $Ca(OH)_2$ crystal. Its C-S-H has a low $CaO\text{-}SiO_2$ ratio and is sometimes replaced by a siliceous gel. Penetration of chloride and sulfate ions is also observed but is not related to any concrete damage. The presence of a large amount of $Ca(OH)_2$ and calcium rich C-S-H(C/S ~ 1.7) below the thin carbonated layer corresponds to a high chemical stability of the concrete.

A-392 Potter, R. J., and Ho, D. W. S. 1987. "Quality of Cover Concrete and Its Influence on Durability," Concrete Durability--Katharine and Bryant Mather International Conference, SP-100, pp 423-446, American Concrete Institute, Detroit, MI.

Durability distress in the external surfaces of buildings is related to the corrosion of reinforcement. The controlling parameters for this distress are the quality of the cover concrete and the depth of cover. The quality of the cover concrete is evaluated in terms of carbonation resistance and water sorptivity.

It is found that of the factors examined in the research program the major one is the length of initial continuous curing received by the concrete. It is concluded that it is doubtful if exposure to weather, especially in typical Australian climates, will enable cover concrete on the facades of buildings to achieve its potential protection capability.

Short-term tests suggest that the resistance to carbonation is increased by increasing the strength of the concrete, using water reducers, and decreasing the amount of fly ash in the mix. The water sorptivity may be reduced by either increasing the strength of the concrete and/or increasing the initial curing period.

A-393 "Concrete Durability: A Multibillion-Dollar Opportunity." 1987. National Materials Advisory Board, Commission on Engineering and Technical Systems, National Research Council, Washington, DC.

Concrete industry practices today fail to take advantage of the many opportunities for increased durability and service life of concrete structures that could be achieved through better use of currently available knowledge. A number of technical and institutional factors have led to this situation; the report discusses specific issues and barriers that affect increased durability. Those deemed most important are: inadequate education opportunities, low levels of research funding and coordination, the lack of technology transfer mechanisms, and the short- rather than long-term economic approach of the industry. The technical sophistication of the managerial, technical, and blue-collar work force is lower than needed, and the necessary close cooperation among industry, government, and universities required to achieve improvements in concrete durability is lacking. Action directed to improve the underlying predicament will prove less costly long term than very expensive premature rehabilitation of deteriorating structures.

Numerous opportunities for improvement are identified. Recommendations are made for steps to be taken by government agencies, industry, and educational institutions to address the many factors that can lead to improvement in the industry's performance.

A-394 Giovambattista, A., and Traversa, L. 1987. "Durability of Basaltic Aggregates Contaminated with Montmorillonite," Concrete Durability--Katharine and Bryant Mather International Conference, SP-100, pp 1285-1296, American Concrete Institute, Detroit, MI.

Contamination of basaltic rocks with clays of the montmorillonite group causes the expansion and failure of the rocks when exposed to moisture changes. When these rocks are used as concrete aggregates, contamination may produce concrete degradation. In Argentina, there are some bridge structures affected by this process. The present paper considers some results obtained by the use of different tests used for basaltic aggregate evaluation, and decision criterium is proposed.

A-395 Rasheeduzzafar, Dakhil, F. H., and Mukarram, K. M. 1987. "Influence of Cement Composition and Content on the Corrosion Behavior of Reinforcing Steel in Concrete," Concrete Durability--Katharine and Bryant Mather International Conference, SP-100, pp 1477-1502, American Concrete Institute, Detroit, MI.

Performance data based on accelerated corrosion monitoring and exposure site tests indicate that cement type, reflecting in particular the C_3A content, significantly affected concrete durability with respect to corrosion of reinforcing steel. On an average, Type I cement (C_3A:9.5 percent) performed 1.7 times better than Type V cement (C_3A:2.8 percent) in terms of time to initiation of corrosion. Further, with

respect to corrosion, concretes made with fly ash blended cements performed better than no-fly ash concretes with the best performance shown for 30 percent cement replacement.

The greatest beneficial effect of pozzolan addition was provided in conjunction with low w-c ratios of 0.385 and 0.45. The electrical resistivity for portland-pozzolan concrete made with 25 percent cement replacement was three times that of straight cement concrete, irrespective of w-c ratio in the range of 0.35 to 0.65. Depending on the extent of replacement, pH values for concretes made with fly-ash blended cements were observed to be in the range of 12.70 to 12.93 after 600 days of exposure to the outdoor environment at Khahran in Eastern Saudi Arabia. However, the pH values dropped below that of pure saturated $Ca(OH)_2$ solution (12.50) for chloride-contaminated concrete made with fly-ash blended cement with observed detrimental consequences for corrosion of reinforcement. Increase in the cement factor with attendant reduction in w-c ratio provided a most beneficial effect on time to initiation of corrosion of reinforcing steel.

A-396 ACI Forum. 1987. "Influence of Chlorides in Reinforced Concrete," Corrosion, Concrete, and Chlorides--Steel Corrosion in Concrete: Causes and Restraints, SP-102, pp 143-154, American Concrete Institute, Detroit, MI.

There was one point on which participants of the forum on "The Chloride Issue: The New Limits" at ACI's annual convention last March in Denver agreed -- there is a great deal to be learned about the influence of chloride ions in reinforced concrete. The purpose of the forum was to determine topics on which research is needed. A list of the topics that surfaced during the forum accompanies this article. The forum was sponsored by ACI Committee 123, Research.

A-397 Hoff, G. C. 1987. "Durability of Fiber Reinforced Concrete in a Severe Marine Environment," Concrete Durability--Katharine and Bryant Mather International Conference, SP-100, pp 997-1042, American Concrete Institute, Detroit, MI.

Durability of concrete in a marine environment is a function of its mixture constituents, freeze-thaw susceptibility, abrasion resistance, fatigue strength, and corrosion of embedded metal. These problems usually manifest themselves in the tidal and splash zones of a structure. Fiber reinforced concrete has improved fatigue characteristics and improved cracking behavior over conventional concrete. These properties can be advantageously applied to concrete in a marine environment, providing the durability in that environment is satisfactory.

A-398 Grattan-Bellew, P. E., and Gillott, J. E. 1987. "Three Decades of Studying the Alkali Reactivity of Canadian Aggregates," Concrete Durability-- Katharine and Bryant Mather International Conference, SP-100, pp 1365- 1384, American Concrete Institute, Detroit, MI.

Early studies of concrete durability problems resulting from expansive

reactions between certain aggregates and cement alkalies implicated opal and other forms of poorly ordered silica as the reactive component in the aggregate. Later work showed that other types of rocks may expand in alkali and cause concrete durability problems as well. Glassy or poorly crystalline volcanic rocks, dolomitic limestones, greywackes, phyllites, and argillites are now recognized as potentially deleteriously reactive. Standard tests were developed that involve the measurement of length-change of mortar bars, concrete prisms, and rock cylinders held under constant temperature and humidity conditions. Other tests have been used in attempts to gain a better understanding of the expansive mechanisms. Petrographic studies were carried out from an early date; with the introduction of more sophisticated equipment such as the scanning electron microscope, x-ray diffraction, and differential thermal analysis, petrography now plays an increased role in this area of engineering geology.

A-399 Popovics, S. 1987. "Classification of the Deterioration of Concrete Based on Mechanism," Concrete Durability--Katharine and Bryant Mather International Conference, SP-100, pp 131-142, American Concrete Institute, Detroit, MI.

Deteriorations that may occur during the service life of a concrete structure are divided into six classes based on the underlying mechanisms. General aspects of concrete deterioration and the description of mechanisms for the six classes as well as subclasses form the major portion of the paper.

A-400 Fujiwara, T. 1987. "Deterioration of Concrete Used in Road Bridges Due to Freezing and Thawing," Concrete Durability--Katharine and Bryant Mather International Conference, SP-100, pp 805-819, American Concrete Institute, Detroit, MI.

Concrete structures in the northern regions of Japan have a higher risk of deterioration due to freezing and thawing because of the cold climate and heavy snows. The resistance of concrete to freezing and thawing is studied actively in the laboratory in Japan, but there is still much to be studied about the deterioration of concrete structures exposed in the field. A survey of the deterioration of concrete used in road bridges was made in Iwate Prefecture, a district in northeastern Japan where there are many different climatic conditions. Over 300 bridges was examined.

The majority of bridges observed were damaged to some degree by freezing and thawing. The degree of deterioration differed in different parts of the bridges. Although the main cause of deterioration is presumed to be poor construction, it can be pointed out that the lack of consideration for design of these structures adds significantly to their deterioration. The degree of deterioration also depends on regional climatic conditions. In this report, the relation between the degree of observed deterioration and the climatic conditions is discussed.

A-401 Figg, J. W., Bravery, A. F., and Harrison, W. H. 1987. "Covenham Reservoir Wave Wall--A Full-Scale Experiment on the Weathering of Concrete," Concrete Durability--Katharine and Bryant Mather International Conference, SP-100, pp 469-492, American Concrete Institute, Detroit, MI.

A full-scale prospective durability experiment was established in the spring of 1970 at Covenham, Lincolnshire, England, when five different concrete mixes were used to construct portions of the wave wall of an 88 Ha inland reservoir. The reservoir is approximately 1.0 by 0.9 km in plan, and the maximum water depth is 1.4 m. The concave face unreinforced wave wall at the top of the embankment faces southwest into the prevailing wind and is subject to wave action in winter.

Variables tested were (a) increased sand proportion, (b) air entrainment, (c) increased cement content, and (d) use of a lignosulfonate-based water-reducing admixture. The standard concrete mix used for the rest of the reservoir was used as a control. The alternate bay method of construction used for the wave wall ensured adequate replication for both test and control concretes.

To date, all mixes have performed well, although weathering differences began to show at 4 to 6 years when the alkalinity of the concrete surfaces had been reduced sufficiently by carbonation to allow growth of microorganims, particularly lichens. Yellow lichen species were most prominent at first, but subsequently were overtaken by grey/green lichens.

After 10 years of exposure, all the modified concrete mixes showed less weathering effects than the control mix with least improvement given by the air-entrained concrete a and the mix containing a higher sand percentage b. Increasing the cement content c gave a significant improvement, but the best performance has been obtained with the concrete d batched with lignosulfonate-based water-reducing admixture.

A-402 Meyer, A. 1987. "Importance of the Surface Layer for the Durability of Concrete Structures," Concrete Durability--Katharine and Bryant Mather International Conference, SP-100, pp 49-62, American Concrete Institute, Detroit, MI.

The surface layer and the remaining core concrete of a structural member are already, immediately after curing, two different materials in composition. The difference in characteristic properties can be considerably increased by outside influences in the lifetime of the concrete building. We have to pay more attention to this fact because the surface layers are important with regard to the long-term behavior of concrete structures and the protection of steel reinforcement against corrosion. The effects on structure and characteristic properties of the surface layer by placing, compacting, and curing in the early states and later when subjected to different environmental conditions are studied and discussed. Some methods to test in practice the

properties of the surface layer--strength, porosity, alkalinity, and frost resistance--are described.

A-403 Dransfield, J. M. 1987. "Durability of Concrete with a Superplasticizing Admixture," Concrete Durability--Katharine and Bryant Mather International Conference, SP-100, pp 741-764, American Concrete Institute, Detroit, MI.

Results of a wide-ranging study undertaken to examine the effect of a superplasticizing admixture on the durability of normal-workability concretes are reported. The investigation was based on cement-reduced concrete mixes covering a range of 28-day strength from 20 to 65 MPa, with water-reduced concretes included to increase the data base. Corresponding normal concretes were used for comparison. The experimental program covered included measurements of air and water permeability to assess the overall durability potential; the rates of carbonation and chloride ion diffusion to assess the possible risk of steel reinforcement corrosion in concrete; and the deterioration under alternate freezing and thawing and wetting and drying to assess the resistance of concrete to frost attack and weathering. The results showed that, for a given workability and design strength, the use of a superplasticizing admixture can be expected to effect improvement in the durability of concrete.

A-404 Ayoub, M. T. 1987. "Stress Induced Corrosion of Concrete Reinforcement in Hot Climates," Corrosion--Industrial Problem Treatment and Control Techniques, Kuwait, 1984, pp 513-521, Pergamon Press, United Kingdom.

It has been produced that the most common source of distress in concrete structures is the corrosion of reinforcement. The phenomenon of stress induced corrosion may occur under the action of certain corrosive media (eg, chlorides, nitrates and sulphides). The stress induced corrosion of rebars is characterized by quite rapid development of deep cracks which induce an electrical potential difference to assist intergranular attack. In hot climates with lower atmospheric humidity, shrinkage cracks will appear in the concrete and promote stress induced corrosion. Therefore, stress induced corrosion will develop as long as the corrosive medium can penetrate to the steel surface. The corrosion product at the rebar interface produces volumeric expansion and internal pressures or surface stress. A mathematical model is developed to simulate the effects of internal pressure and temperature produced from the corrosion process in high-temperature environment. Moreover the model is used to provide an analysis of the deterioration of bond strength between rebar steel and concrete.

A-405 Collins, R. J., and Bereham, P. D. 1987 (Jan). "Alkali-Silica Reaction: Suppression of Expansion Using Porous Aggregate," Cement and Concrete Research, Vol 17 No. 1, pp 89-96, Elmsford, NY.

Concretes containing porous natural aggregate or lightweight aggregate have been monitored for expansion due to alkali-silica reaction. Very

much reduced expansions were found when these aggregates replaced a dense limestone in a reactive mix containing Thames Valley sand. These results are discussed in terms of aggregate absorption, concrete porosity, and potential reactivity of some of the porous aggregates.

A-406 Buist, W. 1987 (Dec). "Maintenance and Repair of Concrete Structures," Cement, Vol 39, No. 12, pp 64-69, Hertogenbosch, The Netherlands.

The corrosion of steel reinforcement is the most common form of damage to concrete and deserves special attention in this series. This article gives an in-depth analysis of the corrosion process of steel in concrete and considers the relative importance of the different influencing factors.

A-407 Shayan, A., Gibbs, P., and Martin, K. G. 1987 (Dec). "Decomposition of a Concrete Floor and Ignition of Gaseous Products Due to Spillage of Molten Aluminium," Magazine of Concrete Research, Vol 39, No. 141, pp 221-28, Thomas Telford Ltd, London, England.

This paper deals with the decomposition of a concrete floor by the spillage of molten aluminum of the Boyne Island Aluminium Smelters in Queensland, Australia. The fire decomposed the floor and partially melted the pot assembly, resulting in enormous repair costs, and delays in production.

A study of the damaged concrete showed that it was made with limestone aggregate. The molten aluminum at about 1,050° C formed ponds about 2m in diameter and 200 mm deep. It decomposed the limestone and produced CO_2 gas which was reduced by the molten aluminum to CO gas, which ignited. The strong exothermic reaction produced further heat and melted the reinforcing bars in concrete. The moisture in concrete formed steam and agitated the system, so that the molten metal was more effectively in contact with the concrete and caused further decomposition of the limestone.

A-408 Pitt, J. M., Schulter, M. C., Lee, D., and Dubberke, W. 1987. "Sulfate Impurities from Deicing Salt and Durability of Portland Cement Mortar," TRR 1110, Transportation Research Board, National Research Council, Washington, DC.

Research on the topic of calcium sulfate impurities in deicing salts adversely affecting the durability of portland-cement mortar is covered in this paper. Natural rock salt may contain as much as 4.0 percent calcium sulfate. When combined with chloride solutions, the solubility of calcium sulfate increases by as much as 3.5 times; hence, the calcium sulfate impurities contained in rock salt brine become highly detrimental, causing attack on cement mortar samples. These impurities can collect in pavement joints and cracks, reaching high concentrations through evaporation and the repeated use of deicing salts. Such a destructive mechanism may account for premature field failure of pavements that passed durability tests in the laboratory. Durability

First, a macro survey was undertaken to determine the frequency of corrosion failures on 95 buildings. The data are sufficiently detailed to enable identification of frequency by member and by orientation as well as an aggregate for each building.

In a closer examination, concrete quality and reinforcement position were assessed at durability faults relative to other locations on the building. Concrete quality was assessed by a measure of relative strength using an impact hammer, the depth of carbonation, and the initial rate of absorption. Reinforcement cover was measured visually and using a covermeter. The findings of both the macro and detailed survey are discussed in the paper.

For the 95 buildings surveyed, a multiple regression analysis did not indicate a higher density of failures on buildings near the coast or harbor than buildings up to 27 km from the coast. Conclusions drawn from the detailed evaluation of 41 faults on existing buildings were that carbonation absorption and strength were not useful indicators of failure in the cases examined. However, the mean cover-to-reinforcement at 227 faults was 5.45 mm, clearly indicating that lack of cover is a major problem associated with failures.

A-411 Stark, D. C. 1987. "Deterioration Due to Sulfate Reactions in Portland Cement-Stabilized Slag Aggregate Concrete," Concrete Durability-Katharine and Bryant Mather International Conference, SP-100, pp 2091-2102, American Concrete Institute, Detroit, MI.

An investigation was made to determine causes of abnormal expansion and heaving of portland cement-stabilized slag aggregate base material in an airfield runway. Field inspection, petrographic examinations, x-ray diffraction studies, and chemical analyses were made in this investigation. It was concluded that deterioration was due to reactions involving cement hydration products and sulfate derived from certain slag aggregate particles. Whether expansion developed depended on the nature of the sulfate-bearing components originally present in the slag. Recognition of potential for this type of problem appears to be lacking in the published literature and in current specifications.

1988

A-412 Mangat, P. S., and Gurusamy, K. 1988 (Jan). "Corrosion Resistance of Steel Fibers in Concrete Under Marine Exposure," Cement and Concrete Research, Vol 18, No. 1, pp 44-54, Elmsford, NY.

The final paper of a series, reporting different aspects of a long-term study on the marine durability of steel fiber reinforced concrete (SFRC), is presented. Two mixes, one with and one without pfa were reinforced with three types of steel fibers. The cement contents of mixes were 430 and 590 kg/m^3, respectively. Prism specimens of the mixes were cured under marine exposure, both in the laboratory and at Aberdeen beach, for up to 2,000 wet-dry cycles (1,200 days). The state of the corrosion of the steel fibers was investigated visually and by

electrochemcial analysis of fibers exposed at fractured surfaces of specimens after flexural testing.

The results show that the generally accepted activation level of 0.4 percent Cl^- by weight of cement does not apply to SFRC. Similarly, the threshold value of 0.61 for the $(Cl^-)/(OH^-)$ ratio, as proposed by Hausemann for initiation of corrosion, is not valid to steel fiber reinforced concrete. No corrosion of the fibers embedded in concrete was evident at Cl^- and $(Cl^-)/(OH^-)$ levels greatly exceeding these values.

A-413 Dahms, J. 1988 (Jan). "Sea-Water Effects on Concrete," Beton, Vol 38, No. 1, pp 14-16, Dusseldorf, West Germany.

Concretes in the tidal water area of the North Sea and the splash water of the Baltic repeatedly have shown damage. The report investigates which types of concrete or concrete compounds are particularly suited for seawater conditions in conjunction with frost.

A-414 Raharinaivo, A. 1988 (Jan-Feb). "Prediction of Corrosion of Concrete Reinforcements Under the Action of Chlorides," Bulletin de Liaison des Laboratoires des Ponts et Chaussees, No. 153, pp 77-79, Paris, France.

Parameters necessary to predict the duration of the onset of metal corrosion are diffusivity of the corrosive substance in the concrete and the critical value of the concentration of that substance in contact with the reinforcements. Chloride ions that penetrate concrete from the surrounding medium cause the reinforcements to corrode when their content exceeds a threshold depending on the pH value of the concrete. Article gives physical justifications for the empirical results previously obtained concerning the penetration and critical concentration of chlorides.

A-415 Aimin, X., and Chandra, S. 1988 (Feb). "Influence of Polymer Addition on the Rate of Carbonation of Portland Cement Paste," International Journal of Cement Composites and Lightweight Concrete, Vol 10, No. 1, pp 49-52, Harlow, England.

This paper presents results of accelerated carbonation tests of ordinary portland cement-acrylic monomer-based polymer composites in 100 percent carbon dioxide and 76 percent relative humidity. With the addition of the polymer, the rate of carbonation of the hardened pastes was increased despite the decrease in their porosity and water absorption. The increase in the rate of carbonation reached its maximum when the ratio of the polymer to cement was 10 to 15 percent.

A-416 Hill, J. 1988 (Mar). "Cracks in Structures," Concrete Construction, Vol 33, No. 3, pp 312-314, 316, 318, Addison, IL.

The word crack implies a defective structure. Yet every building constructed using concrete in any shape or form has cracks. It is the size, frequency, and reason for their existence that matters, not that

they occur. Concrete cracking can, however, be the first sign of structural distress. In new buildings, it can signify that some reinforcement has been omitted by poor design or poor construction. It can be due to inadequate stiffening against wind forces. Cracking also can be due to defective concrete. Article covers causes of cracking and cracking standards. Deterioration due to cracking is also discussed, along with which types of cracks can be more harmful.

A-417 Buttler, F. G. 1988 (Mar). "Calculation of Reactive Alkali Content of OPC and PFA Concrete," Concrete, Vol 22, No. 3, pp 18-19, London, England.

Considerable attention has been given to the occurrence of damaging expansion in concrete structures due to alkali-silica reaction (ASR). Relative to the total quantity of concrete produced nationally, the probability of damage due to this reaction is low, and until comparatively recently, the known cases appeared to be restricted to particular localities. It is now recognized that damage due to the reaction could occur in any concrete that has a combination of sufficiently high alkalinity, a critical amount of reactive silica, and sufficient moisture to enable the reaction to proceed.

A-418 Smith, P. 1988 (Apr). "Reacting to Alkali-Aggregate Reactions," Concrete International: Design & Construction, Vol 10, No. 4, pp 33-34, Detroit, MI.

At the 7th International Conference on Alkali-Aggregate Reactions held in Ottawa, Canada, in August 1986, 170 of the world's most notable investigators of alkali-aggregate reactions contributed their knowledge and experience to update the state of the art. In addition to new insights into mechanisms, two of the most pressing practical issues-new rapid tests to detect rock reactivity and methods for the assessment and repair of damage-received due attention.

In his keynote address at the conference, ACI Past President Peter Smith challenged the over 200 participants from 23 countries on two main scores. Firstly, the challenge was to communicate better to concrete users the present state of knowledge and its limitations. Secondly, in so doing, the challenge was to set emotional fears at rest that public safety may be at risk from sudden structural concrete failures induced by alkali-aggregate reaction distress.

A-419 Wafa, F. F., Rizaiza, O. S. A., Mirza, W. H., and Khan, M. Z. A. 1988 (Apr). "Impact of Groundwater Pollution on Concrete Structures," Concrete International: Design & Construction, Vol 10, No. 4, Detroit, MI.

An inadequate wastewater management system in the coastal city of Jeddah, Saudia Arabia, has resulted in a rise in the water table and contamination of the groundwater by sewage and seawater. The rising level of polluted groundwater has seriously impaired the strength and serviceability of concrete and masonry.

A-420 Cohen, M. D., and Bentur, A. 1988 (May-Jun). "Durability of Portland Cement-Silica Fume Pastes in Magnesium Sulfate and Sodium Sulfate Solutions," ACI Materials Journal, Vol 85, No. 3, Detroit, MI.

The effects of magnesium sulfate (MS) and sodium sulfate (NS) solutions on the durability of 0.3 water-to-solid ratio pastes of ASTM Types I and V portland cements with partial replacement of 15 mass percent silica fume were investigated. Results show that silica fume addition to portland cement can improve resistance to sodium sulfate attack, but it can greatly impair resistance to magnesium sulfate attack.

The greater damaging effects of the magnesium sulfate solution on portland cement and portland-cement+silica-fume specimens are due to the decomposition of the C-S-H gel to M-S-H - magnesium silicate hydrate, which is noncementitious. Furthermore, the greater intensity of the attack on portland-cement+silica-fume specimens as compared to the portland-cement specimens may be due to the absence of magnesium hydroxide (MH) in the portland-cement+silica-fume paste. MH is relatively insoluble in water, is known to block the pores, and protects the C-S-H gel from further attack. Its absence in portland-cement +silica-fume specimens, therefore, makes the C-S-H gel more prone to $\overline{MS}$ attack. The greater intensity of the attack may also be the result of the formation of an additional amount of C-S-H gel due to the pozzolanic reaction, "pozzolanic C-S-H gel," which is difficult in the composition from the C-S-H gel produced by the hydration of alite and belite of portland cement - "portland cement C-S-H gel."

The need for establishing failure criteria/performance classifications for sulfate resistance is amplified. These criteria/classifications depend primarily on the mixture proportions, curing, duration, and type of sulfate exposure, and indicator (i.e., change in length, mass, compressive/flexural strength, and modulus of elasticity). These classifications should allow one to point out the specific nature of the sulfate attack (i.e., expansion/cracking and/or softening/spalling) and to distinguish differences in resistance between pozzolanic C-S-H and the portland-cement C-S-H gels.

A-421 Gupta, A. K. 1988 (Jun). "Corrosion of Reinforced Concrete Structures and their Rehabilitation," ICI Bulletin.

Concrete's performance simultaneously depends on a number of factors like the constituents that make it, the quality of construction and aggressiveness of the environment. The chief factors that lead to corrosion of steel in concrete are:

1) Effect of steel chemistry: Low carbon steels have been found to be more susceptible to corrosion.

2) Effect of microstructure of concrete: Concrete that is porous will permit diffusion of aggressive chemicals that will lead to corrosion of reinforcement. High C_3A content and free lime make it weak against sulphate attack. Chlorides disrupt the passivation film around the

reinforcement and activate corrosion. It should be limited to 2 percent by mass of cement. To avoid alkali-aggregate reaction which leads to cracking and corrosion, reactive aggregates should not be used and alkali content should be limited to 0.6% (Na_2O).

3) Effect of internal stress levels: Reinforcing steel subjected to stress above 70 percent of yield stress is vulnerable to stress corrosion and corrosion embrittlement.

4) Effect of environments: One of the severest environment for concrete is marine. Apart from the mechanical wear, it is also responsible for leaching of $Ca(OH)_2$, sulphate attack and chloride corrosion initiation. Sea winds render concrete not in direct contact with seawater, but in the entire coastal region also, as they carry salt-laden moisture along. Other factors that lead to corrosion and deterioration are dissolved chemicals and salts in inland waters, humid air and presence of acidic gases like SO_2, CO_2 and H_2S in the atmosphere.

A-422 Buck, A. D. 1988 (Jun). "Use of Pozzolan or Slag in Concrete to Control Alkali-Silica Reaction and Sulfate Attack," Technical Report SL-88-29, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

Five different materials (one Class C fly ash, two silica fumes, and two ground granulated iron blast-furnace slags (slag) were characterized by a combination of tests, standard physical and physical plus some petrographic examination.

Mortar mixtures were then made using different amounts of each of these materials with high-alkali portland cement. Specimens from these mixtures were tested for expansion due to alkali-silica reaction (ASR) by CRD-C 257 (ASTM C 441) and for expansion due to sulfate attack by CRD-D 211 (ASTM C 1012). The expansion data were evaluated to determine the amount of each material required to control either process or the combined effects of both. A few concrete mixtures were then made using the indicated amounts of the fly ash, silica fume, and slag, and specimens were tested as before to determine the effectiveness of these materials to control deleterious expansion in concrete.

In addition, many of the blends of cement with pozzolan or slag that were used in the mortar mixtures were tested to determine heat of hydration by CRD-C 229 (ASTM C 186). Mortar mixtures were tested for drying-shrinkage in accordance with CRD-C 256 (ASTM C 311).

The results of this work were used to develop a procedure for the evaluation and use of pozzolan (fly ash, silica fume, natural pozzolan) or slag to control the expansive effects of ASR or sulfate attack or both when either or both is considered a potential problem. This procedure is convenient to use and can provide the desired information in as little as 2 or 3 months.

Such an empirical procedure is needed because each combination of a pozzolan or a slag with other materials is a unique situation;

therefore, previous data for other such materials are not entirely suitable to determine the amount that is needed for a specific situation.

A-423 Kittl, P., et al. 1988 (Jul). "On Durability and Mechanical Properties Improvement of a Compacted Copper-Fibre Cement Composite Subjected to General Corrosion," Cement and Concrete Research, Vol 18, No. 4, pp 539-544, Elmsford, NY.

A compacted copper-fiber cement composite subjected to boiling water and to an alkaline solution of 0.84 percent sodium bromate ($NaBrO_3$) did not show any corrosion, but when exposed to an alkaline solution of 0.84 percent sodium bromate plus 3.24 percent ammonium hydroxide (NH_4OH), said composite showed an intense corrosion. This last reagent was used to produce a controlled corrosion to form corrosion products in the fiber-matrix interface, thus increasing fiber-matrix adherence and hence composite strength. The parameters of Weibull's function for the cumulative and the local probabilities of fracture were calculated.

A-424 Kayyali, O. A., and Haque, M. N. 1988 (Jul). "Effect of Carbonation on the Chloride Concentration in Pore Solution of Mortars with and without Fly Ash," Cement and Concrete Research, Vol 18, No. 4, pp 636-648, Elmsford, NY.

One percent of Cl^- ion by weight of cementitious materials was added as $CaCl_2$ to mortar mixes with and without fly ash. Accelerated carbonation was applied on the mortars after short and long fog curing periods. The results showed significant increase of Cl^- ions in the pore solution occurring as a result of carbonation. The increase was much more pronounced in fly ash mortars. Prolonged initial curing helped to retain Cl^- bound within the hydration compounds in the case of plain mortars, while it resulted in the increase of Cl^- content in the pore solution of fly ash mortars.

A-425 Buck, A. D. 1988. "Evaluation of the Frost Resistance of Concrete Using Critical Dilation," Cement, Concrete, and Aggregates, CCAGDP, Vol 10, No. 1, Summer 1988, pp 48-50, Philadelphia, PA.

A new definition of critical dilation is proposed for use in ASTM Test Method for Critical Dilation of Concrete Specimens Subjected to Freezing (C 671). Using this new definition, only a single cycle of freezing is needed to determine whether or not a specimen is frost resistant.

A-426 Rodway, L. E. 1988. "Effect of Air-Entraining Agent on Air-Void Parameters of Low- and High-Calcium Fly Ash Concretes," Cement, Concrete, and Aggregates, ASTM, Vol 10, No. 1, Summer 1988, pp 35-38, Philadelphia, PA.

Five fly ashes with widely varying lime contents from three countries were used for 25 percent of the cement by mass in identical concrete mixes, including the same quantity of air-entraining agent in each

case. The hardened concrete resulted in a satisfactory air-void system in terms of freeze-thaw resistance, regardless of the lime content of fly ash.

A-427 Wong, G. S., and Poole, T. 1988 (Aug). "Sulfate Resistance of Mortars Using Portland Cement and Blends of Portland Cement and Pozzolan or Slag," Technical Report SL-88-34, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

Mortar bars were made from 23 Type I, 9 Type II, 2 Type V, 15 Type IP, 5 Type IS, and blends of Type I with slag and with various pozzolans including one silica fume. The bars were stored in a 5-percent sodium sulfate solution and monitored for changes in length and in resonant frequency. The length changes of the bars indicated that silica fume and a natural pozzolan showed impressive improvement of the blends over the use of a nonsulfate-resistant cement by itself. However, while blends made using slag and other pozzolans in the amounts studied, in some cases showed only slightly improved resistance and in other cases no improvements.

A-428 Strohbauch, G., and Kuzel, H. J. 1988 (Jul). "Carbonation Reactions as Cause of Damage to Heat-Treated Precast Concrete Units" (in German), Zement-Kalk-Gips, Vol 41, No. 7, pp 358-360, Wiesbaden, Germany.

Damage affecting heat-treated precast concrete units on exposure to weather is caused by subsequent formation of ettringite. The crystallization of ettringite is due to carbonation reactions, the behavior and mechanism of which have been clarified by x-ray determination of the phase constitution and by chemical analysis. Heat treatment accelerates the reaction of ettringite to form monosulfate.

A-429 Shayan, A. 1988 (Sep). "Deterioration of a Concrete Surface Due to the Oxidation of Pyrite Contained in Pyritic Aggregates," Cement and Concrete Research, Vol 18, pp 723-730, Elmsford, NY.

Severe blistering of a concrete floor slab has occurred over an extensive area in a 10-year-old building, resulting in unevenness of the surface and rupturing of vinyl tiles covering the floor. The blistering was found to be caused by the oxidation of pyrite in pyritic aggregates located at the surface of the slab. Oxidation of pyrite resulted in the formation of sulfuric acid and ferrous sulfate which reacted with other mineral components of the aggregate to form complex sulfates such as jarosite, halotrichite, and small amounts of other sulfates, and reacted with the mortar surrounding the aggregate to form gypsum. The portion of the vinyl tiles in contact with the highly acidic environment near the degrading aggregate became very brittle and upward movement of the soluble salts and their accumulation beneath the brittle portions caused blistering which grew and finally ruptured the tiles. Pyritic aggregates within the concrete were not affected due to complete protection by the mortar and a general sulfate attack was not observed.

A-430 "D-cracking Pavements." 1988 (Sep). Concrete Construction, Vol 33, No. 9, pp 845-847, Addison, IL.

This article discusses causes and symptoms of D-cracking in concrete pavements and ways to avoid or minimize it. Suggestions include identifying susceptible aggregates, reducing coarse aggregate size, heavy media separation of harmful particles, and blending harmful aggregates with more durable ones.

A-431 Swamy, R. N., and Al-Asali, M. M. 1988 (Sep-Oct). "Engineering Properties of Concrete Affected by Alkali-Silica Reaction, ACI Materials Journal, Vol 85, No. 5, Detroit, MI.

A detailed study of the effects of alkali-silica reaction (ASR) on the engineering properties of concrete such as compressive and tensile strength, elastic modulus, and pulse velocity is presented. Two types of reactive aggregate - a naturally occurring Beltane opal and a synthetic fused silica - were used. The tests were carried out at 20° C and 96 percent relative humidity (RH). The results showed that losses in engineering properties do not all occur at the same rate or in proportion to the expansion undergone by the ASR-affected concrete. The two major properties affected by ASR were flexural strength and dynamic modulus of elasticity. Compressive strength was not a good indicator of ASR, but the flexural strength proved to be a reliable and sensitive test for monitoring ASR. Nondestructive tests like dynamic modulus and pulse velocity were also able to identify deterioration of concrete by ASR. The data indicate that critical expansion limits due to ASR would vary depending on the type and use of a concrete structure.

A-432 Okada, K., Yoshikawa, T., and Himeno, M. 1988 (Nov). "Effects of Admixtures an Alkali Compounds on Alkali Aggregate Reaction," International Journal of Cement Composites and Lightweight Concrete, Vol 10, No. 4, Longman Group, UK Ltd, Harlow, Essex, England.

Tests of mortar bar expansion are reported with bronzite andesite reactive aggregate found in Japan. The effects of chemical admixtures, sodium alkalis, and of fly ash and slag on expansion are presented. Chemical admixtures appeared to reduce expansion whereas alkali compounds caused large expansion with sodium salts more aggressive than potassium salts. Fly ash and slag were found effective in controlling expansion.

A-433 Shayan, A., and Quick G. W. 1988 (Nov). "An Alkali-Reactive Basalt from Queensland, Australia," International Journal of Cement Composites and Lightweight Concrete, Vol 10, No. 4, Longman Group, UK Ltd, Harlow, Essex, England.

Basalts are basic igneous rocks which are normally nonreactive with alkali in concrete. However, a glassy olivine basalt of Tertiary age from Queensland, Australia, has been found to be highly reactive with high alkali cement and unsuitable as a concrete aggregate. Examination of the rock petrographically, by scanning electron microscopy and

electron microprobe analysis revealed the presence of 1.6 percent opaline silica. Also present in the rock was a glass (about 34 percent) of a Si-rich composition, and this together with the opaline silica is suspected as the components causing reactivity of the basalt. However, the 1.6 percent opaline silica alone would be sufficient to render the rock reactive to alkali hydroxide.

A-434 Mullick, A. K. 1988 (Nov). "Distress in a Concrete Gravity Dam Due to Alkali Silica Reaction," International Journal of Cement Composites and Lightweight Concrete, Vol 10, No. 4, Longman Group, UK Ltd, Harlow, Essex, England.

Multidisciplinary investigations to identify the causes of distress in case of a concrete gravity dam and powerhouse structure are described. Instrumental analysis of concrete samples established the occurrence of alkali silica reaction in concrete. Structural analysis of the penstock gallery frame traced the cracking in the RCC structures to the expansions due to ASR. Appropriate repair techniques adopted are described.

A-435 Kobayashi, K., Inoue, S., Yamasaki, I., and Nakano, K. 1988 (Nov). "Alkali Aggregate Reaction in Prestressed Concrete Beams," International Journal of Cement Composites and Lightweight Concrete, Vol 10, No. 4, Longman Group, UK Ltd, Harlow, Essex, England.

In this study, time-dependent strains are measured on a total of 10 prestressed concrete beams, made of two types of concrete with alkali silica reactivity (ASR) and a normal concrete, under an accelerated curing condition of 40° C and 100 percent RH. In addition, the creep factor for concrete in each beam is estimated analytically based on these measured strains. The fundamental structural behavior of the beams affected by ASR is investigated in comparison with those of corresponding normal beams by carrying out static loading tests with shear span to effective depth ratio of 2.5 and 4.0.

A-436 Ono, K. 1988 (Nov). "Damaged Concrete Structures in Japan Due to Alkali Silica Reaction," International Journal of Cement Composites and Lightweight Concrete, Vol 10, No. 4, Longman Group, UK Ltd, Harlow, Essex, England.

Cracking in concrete due to alkali silica reaction (ASR) takes various patterns. In plain concrete and in parts of reinforced concrete structures where there is little or no surface reinforcement, cracking tends to be irregular and maplike. In reinforced and prestressed concrete elements, cracking tends to occur in the direction of the reinforcing bar. This paper presents detailed information on the cracking behavior of a wide range of concrete structures damaged by alkali silica reaction in Japan. The paper also reports test data obtained from cores taken from ASR affected concrete structures. In particular, information is given on crack characteristics, loss of compressive strength and elastic modulus, and the effectiveness of pulse velocity in identifying loss of compressive strength. Although significant and

widespread corrosion has not yet been observed, appropriate repair techniques are needed to safeguard damaged structures from further deterioration.

A-437 Samarin, A. 1988 (Nov). "Alkali Aggregate Reaction Related Concrete Deterioration in Australia," International Journal of Cement Composites and Lightweight Concrete, Vol 10, No. 4, Longman Group, UK Ltd, Harlow, Essex, England.

The paper discusses the alkali aggregate reactivity of reactive aggregates found in Australia. Test methods to evaluate long-term dimensional stability of potentially reactive aggregate are reported. The inclusion of highly reactive pozzolanic materials like fly ash has been more effective in controlling expansion due to Australian reactive aggregates. The compatibility of the pozzolanic material and the optimum amount of the mineral admixture are emphasized.

A-438 Idorn, G. M. 1988 (Nov). "Concrete Durability in Iceland," Concrete International: Design & Construction, Vol 10, No. 11, pp 41-43, Detroit, MI.

This article is an overview of research regarding alkali-silica reactions in Iceland, especially their effects on houses and buildings in the Reykjavik area. Based on notes and observations made at the 20th anniversary meeting of the National Committee on Alkali-Silica Reactions in Iceland.

A-439 Shayan, A. 1988 (Nov). "Alkali Aggregate Reaction in a 60-Year-Old Dam in Australia," International Journal of Cement Composites and Lightweight Concrete, Vol 10, No. 4, Longman Group, UK Ltd, Harlow, Essex, England.

Examination of drilled cores taken from a 60-year-old dam in Australia has shown that the dam has suffered from alkali aggregate reaction. Cracking has been observed on the crest of the dam and its concrete railing. The aggregate used in the concrete is a local dacite excavated from the dam site and shows strong reaction rims particularly in the upper 10-12 m of the dam wall.

Deeper portions of the dam wall appear to be free from reaction rims, but the reasons for this have not been investigated. The reaction product was characterized by X-ray diffraction, infrared spectroscopy, scanning electron microscopy, and electron micro-probe analysis and was similar to previously reported alkali aggregate reaction products. New aggregate from the same locality as that used in the dam was tested for alkali reactivity and was reactive with alkali in concrete.

A-440 Attiogbe, E. K., and Rizkalla, S. H. 1988 (Nov-Dec). "Response of Concrete to Sulfuric Acid Attack," ACI Materials Journal, Vol 85, No. 6, Detroit, MI.

The response of four different concrete mixes to sulfuric acid attack was evaluated in an accelerated laboratory test program. Small test specimens cut from standard concrete cylinders and a 1-percent sulfuric acid solution with a pH of 1 were used in the test program. Changes in weight and thickness of the test specimens were used as physical indicators of the degree of deterioration, while increase in sulfur content of the test specimens was used as a chemical indicator of the degree of deterioration.

The study shows that all three indicators of deterioration are effective measures of concrete response to the acid attack. However, the study suggests that the increase in thickness (expansion) of small specimens (with large surface area-to-volume ratios) may be a more consistent measure than the weight loss of larger specimens when comparing the effects of different sulfuric acid concentrations on concrete. Photomicrographs of the concrete microstructures show that the concrete deterioration starts from the acid-exposed surface and progresses inward. The degree of concrete deterioration is increased by alternate wet-dry cycles of exposure to sulfuric acid. The rate of concrete deterioration along the penetration depth of sulfuric acid could be described by a variation in sulfur concentration with the depth of acid penetration.

A-441 Tikalsky, P.J., Carrasquillo, P. M., and Carrasquillo, R. L. 1988 (Nov-Dec). "Strength and Durability Considerations Affecting Mix Proportioning of Concrete Containing Fly Ash," ACI Materials Journal, Vol 85, No. 6, Detroit, MI.

The results of a 3-year study on the properties of concrete containing fly ash are presented herein. Both the fresh and hardened properties are reported of concrete made using Type I cement, river gravel, natural sand, and fly ashes from several sources. The mixtures were proportioned to have similar slump and a constant cementitious content by weight. Concrete containing fly ash can be proportioned having equal strength properties and adequate durability when a suitable ASTM C 618 Class C or F fly ash is used. Test data on over 1,600 laboratory and field specimens tested for freeze-thaw resistance, flexural strength, compressive strength, creep, shrinkage, and abrasion resistance are presented. Fly ash contents ranging from 0 to 35 percent by weight of portland cement were used with both Class C and Class F fly ashes. Guidelines for the selection of materials and their proportions for producing concrete containing fly ash to meet existing highway specifications for concrete are presented.

A-442 Fattuhi, N. I., and Hughes B. P. 1988 (Nov-Dec). "Ordinary Portland Cement Mixes with Selected Admixtures Subjected to Sulfuric Acid Attack," ACI Materials Journal, Vol 85, No. 6, Detroit, MI.

Several 102-mm cubes were cast from cement paste, mortar, and concrete mixes containing ordinary portland cement and suspended in a channel containing either a 1 or 3 percent nominal solution of continuously flowing sulfuric acid. The parameters investigated included cement content, water-cement ratio (W/C), additions of pulverized fuel ash (PFA), polyvinyl alcohol (PVA), a latex (styrene butadiene), and a high-range water-reducing admixture (HRWA). The changes in weight with time for each cube were determined continuously up to a maximum exposure period of 93 days. The results indicated that the rate of deterioration of the cubes increased with an increase in cement content, W/C, or acid concentration. The addition of polyvinyl alcohol appeared to enhance the resistance and integrity of the cubes.

A-443 Tuthill, L. H. 1988 (Dec). "Lasting Concrete in a Sulfate Environment," Concrete International: Design & Construction, Vol 10, No. 12, Detroit, MI.

The problem of how to make a lasting concrete for use in a sulfate environment has been recognized and studied for a long time. The constitution of sulfate-resisting cement has been known for more than one-half of a century. The problem has been recognized and studied even before Miller and Manson started working on it in the twenties. The Metropolitan Water District (MWD) of Southern California identified the low C_3A cement as the most sulfate resisting in its field laboratory in Banning and used it during the thirties in the Colorado River Aqueduct where needed.

A-444 Berke, N. S., Pfeifer, D. W., and Weil, T. G. 1988 (Dec). "Protection Against Chloride-Induced Corrosion," Concrete International: Design & Construction, Vol 10, No. 12, Detroit, MI.

Concrete structures are exposed to many severe environments: chemical acid attack in chemical plants, sewage attack in underground pipes, acid attack in food processing plants, abrasive action at dam spillways, and freeze-thaw deterioration in northern climates. One of the most severe and widespread problems, however, is the internal damage caused by the corrosive action of external chlorides on embedded reinforcing steel and prestressed strands in concrete. These external chlorides are found in deicing salts and saltwater-marine environments.

A-445 Harmathy, T. Z. 1988 (Dec). "How Much Fire Resistance is Really Needed?" Concrete International: Design & Construction, Vol 10, No. 12, Detroit, MI.

This article presents a method for correlating the performance of building elements in real-world fires and test fires using the concept of normalized heat load, whereby the time at which a structure fails in

standard tests can be related to the six input variables that determine the destructive potential of real-world fires. The technique provides information on the fire resistance required for achieving any prescribed level of failure probability.

A-446 Hoff, G. C. 1988. "Resistance of Concrete to Ice Abrasion--A Review," Concrete in Marine Environment--Proceedings of the Second International Conference, St. Andrews, NB, 1988, SP-109, pp 427-456, American Concrete Institute, Detroit, MI.

The mechanism by which ice floes occurring in rivers, lakes, and oceans can damage concrete structures in the water is hypothesized. Various test methods to evaluate the effects of ice abrasion and impact on concrete are reviewed, and selected results using these methods are presented. Several field studies of the effects of ice abrasion on concrete structures are identified.

A-447 Saeki, N., et al. 1988. "Control of Rust Damage of Reinforced Concrete in a Corrosive Environment," Concrete in Marine Environment--Proceedings of the Second International Conference, St. Andrews, NB, 1988, SP-109, pp 163-178, American Concrete Institute, Detroit, MI.

A new index has been suggested for controlling and protecting reinforced concrete from corrosion. This index, defined as the difference in the average strain between concrete and reinforcing bar, is tentatively called the cracking index. On the basis of the exposure tests, relationships between the cracking index and the rust thickness of reinforcing bars in concrete are evaluated under corrosive atmosphere. Cracking index could be used for the assessment of corrosion. The relationship between the critical rust, which is the rust thickness of reinforcing bars at the onset of longitudinal cracking, and cover thickness is obtained by rapid corrosion tests. It is concluded that the allowable stress for reinforcing bars--thus the corrosion--can be controlled by the required amount of concrete cover.

A-448 Uomoto, T., and Misra, S. 1988. "Behavior of Concrete Beams and Columns in Marine Environments When Corrosion of Reinforcing Bars Takes Place," Concrete in Marine Environment--Proceedings of the Second International Conference, St. Andrews, NB, 1988, SP-109, pp 127-146, American Concrete Institute, Detroit, MI.

Many concrete structures, such as railways and highways, are constructed along the coastal lines or over the oceans in Japan. Most of these structures are deteriorated by corrosion of reinforcing bars. To prevent the corrosion in new structures, many methods are tested and several recommendations are already presented. Considering existing structures, the largest problem now is how to decide when to repair the deteriorated structure.

This paper clarifies how the behavior of concrete beams and columns changes as corrosion of reinforcing bars increases and presents an idea as to when to repair the structures in marine environment.

Results from the studies indicate that the deterioration of marine concrete structures caused by corrosion of reinforcing steel bars is not already directly related to strength reduction of reinforcing bars. When corrosion of reinforcing bars takes place, crack formation in concrete could lead to a greater reduction in strength and ductility of the structure than expected. The repair of the structures must be done when cracks are formed along the reinforcing bars.

A-449 Takagishi, Y., Ichikawa, H., Tabuchi, H., and Moriwake, A. 1988. "Experimental Study on Deterioration and Repairing of a Marine Concrete Structure," Concrete in Marine Environment--Proceedings of the Second International Conference, St. Andrews, NB, 1988, SP-109, pp 253-276, American Concrete Institute, Detroit, MI.

Load-carrying capacity and fatigue strength before and after repairing were investigated for a coastal structure in Tokyo Bay, which was subjected to serious damage by chloride for 15 years. Static and cyclic load tests together with investigation on effectiveness of repair were carried out on specimens taken from the site. It was found that the bearing and yielding capacities of deteriorated slab are 90 and 80 percent, respectively, of those of sound structure. These losses were mainly caused by 10 percent loss of reinforcement corrosion. The specimens repaired by material with high tensile strength suggested brittle failure in static load tests. It was also found that fatigue failure of deteriorated reinforcements was accelerated by pitting corrosion.

A-450 Holm, T. A., Bremner, T. W., and Vaysburd, A. 1988. "Carbonation of Marine Structural Lightweight Concretes," Concrete in Marine Environment--Proceedings of the Second International Conference, St. Andrews, NB, 1988, SP-109, pp 667-676, American Concrete Institute, Detroit, MI.

Concrete ships and bridges incorporating structural lightweight concrete were examined for durability with particular attention given to depth of carbonation. The profile of the carbonation front was determined for these mature structures in or over seawater, and the carbonation front approached that of the steel reinforcing even after several decades of exposure. Factors affecting the rate of carbonation are discussed and recommendations are given to limit the extent of carbonation.

A-451 Takewaka, K., and Mastumoto, S. 1988. "Quality and Cover Thickness of Concrete Based on the Estimation of Chloride Penetration in Marine Environments," Concrete in Marine Environment--Proceedings of the Second International Conference, St. Andrews, NB, 1988, SP-109, pp 381-400, American Concrete Institute, Detroit, MI.

For selecting concrete cover for reinforcement in marine structures, consideration of the corrosion protection of steel bars is indispensable. Therefore, requirements for quality and thickness of concrete cover must be established so the concrete cover prevents chlorides,

oxygen, water, etc., from reaching reinforcement through the life of the structure.

To ensure good performance of concrete cover, the chloride penetration process should be understood. A dualistic diffusion equation was adopted to explain this. In solving equations, the following were clarified through referral to data of experiments: (1) the relationship between the quality of concrete and chloride diffusion coefficients; (2) the effect of the chemical or physical adsorption of chloride in concrete on the diffusion process; and (3) boundary condition to concrete surface for chloride concentration in various marine environments. On the basis of these studies, a close agreement between observed and calculated values was obtained.

Through the calculations of chloride penetration, the rational design for quality and thickness of concrete in various marine environments has been suggested.

A-452 Nishibayashi, S., et al. 1988. "Effect of Admixtures on the Durability of Concrete in An Undersea Environment," Concrete in Marine Environment--Proceedings of the Second International Conference, St. Andrews, NB, 1988, SP-109, pp 481-494, American Concrete Institute, Detroit, MI.

The effect of chemical and mineral admixtures on the durability of concrete in an undersea environment has been studied. Addition of slag, slag-like materials, and water-reducing agents improves the durability of concrete. However, alkali-silica aggregate reaction aggravated by the marine environment and the corrosion of reinforcing steel bars are enhanced. By the addition of rust inhibitors, these effects can be controlled.

A-453 Ozaki, S., and Sugata, N. 1988. "Sixty-Year Old Concrete in A Marine Environment," Concrete in Marine Environment--Proceedings of the Second International Conference, St. Andrews, NB, 1988, SP-109, pp 587-598, American Concrete Institute, Detroit, MI.

The deterioration of concrete structures due to age, particularly in marine environments, has recently become a subject of great concern. In this study, the properties of 60-year-old concrete in a marine environment were examined. Taking the opportunity of the demolition of the northern breakwater of a port in Japan, samples from the reinforce concrete caissons, from the upper concrete, and from the foot protection blocks. Tests for concrete strength, porosity, salt content, carbonation, and the corrosion status of the reinforcing bars were performed.

The concrete seemed to have retained its strength even after 60 years of exposure to seawater environment. The pore sizes were generally smaller than those of ordinary concrete while the total porosity was the same. The salt content was high at approximately 0.3 to

0.6 percent near the surface of concrete. It reduced, however, to a constant value of about 0.1 percent at a depth of approximately 8 cm.

As a result of the study, the concrete which was made from blast furnace slag and volcanic ash and appeared to contain sea sand had scarcely deteriorated at all even though it had been exposed to seawater environment for 60 years.

A-454 Mehta, P. K. 1988. "Durability of Concrete Exposed to Marine Environment--A Fresh Look," Concrete in Marine Environment--Proceedings of the Second International Conference, St. Andrews, NB, 1988, SP-109, pp 1-30, American Concrete Institute, Detroit, MI.

From recently reported case histories of concrete deterioration in seawater, the author has taken a fresh look at the conclusion presented on this subject at the last CANMET/ACI Conference on the Performance of Concrete in Marine Environment. It is confirmed again that between seawater and the constituents of hydrated cement paste, harmful chemical reactions such as carbonation, sulfate attack, and magnesium ion attack can be limited to the surface when well known measures to assure low permeability of concrete have been put into practice.

From the standpoint of permeability of concrete, the topics discussed in detail include selection of materials and mixture specifications, concreting practice, and control of in-service cracking due to thermal gradients, frost attack, improper loading conditions, fatigue, and corrosion of the embedded steel in concrete. The ACI and FIP Recommended Practice for offshore concrete structures and recent field experience from the North Sea are compared to highlight the issues that are relevant to longtime durability of concrete. Since high-strength concretes (50 to 70 MPa) containing water-reducing and mineral admixtures are relatively impermeable, it is the opinion of the author that they offer an excellent solution to the problem of durability of concrete in seawater environment.

A-455 Hobbs, D. W. 1988. Alkali-Silica Reaction in Concrete, Thomas Telford Ltd., London, England.

Selected papers deal with alkali-silica reaction and its effects on concrete; structural effects and diagnosis of the reaction as the cause of observed deterioration; the effectiveness of cement replacement materials in reducing the risk of cracking due to the reaction; testing aggregates and cement-aggregate combinations for their reactivity; and procedures that have been and are being adopted in the US, West Germany, Japan, and the UK to minimize the risk of cracking due to the reaction in new construction.

A-456 Kaetzel, L. J., and Clifton, J. R. 1988. "Maintenance and Implementation of An Expert System for Durable Concrete," Computer Applications in Concrete Technology-San Antonio, 1987, SP-106, pp 75-86, American Concrete Institute, Detroit, MI.

This paper describes an expert system with a knowledge base consisting of freeze-thaw, sulfate, alkali-aggregate, and corrosion aspects of concrete durability. The system was developed on a microcomputer using an expert-system shell facility. This paper discusses knowledge acquisition, knowledge representation, issues relating to the maintenance of expert systems, and recommendations for field implementations.

A-457 (Deleted)

A-458 Swamy, R. N, Koyama, S., Arai, T., and Mikami, N. 1988. "Durability of Steel Reinforcement in Marine Environment," Canmet/ACI International Conference, SP-109, American Concrete Institute, Detroit, MI.

This paper presents comprehensive test data on the corrosion resistance of plain, galvanized, and epoxy coated reinforcing bars exposed to marine environment. The bars were embedded in concrete prisms, precracked to a steel stress of 200 MPa and then subjected to two exposure regimes in a loaded condition. A natural exposure in a corrosive tidal zone and an accelerated wetting and drying cyclic regime in seawater were chosen for the corrosion tests. In addition, tests were also conducted with bars provided with artificially damaged coatings; further marine exposure tests were also carried out on cracked prisms and damaged coatings in the cracked regions, and made with concrete containing chloride contaminated aggregates. The test results show that even a 70 mm cover is inadequate to protect uncoated bars from corrosion in marine environment. Galvanized bars exhibited improved performance but did not provide complete protection. Epoxy coated bars can afford long-term protection against corrosion even under severe exposure conditions and with damaged coatings.

A-459 Espelid, B., and Nilsen, N. 1988. "A Field Study of the Corrosion Behavior on Dynamically Loaded Marine Concrete Structures," Canmet/ACI International Conference, SP-109, American Concrete Institute, Detroit, MI.

Experience and research have shown that reinforcement in submerged concrete appears to be well protected against corrosion. Even steel exposed in statically loaded submerged cracks is not susceptible to localized corrosion attack. Questions have been raised as to whether this durability will be present in structures subject to dynamic loads and in structures spanning through several environment zones.

To clarify the effect of loading, eight concrete beams were exposed dynamically loaded at VERITEC's Seawater Laboratory. Four of the specimens were allowed to corrode freely, while the rest were cathodically protected. For reference, 16 reinforced concrete beams were exposed fully submerged in the sea, and of these, 8 were statically loaded

while the rest were unloaded. One-half of the specimens in the sea were also cathodically protected.

To study the corrosion behavior of multizone exposed concrete structures, eight concrete columns with a diameter of 0.6 m and a height of 5 m were installed in the sea. One of the main objectives with this installation was to study the cathodic current density demands of embedded steel exposed to different environmental zones and of multizone exposed embedded steel.

This paper presents the results from the laboratory and the field tests, and the main conclusion is that the corrosion conditions found on a multizone exposed concrete structure differs from those found on a completely submerged structure.

A-460 Al-Tayib, A. J., and Khan, M. S. 1988. "Evaluation of Corrosion Resistance of Reinforcing Steel in Sulfur Concrete," International Journal for Housing Science and Its Applications, Vol 12, No. 4, pp 297-307, International Association for Housing Science, Coral Gables, FL.

Reinforcement corrosion was studied in 12 sulfur concrete and 3 portland-cement concrete mixtures. The reinforced specimens were partially immersed in 5-percent sodium chloride solution for 2 years. Test results indicate that reinforcing steel in sulfur concrete takes longer to corrode as compared to portland-cement concrete. However, once the corrosion of the reinforcing steel initiates in sulfur concrete, the corrosion rate is higher than that of the steel in a good portland-cement concrete.

A-461 Ouyang, C. 1988. "Sulfate Attack of Portland Cement-Based Mixtures Containing Phosphogypsum," Ph.D. Dissertation, University of Miami, FL.

Sulfate attack of portland-cement-based mixtures containing phosphogypsum was investigated in this dissertation. Factors affecting sulfate attack, such as phosphogypsum content, cement content and type, curing condition, method of specimen fabrication, specimen size and shape, coarse aggregate and origin of phosphogypsum, were studied with respect to expansion and strength. Two types of sulfate attack, caused by sulfate rich environments and by the presence of gypsum in cement-based mixtures, were compared. A theoretical model for predicting compressive properties of cement-based mixtures containing phosphogypsum was proposed based on continuous damage theory. The permissible phosphogypsum contents without causing strength loss were derived according to experimental results. Two field tests were conducted for evaluating sulfate attack under weather conditions. The seawater resistance of mixtures was also studied. It was proven that the expansion characteristics of such mixtures can be used to produce a shrinkage compensating mortar. Portland-cement-based mixtures containing phosphogypsum can be used as construction materials without durability problems, provided that a proper amount of phosphogypsum is used in mixtures.

A-462 Kosa, K. 1988. "Corrosion of Fiber Reinforced Concrete," Ph.D. Dissertation, University of Michigan, Ann Arbor, MI.

The following two types of tests were conducted to investigate the deterioration mechanisms of conventional fiber reinforced concrete and SIFCON (slurry infiltrated fiber concrete) due to corrosion:
(1) accelerated corrosion tests of fiber reinforced mortar specimens,
(2) accelerated exposure tests of fibers.

About 2,000 specimens were tested. The results of accelerated corrosion tests of fiber reinforced mortar specimens indicated that severe corrosion would result in a significant reduction in minimum fiber diameter, leading to a noticeable reduction in peak stress and a dramatic reduction in toughness whether the specimens were tested in tension or bending. However, no cracks were detected on the specimen's surface and the corroded fibers failed primarily in tension.

Results from the accelerated exposure tests of fibers showed a behavior similar to the accelerated corrosion tests of fiber reinforced mortar specimens. All experimental results indicated that the reduction of strength and toughness is controlled by the reduction of fiber diameter.

To assess the results obtained from the experimental program, two analytical evaluations were conducted. The first method of evaluation was based on an approximation that takes into account the reduction in fiber diameter due to corrosion. The second method of evaluation was based on a nonlinear numerical analysis technique. Both methods supported the experimental observations that deterioration of stress-strain response in the tension zone of flexural specimens leads to a moderate reduction in peak-load and a dramatic reduction in toughness.

Two nondestructive tests were also used to detect steel fiber corrosion. The half-cell potentials method was found capable of detecting different corrosive atmospheres including concretes of different compositions. The electrical resistance method was found to reliably detect the reduction of fiber area due to corrosion.

A-463 ACI Committee 201. 1988. "Guide to Durable Concrete," ACI 201.2R-77 (Reapproved 1982), ACI Manual of Concrete Practice, Part 1, Detroit, MI.

This guide is essentially an update of the committee report "Durability of Concrete in Service" which appeared in the December 1962 ACI Journal. There are a number of major revisions reflecting increased knowledge of the subject.

A separate chapter is devoted to each of the main types of concrete deterioration. Their mechanism is described and the requirements for materials, design, and construction procedures necessary to prevent damage to the concrete are given. A selected bibliography is included with each chapter.

A-464 ACI Committee 222. 1988. "Corrosion of Metals in Concrete," ACI 222R-85, ACI Manual of Concrete Practice, Part 1, Detroit, MI.

This committee has been prepared to reflect the state of the art of the corrosion of metals, and especially steel, in concrete. Separate chapters are devoted to the mechanisms of the corrosion of metals in concrete, protective measures for new concrete construction, procedures for identifying corrosive environments and active corrosion in concrete, and remedial measures. A selected list of references is included with each chapter.

A-465 ACI Committee 309. 1988. "Identification and Control of Consolidation-Related Surface Defects in Formed Concrete," ACI 309.2R-82, ACI Manual of Concrete Practice, Part 2, Detroit, MI.

This report provides guidelines for identifying and controlling consolidation-related surface defects in precast or cast-in-place formed concrete. It includes a summary of direct and indirect causes of such defects, some of which are frequently attributed to inadequate consolidation practices. An outline to assist in the reporting on surface conditions and photographs to illustrate typical concrete surface defects are also included.

Surface defects may be minimized by proper planning during the design and specification stages. Of equal importance is the employment of properly trained and motivated supervisory and construction personnel to achieve the intended concrete finishes and surface textures.

The report emphasizes significant consolidation factors that prevent surface defects. The reader is cautioned that concrete is a hand crafted product; therefore, other potential causes may exist beyond those listed in this report.

SECTION B

EVALUATING THE CONDITION OF EXISTING STRUCTURES

1978

B-1 Chung, H. W. 1978 (Mar). "Effects of Embedded Steel Bars Upon Ultrasonic Testing of Concrete," Magazine of Concrete Research, Vol 30, No. 102, pp 19-25, London, England.

Ultrasonic testing of a reinforced concrete member by means of a portable apparatus is affected by the steel bars embedded in the concrete. An investigation of the effects of the reinforcement has been made using the bar diameter and the concrete strength as the variables. The steel bar appears to act compositely with the surrounding concrete in transmitting ultrasonic pulses. The effective pulse velocity is somewhat between the pulse velocities in the two separate media and varies with the diameter of the bar and the pulse velocity in the concrete. An empirical formula for the effective pulse velocity is proposed. On the basis of this formula and further theoretical consideration, the zone of steel influence is defined. A correction factor is derived whereby the measured pulse velocity in a concrete-steel medium is adjusted to give the pulse velocity in the plain concrete.

B-2 Grattan-Bellew, P. E., Quinn, E. G., and Sereda, P. J. 1978 (May). "Reliability of Scanning Electron Microscopy Information," Cement and Concrete Research, Vol 8, No. 3, pp 333-342, Elmsford, NY.

The reliability of information obtained with the scanning electron microscope is influenced by human and instrumental factors. The human factors enter, for example, when a microstructure is described as being typical of the material when, in fact, it is only a minor component. Some instrumental factors include charging of the specimen, problems differentiating between positive and negative relief, and distortion of the shape of the sample in micrographs. The determination of the amount of a phase present in a composite is a complex problem involving both preparation of representative surfaces and appropriate methods of evaluation. A number of experimental results are provided. Where smearing of surfaces is not a problem, point counting evaluation on sawn surfaces provides reliable results.

B-3 Pace, C. E. 1978 (May). "Engineering Condition Survey and Evaluation of Troy Lock and Dam, Hudson River, New York; Report 1, Engineering Condition Survey," Miscellaneous Paper C-78-6, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

A condition survey was made of Troy Lock and Dam (Phase I of the study). An analysis of the condition survey gives adequate information for sound engineering decisions needed for developing a proposal for the total evaluation of the lock and dam (Phase II of the study).

Initial observations of Troy Lock and Dam gave misleading impressions of structural deficiencies. The Phase I study revealed that the interior concrete of the lock is sound and of sufficient strength. The cracking of the concrete in the lock is sound and of sufficient strength. The cracking of the concrete in the lock is negligible and is insignificant

in the dam and gated spillway except for (a) the pier where the access to the dam tunnel on the powerhouse side of the river is located and (b) the piers of the gated section.

It is recommended that concrete cores be obtained to determine the depth of deterioration of the surface concrete and typical cores be used for petrographic analysis, examination for deteriorating agents, material property determination, and evaluating dam monolith contact with the foundation.

Stability analyses should be performed on selected monoliths of the lock and dam. Stress analyses should be performed on the badly cracked monolith of the dam that contains the shaft which allows access to the dam tunnel from the powerhouse side of the river, and stress analyses should be performed on one monolith of the dam to determine the effects of water-produced vibrations. Specific methods of repair should be recommended. A feasibility study should then be made and the repair or replacement of Troy Lock and Dam should be suggested.

If it is assumed that the structural evaluations in the Phase II study reveal no serious deficiencies and that the concrete cracking in the dam and gated spillway can be effectively repaired and preventative measures implemented, the lock, dam, and gated spillway are structurally adequate and can be repaired. At this stage of the study, all conditions have not been evaluated so that the feasibility of repair is certain, but the Phase I study indicates that repair is highly feasible if the deficiencies listed herein can be economically corrected.

B-4 Stowe, R. L. 1978 (May). "Concrete and Rock Tests, Rehabilitation Work, Brandon Road Dam, Illinois Waterways, Chicago District," Miscellaneous Paper C-78-4, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

Drilling for field testing and laboratory testing was carried out for the US Army Engineer District, Chicago, as part of a stabilization program at the Brandon Road Dam on the Illinois Waterway. A previous stability investigation concluded that all sections of the dam failed to meet current overturning criteria. It was recommended that the dam be stabilized by installation of grouted, prestressed tendons. This report presents physical property data of concrete and foundation rock for use in a stability analysis and the design of an anchorage system involving grouted steel tendons. A down hole teleview was used to obtain orientation of natural discontinuities in the foundation rock. Pressure transducer measurements were taken in the field to monitor uplift pressures at the base of the dam. Laboratory testing included the determination of characterization properties (compressive strength, unit weight, tensile strength, compressional wave velocities) and engineering design properties (elastic moduli, triaxial strength including multistage loading, direct shear of intact and discontinuous rock samples, and consolidated-undrained (R) and drained (S) triaxial strength of overburden samples).

B-5 Buck, A. D., and Mather, K. 1978 (May). "Alkali-Silica Reaction Products from Several Concretes: Optical, Chemical, and X-Ray Diffraction Data," Miscellaneous Paper C-78-7, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

Alkali-silica reaction products from six different concretes were examined by X-ray diffraction and light microscope, and four of the gels were chemically analyzed. Most of the reaction products were crystalline in considerable part and were composed of one or more of four phases. Two of the phases were tentatively identified as variants on CSH(I) and CSH(II).

B-6 Schulze, W., and Munse, M. 1978 (May-Jun). "Characteristics of Concrete Surface with Regard to Concrete Synthetic Resin Bond" (in French), Materials and Structures, Research and Testing, Vol 11, No. 63, pp 185-190, Paris, France.

When plastic coatings are used, stresses occur on the interface between the plastic coating and concrete due to the different properties of these materials. The durability of a coating depends largely on the surface strength of the concrete.

For determining the surface strength of concrete various testing methods were evaluated. A testing apparatus was developed by which both the surface strength and the bond may be investigated. Under laboratory conditions, the apparatus delivers reproducible results and in practice it was used for the investigation into cases of damage.

B-7 Shah, G. N. 1978 (Jun). "Performance Study of Continuously Reinforced Concrete Pavement on I-95," Report FHWA-MD-R-78-11, Maryland State Highway Administration Bureau of Research.

The purpose of the study was to evaluate the performance of the continuously reinforced concrete pavement on I-95. Pavement observations and measurements were made on all construction contracts and included intensive crack surveys, measurements of the widths of selected cracks, measurements of changes of width of terminal joints and expansion joints, road roughness, Present Serviceability Index determinations, and skid resistance. This final report presents the results and observations and measurements made during the entire study. The evaluation of observations and test results has indicated that in general the I-95 pavement structure is sound and it has exhibited satisfactory performance. Also, it has been observed that the width of a crack is greatest and most noticeable at the surface.

B-8 Raina, S. J., Vishwanathan, V. N., and Ghosh, S. N. 1978 (May-Jun). "Instrumental Techniques for Investigation of Damaged Concrete," Indian Concrete Journal, Vol 52, No. 5-6, pp 147-149, Bombay, India.

Identifying agents which attack cement mortar or concrete exposed to an aggressive environment is essential. Since the products of decomposition can be analyzed by x-ray diffraction, differential thermal

analysis, or infrared spectroscopy methods, the agencies responsible for the decomposition can also be identified. The paper discusses such an investigation carried out on two affected samples and gives details of the readings obtained. In one case, the major decomposition product of C-S-H gel was gypsum, and in the other case, the thermal damage to C-S-H gel destroyed the bond between the cementitious material and aggregates.

B-9 Buck, A. D., and Burkes, J. P. 1978 (Aug). "Alkali-Silica Reaction in Concrete from Hiwassee Dam, North Carolina, Tennessee Valley Authority," Miscellaneous Paper C-78-10, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

The TVA requested a petrographic examination of concrete cores from Hiwassee Dam to determine whether an alkali-silica reaction had occurred. There is substantial cracking of the concrete in the dam and such a reaction could be responsible for the cracking. Construction of Hiwassee Dam was completed in 1940, so the concrete is over 38 years old. Signs of alkali-silica reaction were found in the top and bottom portions of two 6-in.-diam cores taken from the dam. The main signs of the reaction were white alkali-silica gel in some voids, on old broken surfaces or at aggregate-paste contacts, and the presence of reaction rims on many particles of the brown quartzite. Some cracking of aggregate and paste was also detected.

The presence of this reaction does not automatically prove it was the cause of the cracking in the concrete, but it would seem to be a reasonable assumption that it was one cause of the cracking since no other evidence of potentially deleterious chemical or physical damage was found. This conclusion is based on laboratory observation only.

B-10 Stowe, R. L., Pavlov, B. A., and Wong, G. S. 1978 (Sep). "Concrete and Rock Core Tests, Major Rehabilitation of Starved Rock Lock and Dam, Illinois Waterways, Chicago District, Phase I, Rehabilitation," Miscellaneous Paper C-78-12, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

Drilling for laboratory testing of concrete and foundation rock was carried out for the US Army Engineer District, Chicago, as part of a major rehabilitation program at the Starved Rock Lock and Dam. The structures are on the Illinois Waterway. Laboratory testing of the concrete core was done to ascertain the extent of concrete deterioration and to determine selected physical obtaining characterization properties and engineering design parameters. The rock test results, if found to be significantly lower than previously reported, are to be used for checking a structural stability analysis. Laboratory testing included the determination of compressive strength, unit weight, compressional wave velocity, elastic modulus, triaxial strength, and direct shear strength. Direct shear tests were conducted on intact and discontinuous rock specimens. The concrete core indicates moderate to severe deterioration on most all exposed concrete surfaces. The predominant cause of the deterioration has been cycles of freezing and thawing. The average depth of frost-damaged concrete in the lock chamber walls is 0.20 ft; in

tunnel shape, as well as actual stresses in the rocky mass, were taken. Measurements included peripheral pressures, convergences, and strains in the direction of the axis of the steel anchors in phase. The walls of the partially excavated tunnel profile were covered with pumped concrete, lagged with steel mesh, supported by steel ribs, and anchored when the concrete lining was finished. In the final phase the tangent stresses in the concrete linings were also measured. The rock in the profile investigated was of gray sandy marl, rather shaly, and pitted with numerous sliding planes.

B-15 Clemena, G. G., and McKeel, W. T., Jr. 1978. "Detection of Delamination in Bridge Decks with Infrared Thermography," Transportation Research Record 664, pp 180-182, Transportation Research Board, Washington, DC.

The use of infrared thermography to accurately define variations in surface temperatures was evaluated as a means of defining delaminated areas caused by corrosion of reinforcing steel in concrete bridge decks. Differences in the temperatures of the deck surface, shown in various shades or colors on a cathode-ray tube, were photographed to provide a permanent graphic record of the location of the warmer, distressed areas. In a comparative study of infrared thermography and conventional deck evaluation techniques, including the sounding of the surface with a hammer and chain drag and the use of rolling delamination detector, all were generally satisfactory in locating severe to medium delaminations. However, the infrared thermography procedure had important advantages in disclosing incipient delaminations, those in which the cracking is confined to close vicinity of the reinforcing steel, and in providing detailed records of the separated areas.

B-16 Vassie, P. R. W. 1978. "Evaluation of Techniques for Investigating the Corrosion of Steel in Concrete," TRRL Supplementary Report 397, Transportation and Road Research Laboratory, Crowthorne, Berkshire, England.

Electrode potential, constant anodic current polarization, and electrical resistance probe measurements have been employed to investigate the corrosion of mild steel in concrete and cement-water grouts. The usefulness of data obtained is discussed and corrosion threshold sodium chloride concentrations reported. The influence of moisture content on the electrode potential measurements is examined and shown to be of critical significance. It is indicated that corrosion threshold data are dependent on exposure conditions and surface state of the steel. The difficulty in relating results in calcium hydroxide solutions and concrete is described.

B-17 Chamberlin, W. P., and Amsler, D. E. 1978. "Measuring Surface Texture of Concrete Pavements by the Sand-Patch Method," Report FHWA-NY-78-RR 62, Engineering Research and Development Bureau, New York State Department of Transportation, Albany, NY.

The components of variance were analyzed for 720 measures of concrete pavement texture depth obtained by the sand-patch method. The

measurements were made in connection with a complete factorial field experiment involving four texturing methods on two sections each of five different paving jobs. Each pavement section was tested at three different sites by three different operators performing two tests each. The analysis permitted estimates of the repeatability and reproducibility of the sand-patch test, as well as errors than can be expected in measuring the mean texture depths of a section of textured pavement.

B-18 Holzenbein, H. 1978. "Breaking Load Test On A Reinforced Concrete Factory Beam Damaged By Fire," Betonstahl in Entwicklung, Vol 66, Tor-Isteg Steel Corp, Vienna, Austria.

Due to a fire in a factory, the reinforced concrete structure showed damage that required a demounting of the beams. The beam with the greatest damage was subjected to a large-scale load test until failure occurred. The beam was 18 m long and had a cross section of 0.3 m by 1.3 m. Tensile reinforcement consisted of eight ⌀ 26-mm bars. The test showed that the fire damage had not yet caused a decrease of the bearing capacity or a change in the behavior of the beam. The test results correspond well with the calculated values.

B-19 O'Rourke, P. W., and Ritchie, J. M. 1978. "Bridge-Deck Concrete-Cover Investigation in Michigan," TRR 676, Testing and Research Division, Bridge Design, Evaluation, and Repair, Michigan Department of State Highways and Transportation, Transportation Research Board, National Academy of Sciences, Washington, DC.

Ninety-seven concrete deck structures (two hundred eighty-two spans) in Michigan were surveyed by using a pachometer to determine the average depth and variation of the concrete cover. Fifteen structures (thirty-six spans) were surveyed by using the wet-depth method. It is believed that, if the clear-cover target value is increased to 7.62 cm (3.0 in.) (and no attempt is made to control process variation), fewer than 3 percent of the structures will have less than 5.08 cm (2.0 in.) of clear cover over more than 10 percent of their surface area. Increases in the cover specification have had no measurable effect on the mean span variation. For most structures, the distribution of measurements for individual spans is consistent with approximately 95 percent of the measurements within 1.9 cm (0.75 in.) of the average value. Wet-depth measurements do not compare favorably with pachometer measurements and, in more than 50 percent of the spans, the mean difference between the two methods was greater than 0.64 cm (0.25 in.). To adequately determine the depth of concrete cover, a span of 100 measurements or one measurement for each 2.32 m^2 (25 ft^2), whichever is less, should be taken.

B-20 Cantor, T., and Kneeter, C. 1978. "Radar and Acoustic Emission Applied to Study of Bridge Decks, Suspension Cables, and Masonry Tunnel," TRR 676, Bridge Design, Evaluation, and Repair, Transportation Research Board, National Academy of Sciences, Washington, DC.

Studies have been conducted suggesting that it is feasible to use

B-28 Lenzner, D., and Ludwig, U. 1979 (Aug). "Detection of Alkali-Silica Reactions in Concrete Structures" (in German), Zement-Kalk-Gips, Vol 32, No. 8, pp 401-410, Wiesbaden, Germany.

The article describes physical-chemical and mineralogical investigations on drilled core samples from concrete structures damages by alkali-aggregate reaction and reports the results obtained. The expansion of the samples directly after their removal from the structure is a measure of the actual damage. The residual hazard can be determined only from storage tests. It is further shown that the reactive aggregate particles can be made easily visible and can be counted to provide an assessment of the hazard. With the aid of the measures described, the residual hazard to the structure can be estimated. The investigations confirm that concretes of higher quality class are more severely damaged.

B-29 Ainsworth, D. L., Buck, A. D., Ragan, S. A., and Mather, K. 1979 (Aug). "Testing of 6-in.-Diameter Concrete Cores from Martin Dam, Alabama Power Company," Miscellaneous Paper SL-79-17, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

Thirty-three lengths of 6-in.-diam concrete core from three drill holes in Martin Dam were examined. All three drill holes ran from the crest of the dam to the foundation. Part of the core from each hole was retained by the Alabama Power Co. The lengths received at the US Army Engineer Waterways Experiment Station, Structures Laboratory, were examined petrographically. Twenty were tested ultrasonically to measure compressional and shear wave velocities. Of these 20 lengths, 6 were tested in unconfined compression; 9 were tested in triaxial loading in three groups of three cores each at three confining pressures; and 5 were tested for strength in direct tension. The petrographic report presents evidence of the occurrence of alkali-silica reaction in concrete from all three drill holes; however, alkali-silica reaction gel was not in the lower part of hole S-7. The core from the lower part of the hole S-7 contained large flakes of tetracalcium aluminate monosulfate-23-hydrate ($C_4AS\ H_{12}$). This is the first instance, to our knowledge, of the presence of this compound in concrete in crystals large enough to be visible to the naked eye. Although the evidence of alkali-silica reaction is clear, it did not extend to cracks in the mortar except to a minor extent.

The compressional wave velocities ranged from 13,400 to 14,920 fps; shear wave velocities ranged from 7,870 to 9,290 fps. Calculated dynamic moduli of elasticity ranged from 4.9 to 6.3 by 10^6 psi. Compressive strengths ranged from 3,040 to 8,450 psi; static moduli of elasticity ranged from 2.17 to 4.18 by 10^6 psi, and Poisson's ratios from 0.08 to 0.17. Triaxial compression tests at minimum principal stresses of 2,500, 5,000, and 9,000 psi yielded cohesion values from 500 to 800 psi and angles of internal friction from 41° 00′ to 38° 45′.

assessment of the foundation conditions was made and guidance is presented as to proper choice of design values for the foundation rock.

B-32 Phillеo, R. E. 1979 (Sep). "Need for In Situ Testing of Concrete," Concrete International: Design & Construction, Vol 1, No. 9, pp 43-44, Detroit, MI.

There is a definite need for in situ testing to determine the compliance of structures with designs based on the ACI Building Code and to sort out responsibilities for various aspects of concrete handling during construction. This article covers the importance of concrete strength testing to ensure construction safety, provide quality concrete, and provide documentation of properly placed concrete.

B-33 Malhotra, V. M. 1979 (Sep). "In Situ Strength Evaluation of Concrete," Concrete International: Design & Construction, Vol 1, No. 9, pp 40-42, Detroit, MI.

This article reports on a symposium on in-situ strength evaluation of concrete, sponsored by ACI and held in November 1978 at Houston, TX. A total of 14 papers were presented. They dealt with penetration resistance, pullout, break off, pulse velocity, maturity concept, and combined methods. The presentations and the discussions that followed revealed that, apart from the pulse velocity techniques, the other methods were relatively new but were slowly finding acceptance in the concrete and construction industries. Of all the methods discussed at the symposium, the pullout techniques appear to be the most promising for determining the in situ strength of concrete.

B-34 Johansen, R. 1979 (Sep). "In Situ Strength Evaluation of Concrete--The "Break-Off" Method," Concrete International: Design & Construction, Vol 1, No. 9, pp 45-51, Detroit, MI.

The paper reviews results and experiences derived from the use of a new in-place testing method, with special reference to its application to an airfield pavement made of vacuum concrete.

The testing method directly determines the flexural strength of the concrete in an annular cross section parallel to the concrete surface and at a definite distance from the surface. The sections to be tested are established by the aid of tubular inserts in fresh concrete or by drilling in hardened concrete.

The results and experiences from practical application show that the method is fast and uncomplicated and very sensitive to curing conditions.

The paper also deals with the deficiencies of the prevailing control system and with the technical and economical advantages achieved by putting more emphasis on the performance aspect.

B-35 Bartos, M. J. 1979 (Oct). "Testing Concrete in Place," Civil Engineering, Vol 49, No. 10, pp 66-69, American Society of Civil Engineers, New York, NY.

The use of molded cylinders tested in compression to estimate the strength of concrete in a structure is one aspect of modern construction that has remained essentially unchanged during the past 60 years. Recently, however, the testing of concrete in situ has become more widespread. Methods are of five types: rebound, maturity, pulse velocity, penetration, and resistance to pullout. Test methods and jobs on which they have been used are described.

B-36 Buck, A. D., and Liu, T. C. 1979 (Nov). "Investigation of Lightweight Concrete and Materials East Los Angeles Comprehensive Health Center Building," Miscellaneous Paper SL-79-25, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

The objective of this investigation was to determine the causes of the undulation problem (waffle pattern) that developed in the lightweight concrete floor slabs at the East Los Angeles Comprehensive Health Center and to determine the effect, if any, on the serviceability and the safety of the structure.

Samples of portland cement and lightweight aggregate were examined using petrographic methods. Concrete cores obtained from the structure were tested for air content and unit weight. Simplified model tests and study of early concrete volume changes were carried out in the laboratory to simulate the construction conditions. In addition, two-dimensional thermal calculation for predicting concrete temperatures during construction was performed.

Based on the results of these laboratory examinations and inspection of the construction photographs, it can be concluded that the undulations were not caused by a materials problem and should not have structural implications. It is believed that the waffle pattern was developed due to the movement of the upper reinforcing steel bars while the concrete was still unhardened. The waffle effect seen on the hardened lightweight concrete floor surfaces was largely residual due to incomplete removal during finishing operations. If indeed there was any movement after finishing of these surfaces, it was probably due to a combination of factors such as expansion due to aluminum contamination of aggregates, form settlement, and perhaps, other factors that could not be positively identified.

B-37 Soles, J. A. 1979 (Dec). "Petrography in the Evaluation of Aggregates and Concrete," No. 80-3E, Department of Energy, Mines & Resources, Ottawa, Ontario, Canada.

This paper briefly reviews petrographic and related test procedures used in the study of aggregates and concrete, summarizes conditions and reaction processes which may cause their deterioration, describes characteristic features of known reactions, and discusses the problems faced

and techniques employed to inhibit deterioration of concrete structures in various environments.

B-38 Amon, J. A., and Snell, L. M. 1979 (Dec). "Use of Pulse Velocity Techniques to Monitor and Evaluate Epoxy Grout Repair to Concrete," Concrete International: Design & Construction, Vol 1, No. 12, pp 41-44, Detroit, MI.

Four case histories are presented that show how pulse velocity techniques can be used to monitor and evaluate epoxy grout repairs. The methodology of the evaluations and the limitations of these procedures are discussed.

B-39 Chabowski, A. J., and Bryden-Smith, D. W. 1979 (Dec). "Simple Pull-Out Test to Assess the In Situ Strength of Concrete," Concrete International: Design & Construction, Vol 1, No. 12, pp 35-40, Detroit, MI.

The objective of the research described in this article was to produce a simple test causing little disruption to provide direct information on the strength of high alumina cement concrete in prestressed concrete X-shaped beams produced under factory controlled conditions. A pullout test which is based on the correlation between compressive strength of concrete and the forces in a wedge anchor needed to produce internal cracking in concrete was developed. The test method and research leading to its application are described.

B-40 Mailhot, G., Bisaillon, A., Carette, G. G., and Malhotra, V. M. 1979 (Dec). "In-Place Concrete Strength: New Pullout Methods," ACI Journal, Proceedings, Vol 76, No. 12, pp 1267-1282, Detroit, MI.

The major drawback of existing pullout tests is that they have to be preplanned during the design and erection of formwork. To overcome these problems, investigations were undertaken to develop pullout tests that could be carried out on finished structures. Three possible approaches considered were: (A) pulling out of tapered anchors placed in drilled holes; (B) pulling out of bolts set in hardened concrete using epoxy; and (C) measuring the force required to cause shear failure of concrete using a split-sleeve assembly.

The techniques were tried on 25 concrete slabs. The concrete covered a strength range from 17 to 42 MPa. More than 1,000 pullout tests using the three techniques were performed.

Technique A gave relatively poor results in terms of reproducibility. It also had some inherent difficulties and was discontinued.

Technique B appears promising. It is believed that this approach is viable but further research is needed.

Technique C offers good possibilities and the simplicity of the test makes the method more attractive. However, within-test variations were

higher than those obtained with Technique B. Modification of procedures may reduce the variations.

B-41 Gjorv, O. E., and Veenesland, O. 1979 (Dec). "Evaluation and Control of Steel Corrosion in Offshore Concrete Structures," Corp. Report STF-65A79069, Norges Tekniske Hoegskole, Trondheim, Norway.

To provide a better basis for evaluation and control of steel corrosion in offshore concrete structures, a comprehensive 4-year research program was started at the Cement and Concrete Research Institute, University of Trondheim, Norway, in 1975. The project was terminated in 1978 and in the final report some of the most important findings are briefly reviewed. Concrete as an electrolytical system; sea salts and alkalinity of concrete; diffusion of sea salts into concrete; electrical resistivity; availability of oxygen; corrosion properties of reinforcing steel; cathodic protection; field control, and corrosion monitoring are dealt with.

B-42 Bocca, P. 1979 (Jun). "Non-Destructive Methods for Testing Strength Variations in Concrete Structures," Controle de Qual des Struct en Beton, Stockholm, Sweden, 17-21 Jun 1979, Proceedings Vol, pp 128-132, Swedish Cement and Concrete Research Institute, Stockholm, Sweden.

On the basis of experimental results obtained by pullout, ultrasonic tests, and hardness tests on a large number of specimens, the possibilities afforded by these methods in the investigation of concrete strength are analyzed. Special attention is paid to the efficacy of nondestructive testing methods in assessing strength variations from one point to another, a characteristic which cannot be evaluated by destructive testing.

B-43 Kadlecek, V., and Dohnalek, J. 1979. "Detection of the Deterioration of Concrete by the Microhardness Measurements," Controle de Qual des Struct en Beton, Stockholm, Sweden, 17-21 Jun 1979, Vol 2, pp 77-84, Swedish Cement and Concrete Research Institute, Stockholm, Sweden.

The microhardness test method, which permits identification of mechanical property changes of defined microvolumes of concrete, is used for detecting the formation and development of microcracks. An example of successively loaded concrete shows the application of the microhardness test method. The possibility of applying the method to investigate the development of deterioration of concrete in structures has proved feasible, particularly at the beginning of concrete loading (i.e. when the load values are in the range of 20 to 60 percent of the ultimate load). The successive loading of test specimens causes a decrease of microhardness values by 35 to 65 percent. These values change in accordance with the position of the measured area referred to the external loading direction. Consequently, the microhardness test method can be properly used for investigation of the deterioration of hydrated cement paste and concrete structures.

B-44 Busby, R. F. 1979. "Underwater Inspection/Testing/Monitoring of Offshore Structures," Ocean Engineering, Vol 6, No. 4, Elmsford, NY.

The purpose of this 6-month study was: to identify and describe all actual or potential underwater inspection requirements (national and international) for fixed concrete and steel structures promulgated by the governments of offshore oil and gas producing countries and by the offshore operators themselves; to identify and assess the state of the art in underwater nondestructive testing/monitoring/inspection of offshore structures; to evaluate the capability of servicing and hardware producers to meet the inspection requirements identified; and to describe and establish priorities for specific tasks for technology development that should be undertaken to satisfy current and future requirements. While this study concentrates on fixed offshore oil and gas structures, the results also reflect the state of the art in underwater inspection/testing for other offshore structures as well, e.g., floating power platforms, offshore terminals, and deepwater ports.

B-45 Sommer, H. 1979. "Precision of the Microscopical Determination of the Air-Void System in Hardened Concrete," Cement, Concrete, and Aggregates, Vol 1, No. 2, pp 49-55, Philadelphia, PA.

Twenty laboratories from ten countries took part in an international comparative test to determine the air-void system of hardened concrete. The method of measurement did not seem to have a significant influence on results, but good grinding techniques and the magnifications were important. Further tests were performed with the aim of improving the precision of the results. It is recommended that the entrapped and entrained air voids be counted separately and that the spacing factor be calculated from the entrained air voids only.

B-46 Ahlsen, U., and Bellander, U. 1979. "Estimate of Location and Diameter of the Reinforcement in Finished Structures" (in Swedish), CBI Research, Vol 3, No. 79, Swedish Cement and Concrete Research Institute, Stockholm, Sweden.

The aim of this investigation had been to produce a nondestructive testing method for routinely documenting the location of the reinforcement, even in heavily reinforced finished structures. A new instrument produced in Poland and used for measuring the location and diameter or quantity of unknown reinforcement, particularly in heavily reinforced in situ structures, has been tested.

Evaluation charts and measurement instructions have been produced for the cover meter, and the accuracy has been evaluated for various reinforcement designs. The accuracy has also been compared with a conventional cover meter. The effects, if any, of concrete, reinforcement steel grade, measurement equipment, and bundled reinforcement bars have been studied. The investigation is concluded with measurements in the field.

B-47 Richards, A. M. 1979. "Measurement of Stress in Concrete Pavements," Transportation Research Record 713, pp 9-15, Transportation Research Board, Washington, DC.

Sudden compressive failures of concrete pavements (blowups) are a serious problem for highway maintenance departments. In an effort to predict when blowups will occur, a method of measuring residual stresses within a concrete pavement has been developed. In the procedure, electrical strain gages are attached to the wall of a corehole by means of a specially designed installation tool. The corehole is overcored and the relief strains are measured. Available theory has been adapted to allow computation of longitudinal stress at the level of the gages. Laboratory tests have validated the procedure, but results from tests on actual pavements have proved to be somewhat erratic.

B-48 Walker, H. N., and Marshall, B. F. 1979. "Methods and Equipment Used In Preparing and Examining Fluorescent Ultrathin Sections of Portland Cement Concrete," Cement, Concrete, and Aggregates, Vol 1, No. 1, pp 3-9, American Society for Testing and Materials, Philadelphia, PA.

The method of preparation is explained for fluorescent dye-impregnated polished ultrathin sections of portland-cement concrete used for a study of the microstructure of concrete. The sections were examined with a microscope that combines the features of a petrographic microscope with those of a microscope having incident fluorescing capabilities. Photomicrographs are used to illustrate microcracks, hollow shell hydration, impermeable areas, and the influence of coatings on aggregate particles.

B-49 Yang, N. C. 1979. "Nondestructive Evaluation of Airport Pavements, Volume I: Program References," Report FAA-RD-78-154 I, US Department of Transportation, Federal Aviation Administration, Washington, DC.

The concept of nondestructive evaluation and functional pavement design has been integrated in a computer program which is operational at Transportation Computer Center (TCC) in Washington, DC. The program logic and operational procedures are outlined as follows:

Nondestructive test--The NDT can be used as a substitute for the plate load test without interference to airport operation. All test data are processed and compiled in a NDT inventory file.

Evaluation and design--The strength of existing pavements is evaluated in terms of anticipated functional life as governed by cumulative stress damage and progressive surface deformation. The final program output is the cost information for 10 design alternatives of equal functional performance.

Validation program--Correlations have been made between the NDT data and subgrade geology, regional climate, airport operation, existing pavements and response of airport bridges. The current version of FAA standards is open to divergent interpretations and it does not indicate the cost effectiveness of a pavement program.

Material characterization--A universal testing procedure has been introduced to evaluate the dynamic response of pavement materials.

Computer operation--Two operation manuals have been prepared for the execution on computer hardware system at TCC. The program is written in a high level language, FORTRAN IV, and involves extensive use of data storage and filing techniques.

B-50 Yang, D. 1979. "Nondestructive Evaluation of Airport Pavements, Volume II: Operation Manual for PAVBEN Program at TCC," Report FAA-RD-78-154 II, US Department of Transportation, Federal Aviation Administration, Washington, DC.

Cost/benefit analysis of alternative pavement design is the primary goal of the PAVBEN program at the Transportation Computer Center (TCC) in Washington, DC. The integrated system is data independent based on defined mathematical models and operation logic. The program is written in the high-level language, FORTRAN IV.

The job inputs consist of: NDT field data; types of existing pavements; facility classifications; demand forecast; and local cost values. The default system contains all design data for: 15 air transports; 9 FAA regional cost values; 8 types of pavement design; 22 layer components; 20 types of existing pavement; and universal mechanistic design model. The major outputs will be: NDT inventory file; present functional life; computed engineering data; pavement thickness and cost data; and cost/benefit analysis for four new pavements, three overlays, and three keel constructions. The operation of PAVBEN program involves extensive use of data storage, filing technique, and computed data inputs. The current operation program and this manual are prepared for the execution on computer hardware system at TCC. Modification of these documents will be required if other computer system is to be used.

B-51 Yang, D. 1979. "Nondestructive Evaluation of Airport Pavements, Volume III: Operation Manual for MLGPAV Program at TCC," Report FAA-RD-78-154 III, US Department of Transportation, Federal Aviation Administration, Washington, DC. (Available from NTIS)

Sensitivity analysis of aircraft parameters on functional pavement design is the primary goal of the MLGPAV program at the Transportation Computer Center (TCC) in Washington, DC. The program is an integrated system which is data independent based on defined mathematical models and operational logic. The input data is divided into job and universal default inputs.

The job inputs consist of only the aircraft data such as: forecast of aircraft movements, maximum takeoff weight, natural frequency of aircraft at tire pavement interface, tire pressure of main landing gear wheel, wheel configuration of main landing gear, and gear spacing.

The default system contains all of the data independent of the aircraft, such as: regional cost values; types of facility, runway, taxiway, and

apron; navigation system; operation speed; roughness and maintenance standards; subgrade conditions; and airport traffic distribution.

A unified mechanistic method is used to design five types of functional pavements for identical service requirements of riding quality and maintenance needs. They are: asphalt pavements in southern or northern region; concrete pavements on stabilized or aggregate base, and full depth stabilized base pavement. The MLGPAV program operation involves extensive use of data storage and filling techniques. The current operational program and this manual are prepared for execution on the computer hardware system at TCC.

B-52 Shahin, M. Y., Darter, M. I., and Kohn, S. D. 1979. "Evaluation of Airfield Pavement Condition and Determination of Rehabilitation Needs," Transportation Research Record 700, pp 1-10, Transportation Research Board, Washington, DC.

This paper presents a comprehensive procedure for the evaluation of the condition of a plain-jointed concrete airfield pavement and the determination of its maintenance and rehabilitation needs. The overall procedure consists of three steps: the first is the determination of the airfield pavement condition rating based on a pavement-condition index. This index is a score between 0 to 100 that describes the structural integrity of the pavement and its surface operational condition and is based on measured types, severities, and amounts of distress. The index and, hence, the pavement-condition rating agree closely with the collective judgment of experienced pavement engineers and are strongly correlated to the need of the pavement for maintenance and rehabilitation. The second step is the evaluation of the pavement through a stepwise procedure. The purpose of the evaluation is to provide the necessary background for a rational determination of feasible maintenance and rehabilitation alternatives. The stepwise evaluation procedure depends largely on the pavement-condition-index and distress data, but other direct measurements, such as profile roughness, hydroplaning potential, and load-carrying capacity, are also included. The third step is the determination of the optimum maintenance and rehabilitation alternative. Feasible alternatives are determined through the use of guidelines that are based on the results of the stepwise evaluation and include recommended methods for the localized repair of different types of distress at different levels of severity. After the feasible alternatives are identified, an economic analysis is performed. The optimum alternative is selected based on the results of the economic analysis, the mission of the pavement, and the policies of the airfield management. The procedure is illustrated by an example.

B-53 Carabelli, E., Sampaolo, A., and Sperinde, M. 1979. "Geophysical Methods for Determining the Integrity of Concrete of a Dam," Thirteenth International Congress on Large Dams, Vol II, New Delhi, India, 29 Oct - 2 Nov 1979.

The systematic checking of the state of preservation of the concrete of a dam calls for methods that are localized, nondestructive, rapid, highly reliable, and of sure repeatability.

The more reliable the instruments and techniques used, and the more limited the volume of material involved in each individual measurement, the more valid is the survey.

To this end, dynamic methods of the sonic type may be applied, employing modern geophysical techniques that have been used in civil engineering for years with good results in the study of the elastic characteristics of rocks.

B-54 Pedro, J. O., Florentino, C. A., and Gomes, A. F. 1979. "Observation Methods for Controlling the Safety and Deterioration of Concrete Dams," Thirteenth International Congress on Large Dams, Vol II, New Delhi, India, 29 Oct - 2 Nov 1979.

The Dams Department of Laboratorio Nacional de Engenharia Civil (LNEC), in collaboration with Direccao Geral de Recursos e Aproveitamentos Hidraulicos (DGRAH) and Electricidade de Portugal (EDP), has been in charge of the observation of large concrete dams built in Portugal since 1947.

The dams now under observation at the Dams Department of LNEC are indicated in the table.

Dams are structures designed for a relatively long time; however their deterioration after some years of operation is likely to occur; so observation should be maintained along their life time.

B-55 Johnson, F. G., Crichton, J. R., and Curtis, G. R. 1979. "Surveillance and Deterioration of Dams of the North of Scotland Hydro-Electric Board," Thirteenth International Congress on Large Dams, Vol II, New Delhi, India, 29 Oct - 2 Nov 1979.

The North of Scotland Hydro-Electric Board owns and is responsible for 84 dams at 76 reservoirs which come within the British legislation for the safety of reservoirs. Fifty-six of these dams are listed in the World Register of Dams. There is a wide variety of types made up of 53 gravity, 9 buttress, 3 arch, 1 prestressed concrete, 6 earthfill, 6 rockfill and 6 combined fill and gravity dams. Sixteen dams have gates for the release of flood water and four have syphons. The predominance of concrete gravity and buttress dams is due to the good and tight rock and moderate depth of overburden generally found in the wide glacial valleys of the North of Scotland and the economics at the time of construction.

B-56 Lehtinen, P. 1979. "On the Deterioration of Concrete Observed in Dams and Hydraulic Structures in Finland," Thirteenth International Congress on Large Dams, Vol II, New Delhi, India, 29 Oct - 2 Nov 1979.

Regular and systematic inspection of dams and other hydraulic structures owned by Imatran Voima and affiliated companies was commenced in 1962. The basic objective of the dam supervision activity is to ensure the safety of the structures and to preclude all danger to life and property during the operational life of the dam.

The supervision of dams has been entrusted to the Civil Engineering Department of Imatran Voima Oy (I.V.O). The practical inspection work is carried out by a special dam supervision group (DS-group).

Inspections are made by the DS-group first when the structure has been completed and put into operation and subsequently at intervals of 5 years. In addition, annual inspections are carried out by local maintenance groups belonging to the operation personnel of the power plant.

1980

B-57 Reul, H. 1980 (Jan). "Detection of Admixtures in Hardened Concrete" (in German), Zement-Kalk-Gips, Vol 33, No. 1, pp 47-48, Wiesbaden, Germany.

The detection of admixtures in hardened concrete is becoming increasingly important, especially in connection with damage. This article is concerned with the detection of the active agents of the conventional admixtures in hardened concrete and cement. The analysis of admixtures in concrete deserves much more attention in future.

B-58 Morgan, I. L., Ellinger, H., Klinksiek, R., and Thompson, J. N. 1980 (Jan-Feb). "Examination of Concrete by Computerized Tomography," ACI Journal, Proceedings, Vol 77, No. 1, pp 23-27, Detroit, MI.

A computerized tomography system suitable for the examination of concrete has been developed. The system has been used on various tests specimens of concrete. The tomograms (cross-sectional density maps) of 6-in. (150-mm) diameter piers of various cement-to-aggregate mixes show aggregate and voids down to 1 mm in diameter, and fractures less than 1 mm wide. The location and density of reinforcement bars, the density of the background mortar, and the density of the aggregate are accurately reconstructed.

A Cesium-137 isotopic source was used to provide a 662-kev photon beam, with plastic scintillator strips used to detect and count each transmitted photon.

It is predicted that the technique will find extensive application in quality control in the casting and fabricating of reinforced concrete and steel structural elements. The technique provides periodic inspection for deteriorating elements subjected to wear and repeated

stressing, such as pipe and valves, and provides wear and failure analysis for pipes, concrete piers, and beams.

B-59 Tomsett, H. N. 1980 (Mar). "Practical Use of Ultrasonic Pulse Velocity Measurements in the Assessment of Concrete Quality," Magazine of Concrete Research, Vol 32, No. 110, pp 7-16, London, England.

The wider use of limit-state methods for the design of structures has increased the desirability of assessing the quality of a structure as built rather than isolated test pieces of the material supplied. Ultrasonic pulse velocity measurements are a particularly suitable way to measure the quality of a concrete structure, although the importance of competent engineering judgment in their analysis must be properly stressed. This paper indicates some ways in which the pattern of pulse velocity measurements may be used to assess the quality of concrete construction. The suggested patterns have been derived by applying the fundamental relationships, obtained by research, to site surveys and assessing the deviations permissible before the variations from the normal indicate a defect of engineering significance. The comparative evaluation of structural strength is also discussed.

B-60 "Evaluation of the Quality of Buildings and Equipment by Nondestructive Methods" (in French). 1980 (Apr). Institu du Batiment et des Travaux Publics, No. 382, pp 117-215, Paris, France.

The proceedings of the ITBTP-CESDA meeting on 17 May 1979 contain 19 papers dealing with measurements of buildings and equipment quality.

The selected papers discuss the influence of extensometric recordings for checking the stability of older structures; principles and applications of the granularity technic (speckle) for the recording of displacements (by means of laser photographs); determination of the real static and dynamic behavior of a building by use of dynamic solicitations (eccentric dynamic loading); new applications of measurement of the sound speed through building materials; x-ray checking of timber and reinforced concrete frames in a building; and investigation of reinforcing bars placed in concrete.

B-61 Bracher, D. A., Garrett, D. A., and Heller, C. O. 1980. "Theory and Design of Instrumentation for Bridge Investigation," Failure Prevention in Ground Transportation Systems, Gaithersburg, MD, 22-24 Apr 1980, pp 143-150, US Department of Commerce, National Bureau of Standards, Washington, DC.

The rate of deterioration of concrete structures has increased considerably over the past 10 to 15 years. Commercial instrumentation is available for evaluating the deterioration of small metal probes that can be imbedded in concrete in close proximity to the metal of interest. This may be adequate for future concrete bridge footings but does not address the problem of testing older footings. An "acoustic crack detector" mounted on a back pack is currently used with marginal success. Radiation gaging has been tried and found to give inaccurate diagnostic

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measurements were also made through selected concrete columns that support the service bridge. Areas characterized by low velocities are delineated. The velocity data indicate that a condition of cracking and deterioration exists in the concrete around and near the trunnion, head plates, and connections of the embedded anchorage beams in piers No. 2 through 15. In some piers the condition may extend down the top anchorage beam as far as 15 ft from the trunnion and down the lower beam as far as 6 ft from the trunnion. The columns that were tested have also been damaged by cracking. The cracking on the piers and columns has probably progressed over the years and was probably caused by dynamic and static stress concentrations due to gate vibration and structural movement and aided by freezing-and-thawing action and, possibly, alkali-aggregate reaction. It is recommended that steps be taken to eliminate inordinate vibration of the gates due to hydraulic action, that pooling of water on the structure be prevented, and that appropriate methods be employed for exploratory work to determine the type and extent of repairs needed to ensure the desired long-range performance of the structure.

B-64 Holmes, M., Martin, L. H., Ronan, P. B., and Wilson, J. G. 1980 (May). "Design and Construction," Proceedings, Institution of Civil Engineers, Vol 68, Part 1, pp 241-252, London, England.

The paper describes work carried out during 1978 and 1979 to assess the strength of the beams forming the Snow Hill Underpass built in Birmingham, England, in 1961. A high proportion of the beams were high-alumina cement, prestressed concrete beams which had suffered conversion. Also described is the remedial strengthening method which was subsequently adopted.

B-65 Placido, F. 1980 (Jun). "Thermoluminescence Tests for Fire-Damaged Concrete," Magazine of Concrete Research, Vol 32, No. 111, pp 112-116, London, England.

A new test of fire damage in concrete is proposed based on the technique of thermoluminescence. The thermoluminescence signal remaining in samples of sand extracted from concrete structures is an indicator of probable fire damage in concrete exposed to temperatures in the range of 300-500° C. The thermoluminescence test is easy to apply, requires only small samples, and is a more objective test than those in current use where reinstatement is being considered. An important feature of the proposed test is that it is sensitive to the thermal exposure experienced by the concrete rather than just the maximum temperature reached.

B-66 Stowe, R. L., Wong, G. S., and Pavlov, B. A. 1980 (Sep). "Concrete and Rock Tests, Major Rehabilitation, Dresden Island Lock and Dam, Illinois Waterway, Chicago District, Phase I Rehabilitation," Miscellaneous Paper SL-80-8, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

Drilling and laboratory testing of concrete and foundation rock were carried out as part of a major rehabilitation at Dresden Island Lock and

Dam. The work was performed to ascertain the extent and cause of concrete deterioration and to determine selected physical properties of the foundation rock.

A small section of the lower approach wall is founded on seamy broken limestone, while the rest of the structure appears to be founded on dense shale. Possible weak zones in the foundation are clay seams in the broken limestone and a shaley clay layer underlying the limestone.

New concrete is present at a number of locations as patches or overlays; it is in good condition. Old concrete is lightly to severely deteriorated. About 80 percent of the exposed vertical surfaces in the lock and dam has been affected by frost action to varying degrees. The average depth of concrete deterioration in the lock walls is 0.7 ft; in the upper gate bays, 1.5 ft; in the arch dam future lock walls, 1.3 ft; in the spillway dam abutment, 1.0 ft; in the ice chute pier, 2.0 ft; in the head gate piers and sill, 1.0 ft; and in the upstream one-half of the tainter gate piers, 2.3 ft. Maximum depth of damaged concrete is 3.1 ft. The damaged concrete primarily resulted from cycles of freezing and thawing. The concrete beyond the damaged zones is structurally sound.

B-67 Pace, C. E., and Campbell, R. L. 1980 (Sep). "Stability and Stress Analyses, Marseilles Dam, Illinois Waterway," Miscellaneous Paper SL-80-9, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

The monoliths of Marseilles Dam were analyzed to see if they conform to present-day stability requirements.

In the analysis of the tainter gate monoliths, the keys connecting the pier and spillway sections were determined to be overstressed; therefore, the spillway and pier sections were considered to act independently.

Using this assumption, the pier and spillway sections were analyzed independently for stability considering the following load cases:

a. Normal operation.
b. Normal operation with ice.
c. Normal operation with earthquake.
d. Flood condition.

The results showed that the spillway sections were adequate in stability, and the pier sections were inadequate against overturning. To correct the inadequacy of the pier sections, it was recommended that each pier section be posttensioned using a 602-kip force. The pier sections were reanalyzed to include the recommended posttensioning and were determined to be adequate in stability. The resulting stresses in the structure, foundation, and grouted anchors were computed and determined to be within allowables.

A previous stability investigation by the US Army Engineer District, Chicago, concluded that the stability of the ice chute monoliths was adequate. This paper concurs with that conclusion.

B-68 Denson, R. H. 1980 (Sep). "Investigation of Distressed Composite Walls, U.S. Army Reserve Armory, Greenwood, Mississippi," Miscellaneous Paper SL-80-13, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

The distressed condition of the composite walls was characterized by saturated interior wall portions and water ponding on floors. The walls were of composite design involving brick, parged bedding, and concrete masonry units, with gypsum board as a final interior covering in certain areas. Two composite and two cavity wall models were built on concrete pedestals which represented floor slabs. The models were subjected to static heads of water and water spray applications simulating rain to determine the effectiveness of each type of wall to resist water movement through the wall from the exterior to the interior. Volumes of moisture and times of migration were measured and recorded. No water migrated through the composite-wall model during the spray and static head tests. Water migrated through the veneer of the cavity wall into the cavity and drained out through a weep hole. Based on these tests, properly constructed composite walls should effectively protect against intrusion of rain.

B-69 Denson, R. H., Wong, G. S., and Husbands, T. B. 1980 (Sep). "Investigation of Deterioration of Brick in Navigation Lock Control House Structures, Tulsa District," Miscellaneous Paper SL-80-14, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

The deterioration of brick in certain control house structures at five navigation locks was characterized by partial or complete separation of laminations from the face of several bricks. Some of the laminations had fallen completely off. Deteriorated and nondeteriorated samples were removed from several structures and were evaluated by physical testing and petrographic examination. The deterioration mechanism was identified as moisture intrusion accompanied by freezing and thawing. Six model walls were constructed and each was coated with a different protective coating to determine the effectiveness of such treatment. The six coatings were rated in order of efficiency in producing protection with urethane coatings outperforming epoxy and silicone coatings.

B-70 Pace, C. E., Campbell, R. L., and Wong, G. S. 1980 (Sep). "Structural Stability Evaluation, Pokegama Dam," Miscellaneous Paper SL-80-15, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

The 77-year-old surface concrete of Pokegama Dam is generally in excellent condition. The average unconfined compressive strength of the concrete above an approximate elevation of 1,264 ft is 4,900 psi. The remainder of the concrete has a compressive strength at least as low as 1,360 psi.

The monoliths of Pokegama Dam are adequate in their resistance to overturning, sliding, and base pressures if the clay seams in the foundation are investigated and of such as extent and nature that stability and underseepage at the seams are not a problem. Except for the clay seams, the foundation material under Pokegama Dam appears to be competent and adequate.

The small amount of deteriorated concrete, mainly at the downstream ends of the piers should be repaired to prevent the entrance of water into cracks which will stop the freezing and thawing deterioration and eliminate the need for more costly repairs in the future.

The foundation is variable with clay seams present in core P-P4. It is recommended to:

a. Determine the extent of clay seams beneath the dam in the area of pier 4 by drilling upstream, between, and downstream of the piers.

b. Evaluate the effect of the clay seams on the structural stability of the dam piers.

c. Take remedial action necessary to ensure that the possibility of any seams washing out is reduced to an acceptable level.

The right embankment of the dam should be investigated for voids and imperviousness.

B-71 (Deleted)

B-72 Chabowski, A. J., and Bryden-Smith, D. W. 1980 (Sep). "Assessing the Strength of In Situ Portland Cement Concrete by Internal Fracture Tests," Magazine of Concrete Research, Vol 32, No. 112, pp 164-172, London, England.

The results of a program of about 1,500 internal fracture tests performed on ordinary portland-cement concrete to assess its compressive strength are reported. The influence of the type and size of aggregate on the test results is examined as well as the effect of precompression of the concrete. The variability of the data was assessed statistically to derive relationships between the results of internal fracture tests, i.e., the indicated maximum torques and cube strength as a basis for estimating the compressive strength of in situ concrete. Considerations affecting the use of internal fracture tests as a means of assessing the strength of concrete in structures in service are briefly discussed.

B-73 Anderson, A. H., Jr. 1980 (Sep). "Investigation, Rehabilitation, and Maintenance to Prevent Deterioration of a Concrete Building," Concrete International: Design & Construction, Vol 2, No. 9, pp 35-43, Detroit, MI.

An intensive investigation was undertaken to determine steps necessary

to extend the useful life of a two-story reinforced concrete building constructed in 1960 until requirements for a new facility could be firmly established. The building is part of a solid rocket propellant manufacturing facility and houses equipment for grinding ammonium perchlorate (NH_4ClO_4). The investigation involved examination of the original concrete design data and testing of cores taken from the floor slab, floor beams, and walls. The tests included x-ray diffraction, microscopic analyses of the aggregates, pulse velocity tests, and standard compressive tests. Photographic records of crack growth were also studied.

B-74 (Deleted)

B-75 "Pavement Condition Index (PCI)." 1980 (Sep). Concrete International: Design & Construction, Vol 2, No. 9, pp 90-93, Detroit, MI.

A Pavement Condition Index (PCI) method has been developed by the US Army Corps of Engineers Construction Engineering Research Laboratory which measures the structural integrity and surface operational condition of jointed plain and reinforced concrete roads, streets, parking lots, and hardstands subjected to pneumatic-tired and tracked vehicular traffic. The PCI method enables a pavement engineer to determine maintenance and repair needs and priorities by comparing the indexes of different pavement sections under review. The PCI method also makes it possible to monitor pavement performance through the years. The PCI method does not require the use of expensive equipment operated by highly trained personnel to obtain direct measurements. It is a simple method based on observed pavement distress during a field inspection. The PCI method has been shown to closely reproduce the mean subjective rating of pavement condition by a group of experienced pavement engineers.

B-76 Glass, D., and Sullivan, B. R. 1980 (Sep). "Monitoring Deflection at Lockport and at Brandon Road Locks, Chicago District," Miscellaneous Paper SL-80-18, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

A monitoring program was conducted at Lockport Lock and at Brandon Road Lock to record any movement occurring at specific locations.

Movement of Lockport monolith 63 was measured in comparison with monolith 57; tilt measurements were made on both monoliths. Extensometers were placed across existing cracks in a gallery through monolith 50. These measurements, with temperature data, were automatically recorded for a period of 7 months. The results show monolith 63 to be stable relative to monolith 57 and the cracks in monolith 50 at the gallery to be opening.

At Brandon Road Lock, fixed Whittemore gage points were installed across cracks. The gage points were read periodically by members of the lock staff and the data sent to the US Army Engineer Waterways Experiment Station for analysis. The data show that existing cracks on Brandon

Road Lock opened about 0.06 in. during this period. Readings continue on Brandon Road Lock.

B-77 Browne, R. D., Doyle, V. J., and Papworth, F. 1980. "Inspection and Repair of Offshore Concrete Structures," Proceedings - European Offshore Petroleum Conference & Exhibition, London, 21-24 Oct 1980, Vol 2, pp 103-117, European Offshore Petroleum Conference & Exhibit on Behalf of the Society of Petroleum Engineers, United Kingdom Ltd, London, England.

The approach to planning and carrying out the inspection program on Total's platform MCP-01 could be adopted for any concrete platform. A discussion is presented of how the planning and inspection procedures used ensures that the minimum amount of time is spent offshore and that the detailed information obtained can be used to give an accurate assessment of the structures condition. Once the inspection philosophy has been defined and the structure's critical areas identified, planning consists of the preparation of a comprehensive field specification. When this specification has been approved, inspection of the structure is undertaken using visual, photographic, and nondestructive test techniques.

B-78 Manning, D. G., and Holt, F. B. 1980 (Nov). "Detecting Delamination in Concrete Bridge Decks," Concrete International: Design & Construction, Vol 2, No. 11, pp 34-41, Detroit, MI.

The corrosion-induced deterioration of concrete bridge decks is a serious problem in locations where deicing chemicals are used. The detection of subsurface fracture planes, or delaminations, is necessary when determining the need or priority for repair and when preparing documents for a repair contract. The accuracy and appropriateness of manual methods of detecting delamination detection device in widespread use. A single, heavy chain is a practical and efficient means of manually identifying delaminations.

Infrared thermography has been found capable of detecting delamination because there is a difference in the surface temperature of sound and delaminated concrete under certain atmospheric conditions. The paper describes the equipment and the factors affecting the infrared imagery when used at ground level and from the air. The technique has the potential to become a routine operational procedure.

B-79 Escalante, E., Ito, S., and Cohen, M. 1980. "Measuring the Rate of Corrosion In Reinforcing Steel In Concrete," Report 80-2012, National Bureau of Standards, Washington, DC.

The progress on a research program directed at developing a nondestructive method for measuring the corrosion of steel in concrete as related to bridge deck deterioration is reported. Several polarization techniques for measuring the corrosion rate of steel in concrete are correlated to actual weight loss measured gravimetrically. The design of a prototype automated minicomputer system for measuring the corrosion

of steel in concrete is also described. Included are the results of a laboratory basic study on the effect of pH, Cl-, O_2, and moisture on initiating and maintaining corrosion in mortar.

B-80 (Deleted)

B-81 Roberts, J. J. 1980. "Development of An Electrical-Resistance Technique for Assessing the Durability of Reinforcing Steel In Reinforced Concrete Blockwork," Technical Report 532, Cement and Concrete Association, London, England

As a part of a program of research on reinforced concrete block masonry, a technique was sought to assess the durability of the reinforcing steel. This report describes the literature review that was undertaken and the selection and laboratory development of an electrical-resistance technique for this purpose. The tests show that the technique is suitable for determining the amount of corrosion that might take place on the steel in reinforced masonry. Allowance must be made for the influence of temperature upon the gage resistance, but the moisture content of the surrounding concrete has little effect.

B-82 Runkiewicz, L. 1980. "Non-destructive Assessment of Concrete Strength in Elements and Building Constructions" (in Polish), Prace Instytutu Techniki Budowlanej, Vol IX, No. 3, pp 33-38, Warsaw, Poland.

Principles for nondestructive assessment of concrete strength in buildings are presented. Relations for statistical evaluation of the strength of concrete have been developed for ultrasonic and sclerometric methods with regard to the number of measurements on an element or construction. On the basis of statistical analysis, relations were given for assessment of the warranted, characteristic, and designed strength of concrete in construction. Two proposals are made for defining the correlational coefficients for hypothetical relations with regard to concrete cores testing results of dispersion. The proposed relations and principals can be used for assessment of the designed strength of concrete in elements and buildings.

B-83 Vassie, P. R. 1980. "A Survey of Site Tests for the Assessment of Corrosion In Reinforced Concrete," Report TRRL-LR-953, Transport and Road Research Laboratory, Crowthorne, England.

The significance and extent of the corrosion of reinforced concrete are discussed and a wide range of practical test methods currently being employed in the examination of reinforced concrete structures for corrosion are considered. These techniques are classified according to whether they are destructive or nondestructive, examine the reinforcement of the concrete, provide direct or indirect data on corrosion, or measure, detect, or predict corrosion of the reinforcement. Each technique is considered individually with the significance and the limitations of the method being emphasized. To monitor corrosion in a system as complex as reinforced concrete, it is necessary to utilize a combination of methods giving different types of corrosion information to

achieve a reliable assessment of the extent of corrosion over the structure. A comparatively high number of measurements per unit area of concrete surface are essential since the concrete is never uniform and localized corrosion is common. The techniques which justify a high measurement density are identified. The relative importance of these methods is indicated for some frequently occurring practical conditions. It is anticipated that this report will provide sufficient information to enable the engineer to make a constructive choice of test methods so that a reasonably accurate assessment of which areas of reinforcement are corroding can be established.

B-84 Saeki, N., Takada, N., and Fujita, Y. 1980. "Some Experiments for Scaling Resistance of Hardened Concrete," Transactions of the Japan Concrete Institute, Vol 2, pp 101-108, Tokyo, Japan.

This article describes the behavior of concrete coastal structures during freezing and thawing and their durability. The interrelationships between resistance to scaling, strength of concrete surface layer as affected by water-cement ratio, kind of cement, curing, and weather conditions are examined. Properties of the surface layer and internal concrete were obtained by crack tests, pullout tests, the Schmidt hammer test, and dynamic modulus of elasticity tests. Scaling damage was studied in freeze-thaw tests.

Test results show that deterioration of the surface layer before freezing and thawing is strongly affected by poor curing conditions. Crack resistance capacity is especially affected. Five days of water curing improved surface strength and resistance to scaling damage.

B-85 Park, S. H. 1980. Bridge Inspection and Structural Analysis, Trenton, NJ.

This book is designed to aid in the preparation of bridge inspection reports, which were mandated by the National Bridge Inspection Standard established in 1968.

The most common causes of defects and deterioration in highway bridges and bridges over railways are discussed. Suspension bridges and machinery parts of movable bridges are not covered because they require more specific information. The bridge inspection section covers: general information; concrete deck evaluation; concrete bridges; steel structure evaluation; arch and rigid frame, timber structure, and culvert bridge inspection guidelines; abutment, retaining wall, and pier evaluation; foundation, soil, and waterway evaluation; and approach roadway, traffic safety, and railroad bridge inspection guidelines.

The structural analysis section covers guidelines for concrete structures, steel structures, arches and rigid frames, railroad bridges, and timber structures. The appendix contains diagrams, charts, and a glossary.

B-86 Soles, J. A. 1980. "Petrography In the Evaluation of Aggregates and Concrete," Progress in Concrete Technology, pp 111-140, Energy, Mines and Resources, Ottawa, Ontario, Canada.

The petrographic examination of aggregates and concrete is becoming increasingly valuable in concrete technology for quality and predicting the durability of concretes under the environmental conditions expected, particularly as the causes of alkali-aggregate reaction and the mechanisms of concrete deterioration become better understood. This paper briefly reviews petrographic and related test procedures used in the study of aggregates and concrete, summarizes conditions and reaction processes which may cause their deterioration, describes characteristic features of known reactions, and discusses the problems faced and techniques employed to inhibit deterioration of concrete structures in various environments. (37 refs.)

B-87 Gaidis, J. M., Rosenberg, A. M., and Saleh, I. 1980. "Improved Test Methods for Determining Corrosion Inhibition by Calcium Nitrite in Concrete," Corrosion of Reinforcing Steel in Concrete, STP 713, American Society for Testing and Materials, Philadelphia, PA.

The use of open-circuit potential measurements for determining the extent of corrosion suffers from the inability to assign a corrosion rating with confidence to an observed voltage taken at a given location on a given substrate. We have attacked the problem by using a microprocessor to accumulate multiple readings on a given deck. The solid-state electronics reads, converts, and stores the data faster and with more reliability than is possible with completely manual operation.

One problem in field applications is attachment to the rebar mat to measure the voltage. We report the usefulness of a two-probe method, which can be used without connecting to the metal framework of the bridge. An area large enough to contain active and passive regions must be surveyed.

A new series of reinforced concrete decks has been cast with and without calcium nitrite inhibitor to confirm earlier findings that corrosion can be controlled at an addition rate of 2 percent by weight of cement. Also, the results from the construction of the first highway bridge built with calcium nitrite are reported here.

B-88 Stark, D. 1980. "Measurement Techniques and Evaluation of Galvanized Reinforcing Steel in Concrete Structures in Bermuda," Corrosion of Reinforcing Steel in Concrete, STP 713, American Society for Testing and Materials, Philadelphia, PA.

The performance of galvanized reinforcing steel in concrete structures exposed to seawater in Bermuda was evaluated by measurements of chloride concentrations in the concrete and average depths of corrosion of the galvanized coatings. Results indicate that little more than superficial corrosion of the coatings has occurred in 7- to 23-year-old normal-quality concretes containing as much as 10 times the chloride

concentrations needed to induce corrosion of untreated steel. In all but one case, the outer free zinc layer was still present on the coating. In these instances, the average depths of corrosion ranged from zero to 0.013 mm, with the amount of coating remaining ranging from 92 to 100 percent of the original thickness. Localized corrosion to the steel substrate was found only in uncompacted highly porous concrete in a poorly bonded cold joint.

1981

B-89 Logothetis, L., and Economou, C. 1981. "Influence of High Temperatures on Calibration of Non-destructive Testing of Concrete," Materials and Structures, Research and Testing, Vol 14, No. 79, pp 39-43, Paris, France.

The intention of this experimental work is to investigate the influence of elevated temperatures of short duration (usually during fires in buildings) on the properties of concrete that affect the measurements by nondestructive methods (rebound hammer and pulse velocity).

Relationships between strength of concrete as well as rebound and pulse velocity versus heating temperatures are established.

Finally, the results are evaluated to find the direct relation between nondestructive measurements and strength of concrete exposed to fire.

B-90 Kishiya, K., et al. 1981 (Feb). "Experimental Study Relative to a Testing Method to Determine the Effects Exerted by Corrosion Inhibitors Used in Concrete (Drying and Wetting Repetition Method)" (in Japanese), Cement and Concrete, No. 408, pp 18-27, Tokyo, Japan.

This article reports on a 5-year investigation of the effects of corrosion inhibitors on reinforcing steels. Focusing on test apparatus, seven tests are described.

B-91 Guidi, M. C., and Giuseppe, M. 1981 (Mar). "Evaluation of the Strength of Concrete in Finished Structures" (in Italian), Industria Italiana del Cemento, Vol 51, No. 3, pp 195-206, Rome, Italy.

The article examines the quality control problem of concrete mixes, regarding in particular mechanical strength and examining the possibilities and limits of the methods. The methods described are both of the destructive type (such as samples, pull out, or the pores volume method etc.) and nondestructive methods (such as sclerometers, ultrasounds, and curing index). The validity of these methods has been ascertained according to the sensitivity of the equipment used and the number of tests carried out.

B-92 Samarin, A., and Meynink, P. 1981 (Mar). "Use of Combined Ultrasonic and Rebound Hammer Method for Determining Strength of Concrete Structural Members," Concrete International: Design & Construction, Vol 3, No. 3, pp 25-29, Detroit, MI.

An empirical equation derived from nonlinear, multiregression analysis, relating compressive strength, ultrasonic pulse velocity, and Schmidt rebound number of concrete made with natural dense weight aggregate is presented. Correlation coefficients of the equation are generally better than 0.9. Hence, using the combined method, it is possible to evaluate compressive strength of in situ concrete if the type of aggregate used in concrete is known.

B-93 Rowland, J. K., Cooper, G. C., and Williams, F. W. 1981 (Mar). "In Situ Strength Evaluation of Concrete Case Histories and Laboratory Investigations," Concrete International: Design & Construction, Vol 3, No. 3, pp 66-71, Detroit, MI.

The critical need for reliable information on in situ strength of concrete, both for safety and economics, is discussed in detail. Included is the rate of strength gain under various curing conditions and available methods of determining variations in concrete strength in structural elements. Field data, illustrations, actual test reports, and photographs are presented as a proposed basis for determination of optimal methods and the need for such methods and the need for proper judgement leading to statistical analysis of data.

The interrelation of ACI 318 and 214, ASTM C 31, C 39, and C 42 as related to various building codes are reviewed with particular emphasis on certain ambiguities related to moisture condition at the time of test and reasonable adjustments allowable to arrive at meaningful conclusions. Included with field data of private consulting engineers, concrete product producers, and commercial testing laboratories are certain important Federal agency reports on nondestructive in situ test methods.

B-94 Pollock, D. J., Kay, E. A., and Fookes, P. G. 1981 (May). "Crack Mapping for Investigation of Middle East Concrete," Concrete, Vol 15, No. 5, pp 12-18, London, England.

The outward signs of lack of durability of Middle East concrete are generally visible from an early age. The factors of poor aggregates and cements, harsh environment, unskilled labor, and unsuitable applications of specifications and designs are well-recognized characteristics that do not enhance durability. In this article, early-age performance of concrete structures is discussed, and crack mapping is developed as a diagnostic tool for predicting middle- and long-term behavior. The techniques have been used successfully to assist in decision-making on the extent, type, and timing of remedial work on recently constructed projects. Rates of concrete deterioration, and specific problems of chloride ingress will be considered in two future papers.

The technique consists of the plotting of data from a combination of relatively simple procedures. Mapping and the careful observation and recording of surface defects is generally carried out in conjunction with other forms of sampling and testing. Crack patterns characteristic of and corresponding to specific physical and mechanical occurrences are well known and are described in a table. From the crack map, preventive or remedial measures can be determined. Cracking can be called progressive or nonprogressive, depending on whether the deterioration occurs and stops, or continues with age. Progressive (continuous) deterioration is common in the Middle East, caused mainly by corrosion of reinforcement in concrete.

B-95 Tritthart, J., and Geymayer, H. 1981 (Jun). "Non-destructive Detection of Reinforcement Corrosion Areas" (in German), Beton Herstellung Verwendung, Vol 31, No. 6, pp 237-240, Dusseldorf, West Germany.

When reinforcement corrosion areas are detected early enough, there is still time to carry out necessary repairs. In the US, potential measurements have been used for 10 years for the nondestructive detection of active corrosion areas in reinforcement, particularly in bridge floor slabs. Necessary bases and test results, as well as conclusions, are described in the report.

B-96 Symposium On Concrete 1981, Towards Better Concrete Structures, Preprints of Papers, 1981, Adelaide, Australia, 2 Jun 1981, National Committee on Concrete Research and Engineering, Barton, ACT, National Conference Publication - Institution of Engineers, Australia, No. 81/3, Institution of Engineers, Barton, Australia.

These symposium proceedings contain 13 papers. The topics covered include stress-ribbon bridges, evolution of precast concrete facades, structural assessment of existing concrete buildings, properties of concrete containing pigments, proposed modifications of the Australian code estimates of strand relaxation, prediction of long-term deformations or r. c. beams, shrinkage cracking, restoration of existing structures, in-built defects in concrete structures, corrosion of r. c. in marine environments, durability of precast concrete facades, and cover specifications of r. c. corrosion.

B-97 Thornton, H. T., Jr., Pace, C. E., Stowe, R. L., Pavlov, B. A., Campbell, R. L., and Alexander, A. M. 1981 (Jun). "Evaluation of Condition of Lake Superior Regulatory Structure, Sault Ste. Marie, Michigan," Miscellaneous Paper SL-81-14, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

In May 1978 the US Army Engineer District, Detroit (NCE), requested the US Army Engineer Waterways Experiment Station (WES) to participate in the organization and execution of a program to accomplish detailed testing to determine the condition of the Lake Superior Regulatory Structure and its foundation.

WES helped to plan and direct a testing program that included nondestructive and microseismic tests, concrete core drilling, laboratory analysis of core samples, tests and analysis of the steel structure and machinery, structural analysis of the substructure and superstructure, and preparation of written reports and recommendations.

Nondestructive tests performed on the gates and operating machinery and the concrete piers indicate that there has been no appreciable loss in gate skin thickness, that the rivets are sound, and that the concrete in the piers is of generally good to excellent quality. Load tests performed on the gate lifting machinery showed that the loads present during normal operation of the gates are compatible with design loads. Some difference was noticed in loads between the sides of gates No. 9 and 10.

Laboratory tests of the concrete cores indicate some minor amounts of surface frost-damaged concrete in three of the piers, and some alkali-silica reaction damage in one of those three. The interior concrete of the aprons and piers is in good condition and should continue to give excellent service.

The foundation rock beneath the dam consists of continuous beds of sandstone from 1 to 13 ft thick; the beds dip upstream about 2 deg. Soft clay and shale seams occur throughout the foundation profile and are considered the weakest zones within the foundation. Severe scouring, exposing the upstream and downstream apron base, and undercutting of the dam have left most of the dam sitting on a pedestal. Protective aprons are necessary to stop the scouring and undercutting.

The concrete piers were found to be adequate in their resistance to overturning and base pressure, but inadequate to sliding. Remedial stability measures are recommended.

The gate lifting mechanisms are considered adequate for normal loading performance. Stresses in the gate ribs, rivets, and plates were excessive for case loading of normal plus ice, but acceptable for normal operation. It is possible that the stress analysis for normal plus ice loading is overconservative.

Recommendations for future action are made where warranted in each area of evaluation in this investigation.

B-98 Whiting, D. 1981 (Aug). "Rapid Determination of the Chloride Permeability of Concrete," Report FHWA/RD-81/119, Construction Technology Labs, Portland Cement Association, Skokie, IL, Federal Highway Administration, Washington, DC.

Techniques have been developed for determination of the permeability of a variety of concretes to chloride ions in a relatively rapid period of time. The most promising method involves application of DC voltage in the range of 60.0-80.0 volts for 6 hr to either a section of a reinforced concrete bridge deck or a core taken from a concrete structure.

Both variations involve conditioning of the specimen prior to test to eliminate test anomalies caused by low sample moisture contents. Core specimens can be tested at the rate of one specimen per day with a total of 2 days needed for a complete test including conditioning. The field apparatus is capable of conducting four tests within one working week on a given bridge deck. Results yield reasonably good correlation with FHWA 90-day ponding data on companion specimens. Concretes can be ranked according to high, moderate, low, or very low chloride permeability. Further work is needed to make the test more applicable to field testing of bridge deck overlays.

B-99 Weber, J. W. 1981 (Aug). "Concrete Ties: Update '81," Railway Track and Structures, Vol 77, No. 8, pp 26-28, Chicago, IL.

Inspection techniques and work on specification for concrete ties and fastenings are discussed. The procedure of walking the track and observing exposed surfaces and selected side faces of ties is described; defects found include cracks, chips, and spalls. Inspections in several test locations on the track revealed flexural cracking beneath the rails, but there was no cracking in one section of the research loop. It was concluded that careful maintenance of wheels kept irregularities to a minimum, and as a result track was not damaged. Since it is unlikely that wheel conditions on the track will change in the near future, efforts are being made to find pad materials to attenuate the damage of irregular wheels.

Seven problem areas in specifications for concrete ties are being studied by committees. An inspection trip to a new 90.3-mile line containing 23.550 concretes ties is described; line and surface were found to be excellent. More railroads are considering the use of concrete tie track. Though flexural cracking in ties has been found, early failures of ties are not anticipated. Testing procedures need upgrading to better reflect field conditions. This article is part of a special issue on the concrete tie.

B-100 Cavalier, P. G., and Vassie, P. R. 1981 (Aug). "Investigation and Repair of Reinforcement Corrosion in A Bridge Deck," Proceedings, Institution of Civil Engineers, London, Part 1, Vol 70, pp 461-480.

Since the mid-1960's, large amounts of deicing salts have been used on main roads. Many bridges built before that time lack adequate protection against the harmful effects of these chloride salts on reinforced concrete deck slabs. Damage to the deck of a 13-span viaduct by road salts, tests on the concrete to establish areas needing repair, and remedial work are described. The use of a half-cell potential test to detect possible corrosion of the reinforcement is reported, and the factors influencing the susceptibility of bridge decks to attack by chloride salts are discussed. An appendix on techniques for monitoring concrete repairs is included.

B-101 Dahir, S. H. 1981. "Relative Resistance of Rained-On Concrete Pavements to Abrasion, Skidding, and Scaling," Cement, Concrete, and Aggregates, Vol 3, No. 1, pp 13-20, Philadelphia, PA.

Cores from concrete pavements exposed to rain while plastic and specimens prepared in the laboratory and exposed to artificial rain showers were tested for abrasion, skid resistance, and scaling. Companion not-rained-on cores and laboratory specimens were similarly tested. Results indicated that average skid resistance was similar on both rained-on and not-rained-on cores and specimens. Full-scale tire skid numbers were about 10 percent higher on not-rained-on untraveled pavement sections than on adjacent rained-on sections. Scaling caused by freeze-thaw exposure and abrasion loss was consistently higher on rained-on than on comparable not-rained-on cores and specimens. Abrasion loss was higher on untraveled pavements than on those in use for several years and on specimens exposed to heavier rain intensity, longer rain duration, and deeper texturing.

Comparison of abrasion loss, scaling, and frictional British Pendulum Tester numbers showed that British Pendulum Numbers can be predetermined from specimens made and tested in the laboratory. Examination of two field sections after exposure to traffic and weathering for 2 years confirmed the validity of laboratory testing predictions. Two abrasion machines made to the specifications of the US Corps of Engineers Procedure CRD-C52-54 gave two different levels of abrasion loss on paired specimens, but resulting trends were similar.

B-102 Lee, N. K., Mayfield, B., and Snell, C. 1981 (Sep). "Detecting the Progress of Internal Cracks in Concrete by Using Embedded Graphite Rods," Magazine of Concrete Research, Vol 33, No. 116, pp 180-183, London, England.

Cracking within block-ended anchorage was investigated by pullout tests on concrete blocks, 900 by 600 by 200 mm, with 16 embedded graphite rods acting as electrical conductors. The rods were positioned in groups of four, equally spaced in four directions around the anchorage.

Each rod was arranged in a direction crossing the predicted failure surface.

The test results, along with the failure profile, showed that cracking within concrete is initiated at or near the block-end and propagates for a relatively long period before total failure of anchorage occurs. Initial cracking of the concrete was detected by a slight drop in voltage, indicated on an ultraviolet recorder output before it showed up on the indicator unit.

B-103 Nyame, B. K., and Illston, J. M. 1981 (Sep). "Relationships Between Permeability and Pore Structure of Hardened Cement Paste," Magazine of Concrete Research, Vol 33, No. 116, pp 139-146, London, England.

This article describes the steady-state method of measuring permeability of hardened cement paste. The water's rate of movement through concrete has an important bearing upon the degree and rate of deterioration of reinforcing steel. When the water is carrying such ions as sulfates, the deterioration rate of concrete may be affected. Permeability is a measure of the rate of movement and is sometimes regarded as a direct measure of porosity. The steady-state method uses applied hydrostatic pressure in sealing truncated conical disc specimens at hydraulic gradients up to 150,000. Relationships between saturated permeability and pore structure parameters, as determined by drying at 105° C and mercury intrusion porosimetry, are presented for hardened cement pastes of differing water-cement ratios and hydration times.

No unique relationship was found between permeability and porosity, although well defined trends were evident with the effect upon permeability of hydration time at constant water-cement ratio. Similar trends were found between permeability and surface area at constant time of hydration. A broad-banded relationship was determined between permeability and hydraulic radius for all the grouped results. Reasonably close agreement was found from the hydraulic radius theory between the structural parameter and permeability, but some discrepancies occurred at low permeabilities.

B-104 "Assessment of Chemical Attack of High-Alumina Cement Concrete." 1981 (Nov). BRE Information IP 22/81, Building Research Establishment, Garston, Watford, England.

This article describes tests to establish the cause of visible surface deterioration and the extent of any chemical attack within high-alumina cement concrete (HACC). This paper was prepared to assist professional inspections and appraisals of constructions containing HACC and aid testing organizations.

B-105 Tomsett, H. N. 1981 (Dec). "Non-destructive Testing of In Situ Concrete Structures," NDT International, Vol 14, No. 6, pp 315-320, Birmingham, England.

The present, rather unsatisfactory, status of nondestructive testing of concrete and the variety of 'strength' tests which dominate the technique are examined. The proposal is made that the uniformity and durability of a structure are as important as the precise 'strength' level of the structure, normally measured by the standard specimen. Some of the 'new generation' of nondestructive tests aimed at testing specific aspects of the potential usefulness of a structure are briefly described. It is suggested that NDT of concrete will only become fully accepted when the most appropriate test is chosen for a given situation and economic benefits may be clearly seen to accrue from its use.

B-106 Long, A., and Murray, A. 1981 (Dec). "'Pull-off' Test For In Situ Concrete Strength," Concrete, Vol 15, No. 12, pp 23-24, London, England.

This article briefly relates the background and reliability of the pull-off test to predict the compressive strength of concrete. Until recently, in situ methods could be categorized as simply either destructive or nondestructive tests, with destructive tests involving the testing to failure of a complete structural member or concrete core.

Pull-off testing involves bonding by an epoxy-resin adhesive a circular steel probe to the surface of the concrete under testing. A slowly increasing tensile force is then applied to the probe. Because the tensile strength of the bond is greater than that of the concrete, the latter will eventually fail in tension.

The amount of overbreak is usually small so that the failure area can be taken as being equal to that of the probe. It is possible to calculate a nominal tensile strength for the concrete specimen from the above area and force applied at failure. The advantages and disadvantages of pull-off testing are also listed.

B-107 Heins, C. P. 1981a. "Bridge Rating and Computerization," Proceedings of an International Conference on Rehabilitation of Buildings and Bridges Including Investigations, National Science Foundation, 21-23 Dec 1981, Washington, DC.

The rating of bridges requires a structural analysis of the system, when the bridge is subjected to assumed dead and live loads. These analyses may be complex or simple, depending on the structural type. In order therefore to expedite such analyses, a series of computer programs has been developed and is available for direct use by the engineer.

The purpose of this paper is to present details of these computer programs.

B-108 Heins, C. P. 1981b. "Bridge Evaluation by Field Testing," Proceedings of an International Conference on Rehabilitation of Buildings and Bridges Including Investigations, National Science Foundation, 21-23 Dec 1981, Washington, DC.

The cost of replacement of many old truss bridges is often prohibitive, however such bridges provide a very necessary service to the community. Thus, the integrity of these bridges is paramount to ensure safety for the public.

This paper will therefore present information relative to the load carrying capacity of six truss bridges, as observed during load field tests. The resulting data were then used to rate the structures.

B-109 Cope, R. J., Bungey, J. H., and Rao, P. V. 1981. "Assessment of Reinforced Concrete Bridge Slabs," Proceedings of an International Conference on Rehabilitation of Buildings and Bridges Including Investigations, National Science Foundation, 21-23 Dec 1981, Washington, DC.

The integrity of a reinforced concrete bridge slab may need to be assessed when the structure is showing signs of possible distress, excessive cracking or deflections, an overload is expected, and structural modifications are desired. Methods of estimating concrete strength in prototype structures are described, and interpretation of such measurements for use in calculations is discussed. Use of nonlinear finite element procedures to predict the complex stress state compatible with measured deflections is described. Methods for extending the analysis to estimate the effects of overloading and structural modifications are proposed.

B-110 Gangarao, H. V. S. 1981. "Performance Studies of Grid Decks for Office Floors," Proceedings of an International Conference on Rehabilitation of Buildings and Bridges Including Investigations, National Science Foundation, 21-23 Dec 1981, Washington, DC.

This report summarizes the manufacturing and erection practices and highlights the maintenance problems of grid decks. Causes of failures of main and secondary bars of open grid decks and maintenance problems of concrete filled decks are established and corrective measures are suggested. The present AASHTO design philosophies and other criteria for transverse load distribution and stiffness are critically reviewed. Stress improvement factors and rating improvements of bridges utilizing open or filled grid decks in place of concrete decks are investigated. Certain design manufacturing and erection alternatives are recommended to maximize the grid span between stringers and to minimize maintenance problems. Specific recommendations are made for future research in this area.

B-111 Shroff, A. C. 1981. "Rehabilitation of Pelham Parkway Bridge, In Depth Inspection," Proceedings of an International Conference on Rehabilitation of Buildings and Bridges Including Investigations, National Science Foundation, 21-23 Dec 1981, Washington, DC.

The Pelham Parkway Bridge over Eastchester Bay in the Bronx, New York, is a seven-span, four-lane structure constructed in 1907. The seven spans consist of a moveable span in the center and three fixed-approach spans on each end. The moveable span is a double-leaf Scherzer Rolling Lift, bascule structure. The fixed spans are concrete spandrel arches with the roadway placed on fill. Overall length of the structure between ends of wingwalls is about 855 ft. The width of the bridge is 52 ft out to out of parapets.

The entire project was divided into four major phases of work, namely: in-depth inspection of the entire structure, stress analysis and rating of both the basic structure and bascule machinery, preparation of reconstruction project report to include recommendations and

construction cost estimates along with results of inspection and stress analysis, and finally, preparation of contract documents for the rehabilitation of the bridge.

This paper, the first one in a series, discusses in-depth inspection (Phase 1) of the basic structure exclusive of bascule machinery and preparation of the reconstruction report (Phase 3) of the project. The paper includes discussions on inspection equipment, methods and techniques utilized along with results of the inspection. The paper also describes an innovative method of utilizing photographic techniques in preparing an engineering inspection report.

B-112 Patel, R. R. 1981. "Investigation into Safety and Rating of Through Truss Bridges-Two Case Studies," Proceedings of an International Conference on Rehabilitation of Buildings and Bridges Including Investigations, National Science Foundation, 21-23 Dec 1981, Washington, DC.

Recent estimates of deficient bridges indicate that, nationally, there are over 7,000 bridges classified structurally or geometrically deficient and 28,000 classified functionally obsolete. Like most other states, West Virginia, the second leading coal producer in the USA, is also faced with the problems of maintaining and upgrading old highway structures. During this last decade, the increased threat of an energy crisis has intensified coal consumption. Consequently, the increased heavy traffic on country roads and highways became a major concern of the West Virginia Department of Highways resulting in an investigation into the safety and rating of all bridges.

Most of the bridges built during the early part of this century are truss bridges of spans up to 200 ft. Most of them also have narrow roadways. The field inspection of Ellamore and Harmon truss bridges revealed that the lack of periodic inspection and poor maintenance were the major factors causing many unsafe structural deficient bridges.

B-113 Kavanagh, I., and Shroff, A. C. 1981. "Rehabilitation of Pelham Parkway Bridge Structural Evaluation-Concrete Arch Spans," Proceedings of an International Conference on Rehabilitation of Buildings and Bridges Including Investigations, National Science Foundation, 21-23 Dec 1981, Washington, DC.

The Pelham Parkway Bridge over Eastchester Bay in the Bronx, New York, is a seven-span, four-lane structure constructed in 1907. The seven spans consist of a moveable span in the center and three fixed-approach spans on each end. The moveable span is a double-leaf Scherzer Rolling Lift, bascule structure. The fixed spans are concrete spandrel arches with the roadway placed on fill. Overall length of the structure between ends of wingwalls is about 855 ft. The width of the bridge is 52 ft out to out of parapets.

The entire project was divided into four major phases of work, namely: in-depth inspection of the entire structure, stress analysis and rating of both the basic structure and bascule machinery, preparation of

reconstruction project report to include recommendations and construction cost estimates along with results of inspection and stress analysis, and finally, preparation of contract documents for the rehabilitation of the bridge.

This paper, the second in a series, discusses stress analysis, quality and strength evaluation and rating (Phase 2) of the concrete arches. Petrographic analyses, compressive strength tests, air content tests, freeze-thaw tests, and chloride tests were performed on samples prepared from 36 concrete core specimen obtained in the field. The paper discusses how this test data were used to evaluate the quality and compressive strength of the 70-year-old concrete; and then reduced to 28-day strength to compare it with the results of stress analysis.

B-114 Sabnis, G. M., and Millstein, L. 1981. "Use of Non-Destructive Methods to Evaluate and Investigate Condition of Buildings and Bridges," Proceedings of an International Conference on Rehabilitation of Buildings and Bridges Including Investigations, National Science Foundation, 21-23 Dec 1981, Washington, DC.

Use of nondestructive type testing during inspection of various components of buildings and bridges enables one to determine their condition both qualitatively and quantitatively and to accumulate data for the history of the structure. Such inspection can indicate that physical testing may be required during its lifetime for safety and proper serviceability. The application of nondestructive testing as presented in this paper cites the following types of examination of structures: (a) acceptance criteria and control; (b) preventative inspection; (c) examination with nondestructive equipment; and (d) inspection prior to rehabilitation. The procedures are discussed in detail to throw light on parameters such as geometry, strength, and deformation and other material properties as applicable to the strength and serviceability of the structure.

B-115 Hobbs, B. 1981. "Analysis of R. C. Buildings Subjected to Localized Damage," Proceedings of an International Conference on Rehabilitation of Buildings and Bridges Including Investigations, National Science Foundation, 21-23 Dec 1981, Washington, DC.

This investigation concerns the response of typical reinforced concrete office buildings to localized damage, in the form of the effective removal of one or more columns in a given level. Using model test results as a guide, an analytical approach is developed. Particular features of the analysis are discussed and it is extended to include the influence of infill wall panels on the behavior of the damaged building frames. The analysis is applied to two sample buildings and results are presented showing how the load factor against collapse varies with the number of columns removed. It is shown that the presence of infill panels considerably increases the ability of structures of this type to withstand localized column damage, and it is suggested that the addition of such panels to existing structures may be a suitable means of increasing their ability in this respect.

B-116 Woodward, R. J. 1981. "Case Studies of the Corrosion of Reinforcement in Concrete Structures," Report TRRL-LR-981, Transport and Road Research Laboratory, Crowthorne, England.

The TRRL has been evaluating testing techniques which can be used to assess the risk of corrosion of steel in concrete. This report describes the application of a number of these techniques to five reinforced concrete structures. In each case the work was initiated by some form of visible distress. It is shown that by careful application of a number of complementary techniques it is possible to obtain sufficient information about the condition of a structure to make a qualitative assessment of the corrosion risk. The development of techniques for measuring the strength and permeability of in situ concrete would enable a more reliable assessment to be made.

B-117 Runkiewicz, L. 1981. "Effect of Statistical Analysis of Nondestructive Test Results Upon Assessment of Concrete In Structures" (in Polish), Building Research Institute Quarterly, Vol 37, No. 1, pp 19-27, Warsaw, Poland.

This paper examines statistical analysis as a tool in estimating the actual strength of concrete. The principle is advanced so that the effect of stress in concrete must be taken into account when evaluating sclerometric tests. Applications to ultrasonic and sclerometric tests are made with examples.

B-118 Steinway, W. J., Echard, J. D., and Luke, C. M. 1981. "Locating Voids Beneath Pavement Using Pulsed Electromagnetic Waves," NCHRP Report 237, Transportation Research Board, Washington, DC.

Pulsed electromagnetic wave technology has been useful for locating and sizing voids beneath reinforced and ordinary portland-cement concrete (PCC) pavement. Specific signal processing techniques have been developed that provide field personnel with information for void detection with spatial location to within ± 6 in. and sizing to ± 0.5 in. Signal processing techniques were implemented on a microcomputer system so that the results could be displayed on a video unit, permanently stored on magnetic diskettes, and printed directly on paper for permanent hard copy.

Experimental evaluation of pulsed electromagnetic wave equipment and signal processing techniques for void detection and sizing was done under laboratory conditions. The equipment accuracy, precision, reliability, limitations, and operational characteristics were evaluated using 9-in.-thick sections of reinforced and ordinary PCC pavement and base materials of PCC, asphaltic concrete, dense-graded aggregate, and portland-cement stabilized clay. Void depths from 0 to 8.5 in. in 0.5-in. increments were measured including several moisture levels.

Additional measurements were made on a specially constructed outdoor PCC pavement test lane, 72 ft by 8 ft by 9 in. thick. Calibrated voids of various shapes and depths were surveyed in-place before concrete was

placed, and reinforcing steel was implanted in one-half of the test lane. Initial measurements made at 100° F temperature enabled trained operators to detect voids, but the magnitude of the signal return was not large enough for the microprocessor algorithms to detect and size the voids. This lack of signal strength was attributed to moisture content and temperature conditions. Succeeding measurements made at temperatures ranging from 32 to 70° F yielded excellent estimates of void location and size. The signal processing algorithms, making use of both amplitude ratios and time differences with respect to reference calibrations, have been verified to perform as designed.

B-119 "Runway Testing Program." 1981. Concrete Industry Bulletin, Vol 21, No. 4, New York, NY.

An innovative, nondestructive method of testing airport runway pavement will save time and maintenance costs. The nondestructive process uses equipment mounted on a truck that simulates moving aircraft weight on the runway. An accelerometer will measure movement of the pavement as it responds to various frequencies and force levels of the applied loads. The strength of the pavement can be determined by engineers using these readings.

The data are fed into a computer which outputs a pavement service ability prediction and repair design alternatives. This data is evaluated to establish a 10-year pavement maintenance and strengthening program.

Annual savings in maintenance costs will differ, but a recent application of these testing methods at LaGuardia Airport resulted in a $200,000 savings for an evaluation of 95,000 sq yd of runway pavement. John F. Kennedy and Newark International Airports are scheduled to use this procedure.

B-120 Taute, A., and McCullough, B. F. 1981. "Manual for Condition Survey of Continuously Reinforced Concrete Pavements," Research Report 177-19, Center for Transportation Research, Austin, TX.

This report presents in detail a condition survey procedure which has been used to survey all the rural continuously reinforced concrete pavements (CRCP) in Texas. The procedure involves the objective measurement of the most severe and prevalent forms of distress in CRCP's.

The development of this procedure from an earlier one is described. Some recommendations regarding computerized storage and manipulation of the data are made. A procedure for surveying jointed concrete pavement is also presented.

B-121 Kusenberger, F. N., and Barton, J. R. 1981. "Detection of Flaws in Reinforcing Steel in Prestressed Concrete Bridge Members," Report FHWA/RD-81/087, Federal Highway Administration, Washington, DC.

This report summarizes development of a practical nondestructive method for detecting deterioration in reinforcement of prestressed concrete

bridge structural members. The problem is thoroughly defined and the technical approach described. The basis for selecting and assessing 15 nondestructive methods is reviewed, and results of a limited laboratory investigation of the magnetic method prior to developing inspection equipment are summarized.

Preliminary magnetic inspection equipment development is described, as well as details from records of laboratory evaluations that used a 20-ft (6-m) section of Texas Type C-beam and field evaluations at Salt Lake City, UT. Correlation investigations that illustrate promising electronic signature enhancement and recognition methods for discriminating between steel artifacts and deterioration are discussed. Recommendations for further development are outlined.

B-122 Zivkovic, S. 1981. "Testing the Concrete Quality in Structures by Combining Ultrasound Method With Concrete Cylinder Extracting," Nase Gradevinarstvo, Vol 35, No. 9, Belgrade, Yugoslavia.

This article describes the application of a method to test structural concrete quality based on a combination of the ultrasound method and concrete cylinder extracting. Specific problems connected with the application of the procedure are solved. Problems associated with testing small structural elements and concrete of different maturities are discussed.

Conclusions about nondestructive testing procedures are given, based on the author's experience in applying these methods.

B-123 Mather, K. 1981. "Condition of Concrete In Martin Dam After 50 Years of Service," Cement, Concrete, and Aggregates, Vol 3, No. 1, pp 53-62, Philadelphia, PA.

The concrete in an arch-gravity hydroelectric power dam in Alabama was sampled by three 152-mm (6-in.) cores drilled in the crest of the dam to the foundation. Samples taken from these cores were examined petrographically and tested: 1) ultrasonically to measure compressional and shear-wave velocities; 2) in unconfined compression; 3) in triaxial loading in groups of three cores each at three confining pressures; and 4) for strength in tension.

The petrographic examination showed evidence of alkali-silica reaction in the three drill holes. However, alkali-silica reaction gel was not found in the lower part of one hole. The core from this zone contained large flakes of tetracalcium aluminate monosulfate-12-hydrate.

Although the evidence of alkali-silica reaction is clear, it extended to cracks in the mortar only to a minor extent. The mechanical tests indicated that the concrete is in good physical condition. Despite the presence of alkali-silica reaction, it was concluded that the Martin Dam is in acceptable condition.

B-124 Mohr, P. 1981. "Inspection of Prestressed Concrete Structures" (in Swedish), Nordisk Betong, Vol 25, No. 4, pp 18-20, Stockholm, Sweden.

There is a need for information on the condition of the prestressing steel tendons in existing structures. Formerly, it was necessary to cut out large windows in the prestressed concrete for inspection. The use of glass fiber optics can improve the quality of inspection and at the same time make it less destructive and time-consuming.

B-125 Lindgren, M. N. 1981. "Prediction of the Freeze/Thaw Durability of Coarse Aggregate in Concrete by Mercury Intrusion Porosimetry," Report FHWMA/IN/JHRP-80/14, Joint Highway Research Project, Purdue University, West Lafayette, IN.

This report refines the validity of Kaneuji's correlation between pore size distribution of an aggregate and freeze-thaw durability of concrete using the same aggregate and defines more thoroughly the pore structure criteria to use in predicting the performance of an aggregate. D-cracking is a serious problem of concrete pavements in freezing climates and is mostly caused by use of a coarse aggregate. Kaneuji developed an expected durability factor (EDF) to determine whether an aggregate will be durable or nondurable.

Aggregates from 52 Indian highway cores and five rock samples supplied by the Portland Cement Association were tested. The EDF values were determined from pore size distributions, and an average value was assigned to each pavement associated with the cores. The values were compared with field performance of the pavement to identify the borderline between EDF values for durable and nondurable aggregates. Good correlation occurred between field performance and average EDF values. A pavement was found to be durable for at least 30 years if its coarse aggregate had an EDF value greater than 50 for 90 percent or more of its aggregate. This applies to stone and gravel aggregates with a maximum size 1-1/2 to 2-1/2 in.

B-126 Davies, I. L., and Mavrides, A. 1981. "Integrity of Offshore Structures," Applied Science Publication, Bronx, NY.

Assessment of the damage arising from collisions between ships and offshore structures is reviewed.

B-127 Welch, B. H., Witczak, M. W., Zimmer, D. C., and Hacker, D. G. 1981. "Pavement Management Study: Illinois Tollway Pavement Overlays," Transportation Research Record 814, Pavement Management and Rehabilitation of Portland Cement Concrete Pavements, Transportation Research Board National Academy of Sciences, Washington, DC.

Since 1967, when Byrd, Tallamy, MacDonald, and Lewis (BTML) performed the original pavement maintenance study for the Illinois State Toll Highway Authority, there have been major changes in the characteristics of the highway, volume of traffic, and in the pavement composition itself. Several studies have provided information to update the

original maintenance and rehabilitation program, and the study reported here has created a continuity in this process. As the result of the comprehensive pavement evaluation by BTML, data have been accumulated on current conditions of serviceability, slipperiness, surface defects, and deflection. These factors were considered individually as well as collectively to provide recommendations for improvements or rehabilitation. Current pavement condition was determined through visual and instrument surveys to provide present-serviceability-index factors and computations, traffic and axle-load analyses, and skid numbers for each of the three tollways in each direction. The visual pavement deficiencies-cracking, patching, faulting, and pumping-on rigid pavements were addressed by the visual survey. The instrument survey was concerned with the determination of roughness, skidding, and deflection data. Pavement condition was determined through the study of traffic volume, lane distribution, axle load, and the number of axle repetitions. Cumulative 18-kip single-axle loads were determined for the tollway. An integral part of a pavement management system is an adequate data base. The evaluation performed by BTML compiles the data necessary to create a format adaptable for use in an effective pavement management system for the tollway. The pavement management framework is a management tool to aid consistency and optimization in the decision process. It is designed to expand decision-making capability as well as to provide necessary feedback on these decisions.

B-128 Loikkanen, P., and Jumppanen, U. 1981. "Fire Resistance of Concrete and Concrete Structures," (in Finish), Research Notes 16/1981, Technical Research Centre of Finland, Espoo.

The fire resistance of load-bearing concrete structures can be determined with the experimental method and also with computer calculation methods. Applying these methods requires information about the phenomena and influences of fire on both structures and structural materials. Information on thermal and mechanical properties of concrete in fire has been gathered from the literature. Special attention has been paid to the raw materials of concrete, the influence of the structure, and external factors. The time dependency of the properties in high temperatures is so strong that results measured under stationary condition evidently do not sufficiently describe the situation under continuously changing fire conditions. Comparatively few studies corresponding to fire conditions have been published. Results of such studies concerning Finnish concrete, which is different because of its aggregate, do not exist. The research methods needed have been considered, and a proposal has been made to divide the research into projects.

B-129 Bungey, J. H. 1981. "Concrete Strength Determination by Pullout Tests on Wedge-Anchor Bolts," Proceedings, Institution of Civil Engineers, London, Part 2, Research and Theory, Vol 71, pp 379-394.

The paper describes experimental work undertaken in the laboratory to extend the strength calibration data available for pullout tests on 6-mm expanding wedge-anchor bolts. The effect of loading technique was examined and a mechanical direct pull test apparatus was developed.

The results are compared with those obtained by torquemeter, and the reliability of strength prediction is assessed with special reference to aggregate type and size. The influence of flexural stress was examined by testing two 4.8-m reinforced concrete beams, loaded and unloaded. Using the results, the reliability of tests on full-scale members is compared with that of tests on standard laboratory control specimens. The accuracy of the test method is compared with that of other methods available for determining the strength of in-place hardened concrete, and suggestions are made concerning worthwhile applications.

1982

B-130 "Building Failures--Preventing Them, Learning From Them." 1982 (Jan). Civil Engineering, Vol 52, No. 1, pp 44-51, American Society of Civil Engineers, Philadelphia, PA.

The second article in a two-part series on building failures discusses prevention measures that can be learned from studying failures. Accident investigators and the importance of their reports in reducing failures are discussed. The fire investigation teams of the National Fire Protection Association and the accident investigation procedures of the National Transportation Safety Board are described. Two proposals for gathering data on failures in civil engineering works to learn proper prevention techniques are presented. Reduction of errors by implementing a special building design and construction process is illustrated by presenting a case history. Teamwork between designers, contractors, developer, and owner is another method to prevent errors in structural design. Quick response to developing construction problems is an effective method to prevent the filing of claims.

B-131 "Thermoluminescence--A Test for Fire Damage." 1982 (Mar). Concrete Works International, Vol 1, No. 3, p 102, London, England.

This article explains the thermoluminescence technique for evaluating the extent of fire damage in concrete constructions. Until recently, the most widely used test was studying outward appearance. This method supplied minimal evidence only to internal damage; no indication of how far into the structure the fire had penetrated, amount of time the concrete had been exposed to heat, or temperatures reached during the fire was attained. So in many cases, the building was demolished to take the safe course.

The thermoluminescence technique is being used by Dr. Frank Placido, Paisley College, to verify the authenticity of ancient potteries and ceramics. It involves calculating the amount of light emitted by certain crystals and minerals, accurate for dating objects to within 80 years of their manufacture.

Research has shown that the thermoluminescence of sand extracted from concrete can form the basis of a new test for fire damaged concrete

that is the actual measure of thermal exposure experienced by the concrete.

B-132 Sawamura, I., and Takaha, N. 1982 (Apr). "Investigation On the Concrete Quality and the Deterioration of the Notormisaki Lighthouse" (in Japanese), Concrete Journal, Vol 20, No. 4, pp 15-22, Tokyo, Japan.

This article discusses the investigation of deterioration of the Notoromisaki Lighthouse built in 1917 in Hokkaido. Visual inspection, nondestructive concrete testing, concrete characteristics, and amount of the salt penetration into concrete were measured at time of pulling down the structure. Preparation of drawings for the reconstruction are also discussed.

B-133 Placido, F. 1982 (May). "Research Explores New Test Method for Fire-Damaged Concrete," Concrete, Vol 46, No. 1, pp 23-27, Chicago, IL.

This article discusses applying the phenomenon of thermoluminescence (TL) to access fire damage in concrete to determine if reinstatement rather than replacement of the structure is possible. It has been found that temperatures required to remove the stored TL capability of quartz are 570 to 930° F (300 to 500° C), which is the range important in affecting the concrete's compressive strength. Specifics of the test procedure are discussed; two methods for extracting test specimens are evaluated.

B-134 Fitzpatrick, M. D. 1982. "Ten Years Surveillance of Cethana Dam," Fourteenth International Congress on Large Dams, Rio De Janeiro, Brazil, 3-7 May 1982, Paris, France.

Cethana Dam in Tasmania, Australia, is an upstream membrane type of dam of maximum height 110 m. The thin impervious membrane of reinforced concrete was constructed after the embankment rockfill had been placed and compacted virtually to crest level. Construction of the dam was completed in February, 1971, and the reservoir was filled by the end of April, 1971. Design and construction were carried out by the Hydro-Electric Commission of Tasmania.

The monitoring system was focussed primarily on the underwater measurement of deflection and deformation of the membrane, but crest and downstream face deflection, settlement within the embankment, and leakage were also measured.

The results of monitoring are presented and conclusions are drawn on the performance of the dam, based on 10 years of surveillance.

B-135 Gilg, B., Sinniger, R., and Gavard, M. 1982. "Long Term Measurements on Three Swiss Dams Mauvoisin, Grande Dixence and Mattmark," Fourteenth International Congress on Large Dams, Rio De Janeiro, Brazil, 3-7 May 1982, Paris, France.

The 237-m high Mauvoisin arch dam has been brought under full load in

1958 and for 23 years has been subject to a very regular loading cycle because of the fact that the corresponding storage lake has the function of a seasonal regulation reservoir. The deformations caused by the water load and the temperature oscillations show a practically elastic behavior for about 15 years and even the percolation quantities are very steadily following the lake level variations for the last 5 years.

The 285-m high Grande Dixence gravity dam is in the same way subject to a seasonal cyclic load during the past 15 years, and the corresponding deflections are proving very clearly the interesting phenomenon that in a relatively small valley even a gravity dam may act as a three-dimensional structure.

B-136 Martin, R. 1982. "Investigations at Blackwater Dam, Argyllshire, Scotland," Fourteenth International Congress on Large Dams, Rio De Janeiro, Brazil, 3-7 May 1982, Paris, France.

Investigations were carried out at Blackwater reservoir in 1978 to assess the condition of the dam's hearting concrete, the extent of available shear resistance at interfaces within the dam, and uplift pressures at the foundation level.

Six vertical cored boreholes were drilled from the dam's crest and terminated in the rock foundation. In situ and laboratory tests were carried out and pneumatic piezometers were installed at the dam's foundation to enable water pressures to be monitored.

The results suggest that the hearting is in generally sound condition though pockets of weaker material were detected. Chemical analyses showed that lime is being leached out from localized zones near the upstream face of the dam, though this is not thought to be sufficiently widespread to weaken the structure as a whole. The shear strength at lift joints and rock/concrete interfaces appears to be considerable. Uplift pressures are, in general, less than might have been assumed in the absence of observations.

B-137 Rouve, G. 1982. "Inspection and Rehabilitation of Ancient Curved Gravity Dams in Masonry," Fourteenth International Congress on Large Dams, Rio De Janeiro, Brazil, 3-7 May 1982, Paris, France.

In the years 1870 to 1905, dam construction activities in Germany sharply rose through the initiation of Prof. O. Intze in connection with the increased energy demand. With some 20 masonry dams of the so-called Intze-type, the design criteria of that time as well as present defects and damages are discussed. In brief, several investigation programs are presented and explained, for which the Ennepe dam has served as example in a more detailed manner. Suitable test borings as well as necessary analysis of the bore cores are explained.

B-138 Lytle, J. D. 1982. "Dam Safety Instrumentation; Automation of Data Observations, Processing and Evaluation," Fourteenth International Congress on Large Dams, Rio De Janeiro, Brazil, 3-7 May 1982, Paris, France.

The current state of the art has advanced to the stage of automated data acquisition, allowing instruments to be << read >> remotely when the instruments and peripheral equipment are compatible, that is, the devices which monitor piezometric pressures, stress and strain meters, inclinometers (tiltmeters), deformation meters, and other instrumentation are of the transducer or electrical type. Such instrumentation allows interfacing with the data acquisition equipment permitting automation of data observations, processing, and evaluation

B-139 Stowe, R. L., and Ahlvin, J. C. 1982 (Jun)a. "Condition Survey of Cedars Lock and Dam, Lower Fox River, Wisconsin," Miscellaneous Paper SL-82-4, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

A condition survey was performed at Cedars Lock and Dam on the Lower Fox River, Wisconsin. The field investigation included drilling for core samples of concrete, foundation rock, and backfill. Selected specimens of these materials were tested in the laboratory for certain physical and mechanical properties. Results of the field investigation and laboratory tests indicated that the concrete in the lock and dam is locally cracked and lightly deteriorated but structurally sound.

Rock masonry in the lock appears sound even though the outside surface is weathered. Cycles of freezing and thawing have caused the deterioration. The lock and dam is founded on competent bedrock. No soft or otherwise weak zones were detected in the bedrock. Soundings should be made to detect any scouring behind the dam. It is suggested that the reinforcing steel in the tainter gate piers, adjacent to the hinge pins, be examined for corrosion.

B-140 Stowe, R. L., and Ahlvin, J. C. 1982 (Jun)b. "Condition Survey of DePere Lock and Dam, Lower Fox River, Wisconsin," Miscellaneous Paper SL-82-3, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

A condition survey was performed at DePere Lock and Dam on the Lower Fox River, Wisconsin. The field investigation included drilling for core samples of concrete, foundation rock, and backfill. Selected specimens of these materials were tested in the laboratory for certain physical and mechanical properties. Results of the field investigation and laboratory tests indicated that the concrete in the lock and dam is locally cracked and lightly deteriorated but structurally sound.

Cycles of freezing and thawing have caused the concrete deterioration. The lock and dam is founded on competent bedrock. No soft or otherwise weak zones were detected in the bedrock. Soundings should be made to detect any scouring behind the dam. It is suggested that the reinforcing steel in the tainter gate piers, adjacent to the hinge pins, be examined for corrosion.

B-141 Jambor, J., and Zivica, V. 1982 (Jul). "Investigation of Corrosion of Steel Reinforcement in Concrete by Methods of Ascertainment of Electrode Potential and Electrical Resistance" (in Slova' Stavebnicky Casopis, Vol 30, No. 7, pp 563-586, Bratislava, Czec ovakia.

Results proved that the values of electrode potential of steel reinforcement in concrete as well as their changes allow highly reliable conclusions about corrosion or passive state reinforcement. Further, it is possible to determine the state as well as the corrosion course of reinforcement by use of a new method of electrical resistance measurement. The applied device allowed reliable following of the course of corrosion of steel specimens with a cross section of 1 by 3 mm and length of 130 mm. Both tested methods complete each other and their simultaneous use to determine the state of steel reinforcement in concrete is advantageous.

B-142 Mindess, S. 1982 (Aug). "Acoustic Emission and Ultrasonic Pulse Velocity of Concrete," International Journal of Cement Composites and Lightweight Concrete, Vol 4, No. 3, pp 173-179, Harlow, Essex, England.

Both acoustic emission and ultrasonic pulse velocity measurements were used to try to monitor the structural integrity of concrete. Specimens, 150-mm cubes, were loaded monotonically to failure, and acoustic emission and ultrasonic pulse velocity were measured simultaneously. Four different concrete mixes were each tested at ages up to 2 years to provide a wide range of concrete strengths. The results indicated that ultrasonic pulse velocity measurements began to show internal cracking at stresses of about 33 to 66 percent of the ultimate stress; this method therefore appeared to be more sensitive to damage than acoustic emissions, which indicated severe cracking only at about 80 to 90 percent of the ultimate stress. However, both ultrasonic pulse velocity and acoustic emission seemed to be affected by the age of the concrete. It was concluded that, for acoustic emission to be used as a reliable indicator of concrete damage, extensive work would have to be done to establish a standard test procedure.

B-143 Lew, H. S., Carino, N. J., and Fattal, S. G. 1982 (Aug). "Cause of the Condominium Collapse in Cocoa Beach, Florida," Concrete International: Design & Construction, Vol 4, No. 8, Detroit, MI.

This paper gives the results of an investigation into the collapse of a five-story, flat-plate condominium building in Cocoa Beach, Florida. The collapse occurred on March 27, 1981, while the casting of the roof slab was in progress. Eleven workers were killed and twenty-three were injured. The investigators conducted on-site inspections, made laboratory tests, and made analytical studies. It was concluded that the most probable cause of the collapse was inadequate punching shear capacity in the fifth-floor slab to resist the imposed construction loads. The analysis indicated that punching shear stresses at many slab/column connections were close to the ultimate capacity specified by the Code, (ACI 318-77). Consequently, it was concluded that a punching shear failure at a heavily stressed location triggered a

succession of failures at other locations, resulting in the downward collapse of the entire structure.

B-144 Pace, C. E., Stowe, R. L., and Wong. G. S. 1982 (Sep). "Evaluation of Concrete Cores from Waterbury Dam, Waterbury, VT," Miscellaneous Paper SL-82-14, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

Concrete cores were obtained from Waterbury Dam, Waterbury, VT, for examination and analysis. The cores had an average compressive strength of 5,790 psi which reflects that the strength of the interior concrete of the dam is excellent. The dam has more surface concrete deterioration than is indicated by the cores and core logs. The major cause of surface concrete deterioration is freezing and thawing. There are no signs of monolith misalignment or structural damage; therefore, after the surface concrete has been repaired, the concrete dam will be in excellent condition.

B-145 Pace, C. E., and Alexander, A. M. 1982 (Sep). "In-Place Stability and Deterioration of Structures," Miscellaneous Paper SL-82-20, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

Most old lock and dam structures do not meet current design requirements for stability. Since it is important that current stability requirements are met to ensure structural safety, most of these structures must be modified to increase their resistance to sliding and overturning. These modifications are very expensive and could possibly be avoided if a more exact stability evaluation could be determined.

The stability of structures is presently evaluated by conventional rigid body stability computations, which require many assumptions that may be too conservative. For example, the base of the structure is considered flat when in fact, it may be irregular and keyed into the foundation giving a much greater resistance to sliding. A procedure for determining in-place stability could be very attractive and cost-effective.

A good background in stability evaluation is a prerequisite to beginning in-place stability studies. A brief summary of conventional stability evaluations and some comments about their strengths and weaknesses are presented.

This study verified that in-place stability evaluations can be made. Tests were performed to evaluate in-place stability in the frequency domain. The only realistic evaluation was to determine displacement at zero frequency ($\omega = 0$, static condition). This was not successful because the equipment available for this study would not allow a good definition of D/F close to $\omega = 0$. Other equipment and some development of measurement techniques would allow a good definition of D/F close to $\omega = 0$. The time domain was then investigated and an in-place stability relationship was determined. The ratio of peak dynamic displacement and force, when plotted against ultimate static sliding resistance, gave a good relationship for a wide variety of

interface conditions. Some details of this relationship should be evaluated but are beyond the scope of this study.

B-146 Denson, R. H., Wong, G. S., and Bean, D. 1982 (Sep). "Crack Survey and Gage Installation In Cross-Over Galleries, Kaskaskia Lock, Chester, Illinois," Miscellaneous Paper SL-82-16, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

Previously repaired cracks in the cross-over galleries had begun to weep and form exudation products. These products were sampled and tested. The cracks were cleaned, mapped, and monitor gages were installed. Initial gage readings were made and recorded.

B-147 Mlakar, P. F., and Jones, P. S. 1982 (Oct). "Seismic Analysis of Intake Towers," Technical Report SL-82-8, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

This report discusses practical analytical methods for evaluating the seismic safety of intake towers. Methods of various degrees of sophistication and conservatism are examined which approximately consider linear structural dynamic behavior and site-specific earthquake motion. The need for further research to incorporate other considerations is explained.

B-148 Shah, C. B. 1982 (Nov). "Estimation of Strength of In Situ Concrete," Indian Concrete Journal, Vol 56, No. 11, pp 292-294, Bombay, India.

This article presents an analysis of test results of ultrasonic pulse and rebound hammer methods and shows their correlation with compressive strength.

B-149 Borjan, J. 1982. "Reliability of Nondestructive Concrete Tests," Periodica Polytechnica: Civil Engineering, Vol 26, No. 1-2, pp 109-118, Budapest, Hungary.

Evaluation of the reliability of nondestructive strength assessment must take into consideration that nondestructive strength assessment is an indirect test to estimate the resistance of engineering structures to mechanical effects, as are tests to failure.

Variables of the nondestructive strength assessment are considered as random variables and so are relationship functions of the variables. After a criticism of published strength assessment methods, a short description is given of the research that the five statements of reliable nondestructive strength assessment conditions were deduced from. The procedure has been successfully applied in practice.

B-150 Lozinski, W., and Michalski, B. 1982. "Photoelastic Coating Investigations of Cracking in Concrete" (in Polish), Archiwum Inzynierii Ladowej, Vol 28, No. 3-4, pp 281-293, Warsaw, Poland.

A new concept is presented to detect and localize surface microcracks

as well as to determine their width in reinforced concrete elements. The method developed is employed in investigations of concrete beams reinforced with fibers. The comparison with measurements made by highly sensitive mechanical gages shows its ability to precisely determine crack width during the very initial stages of the cracking process. The photoelastic coating technique seems to be applicable also in analyzing cracking of conventional reinforced concrete elements.

1983

B-151 Knab, L. I., Blessing, G. V., and Clifton, J. R. 1983 (Jan-Feb). "Laboratory Evaluation of Ultrasonics for Crack Detection in Concrete," ACI Journal, Proceedings, Vol 80, No. 1, pp 17-27, Detroit, MI.

A laboratory study was performed to quantify the capabilities of ultrasonic through-transmission methods to detect cracks in concrete. Pulse velocity and amplitude measurements were taken perpendicular to the crack plane (in cracked concrete) and compared with measurements parallel to the crack plane (in uncracked concrete). The direct path length was 152 mm (6 in.). Parallel crack surfaces, approximately 0.55 mm (0.002 in.) apart and having depths of 19, 38, and 57 mm (0.75, 1.50, and 2.25 in.) and widths of 152 mm (6 in.), were fabricated in the specimens. Transducer frequencies of 150 and 54 kHz were used.

Concrete specimens with a 28-day compressive strength of about 36 MPa (5.2 ksi) were tested at several ages.

A sensitivity ratio was used to determine if the cracks could be detected. The numerator of the sensitivity ratio was the difference between velocity or amplitude values in the cracked as compared to uncracked concrete, while the denominator represented the variability of the velocity or amplitude values in both the cracked and uncracked concrete. With the 57- and 38-mm (2.25- and 1.5-in.)-deep cracks, nearly all the sensitivity values for velocity and amplitude indicated that these crack depths could be detected under the test conditions. The velocity and amplitude sensitivity values with the 19-mm (0.75-in.) crack depth were lower, indicating that the 19-mm (0.75-in.) crack depth could not be clearly detected. In this study, it was concluded that both velocity and amplitude were meaningful parameters in crack detection. Based on the sensitivity values, however, velocity appeared to be the more meaningful parameter.

B-152 Gast, V. R., and Hoba, J. 1983. "Non-Destructive Testing of Concrete - Experience Obtained with DIN 1048 Parts 2 and 4" (in German), Beton, Vol 1, No. 33, pp 20-23, Dusseldorf, West Germany.

To determine the resistance of existing concrete structural elements, architects and structural engineers are often forced to test structures. By applying the destructive and nondestructive testing procedures of DIN 1048, Part 2 and 4, the compressive strength of concrete in structures and parts of structures can be determined. A commission

for the verification of the values established by these standard sheets has been formed by the Union of German Concrete Engineers, and experiences with nondestructive testing procedures have been compiled.

B-153 Romer, B. 1983. "Microscopic Examinations and Analyses for the Diagnoses of Damage Structures and the Restoration of Structures: Damage to Concrete Weathering of Natural Stone," Proceedings of the Fifth International Conference on Cement Microscopy, Nashville, TN, 14-17 Mar 1983, pp 189-203, International Cement Microscopy Assoc., Duncanville, TX.

The use and indications of microscopic microstructure-analytical examinations of building materials are discussed as a further diagnostic determination of the durability of concrete. Concrete and natural stone on structures, also other porous building materials, often exhibit deficient performance and consequential damage which lead to premature failure and damage to structures. The fundamental cause of deficient performance of building materials is overloading caused by either insufficient quality and stability or by excessive influence from the design, utilization, and environment.

B-154 Fookes, P. G. 1983 (Apr). "Field Investigation of Concrete Structure in South-West England," Concrete, Vol 17, No. 4, pp 60-65, London, England.

This article presents results of a field classification system for concrete structures and detailed mapping of members. Signs of deterioration discovered in the concrete and the mapping process and defects observed in a parking facility are described. The classification system and determining rates of deterioration are also discussed.

B-155 Chiem, C. H., et al. 1983 (May). "Detection of Cracks on Highway Pavements," Research Report No. 256-3, Center for Transportation Research, University of Texas, Austin, TX.

In a maintenance management program for continuously reinforced concrete pavement, the rate of change of the crack spacing should be determined. When the spacing becomes smaller than the designed spacing, there is potential for failure, and therefore, preventive maintenance may be considered. Measurement of spacing is impractical in areas with heavy traffic, so image processing techniques using aerial photographs are used. Algorithms for crack detection in aerial photographs are also used.

This report explains the problems associated with detecting crack spacing on pavement. It also covers edge detection, detection of road sections, algorithms for locating cracks, and evaluates the different types of algorithms that may be used for crack detection.

B-156 Gross, K. P. 1983 (Jun). "New Method for Determining Deformations and Crack Widths, of Reinforced Concrete Load Structures" (in German), Material-pruefung, Vol 25, No. 6, pp 193-197, Germany.

Laser speckle photography is a new optical method for nondestructive measurement of deformations in a plane perpendicular to the optical axis of the recording system. The method is also suited for studying test samples made of concrete. The limits of a measurement range may be varied by choosing suitable imaging scales and diaphragm number. The only disadvantages of the method are the sensitivity to movements of the test sample in the direction of the optical axis and the relatively large amount of work required in the evaluation. With a view to solving this problem, a semiautomatic system which has been in operation for some time has proven itself to be very effective in crack detection and crack width measurement.

B-157 Gupta, P. K. 1983 (Jul). "Survey of Concrete Deterioration in Bridge Substructures," New York Division Report No. SR-73; FHWA/NY/SR-83/73, New York State Department of Transportation, Engineering Research and Development Bureau, Federal Highway Administration, Albany, NY.

The condition of bridge substructure elements in New York State was examined through a reconnaissance survey of 45 bridges in Regions 1 (Albany), 4 (Rochester), 7 (Watertown), and 9 (Binghamton) and an analysis of condition ratings of specific substructure elements obtained from the Department's computer-stored inventory. Concrete from substructure beams and columns was sampled and tested to confirm the principal causes of deterioration. The condition of most substructure members was found to be satisfactory and these members are expected to provide long service lives. Some problems were observed with pier cap beams and pier columns in the 11- to 15-year age group in Regions 4 and 5 and are expected to deteriorate with time. Open cracking and spalling were the principal types of defects affecting columns and beams and were due to corrosion of embedded steel.

B-158 Hafermann, G. R. 1983 (Jul). "Application of Thermal Imagery on CRCP (Continuously Reinforced Concrete Pavements) and Bridge Decks," Wisconsin Division Report FHWA/WI-83/1, Wisconsin Department of Transportation, Federal Highway Administration, Madison, WI.

A previous study determined that a van-mounted thermal scanning system provided a practical method of identifying subsurface delamination in continuously reinforced concrete pavements. A 1-year extension of that study was initiated to determine if earlier stages of delamination could be detected and if the severity of delamination could be measured. The report describes the data acquisition, data analysis, problems, conclusions, and recommendations of that 1-year extension. The extended research involved scanning sections of three highway pavements and six bridge decks. Four-in.-diameter cores were taken at 39 locations to evaluate the accuracy of the thermographic system.

B-159 Hom, S., and Kost, G. 1983 (Jul). "Investigation and Repair of Post-Tensioned Concrete Slabs - A Case History," Concrete International: Design & Construction, Vol 5, No. 7, Detroit, MI.

Prestressed concrete floor systems that are rigidly restrained against movement have been experiencing severe structural cracking in many buildings that were constructed 10 to 15 years ago. This paper presents a case history of the investigation of such a floor system in a three-story underground parking garage that was designed and constructed in the late 1960's. The floor system consists of post-tensioned beams and slabs rigidly anchored to the exterior walls.

The indications of a distress condition were (1) the excessive amount of movement at an expansion joint separating two portions of the garage, and (2) the multiplicity of cracks in the slabs and columns. A finite-element analysis was performed to confirm that concrete shrinkage and creep were the main contributors to cracking. The crack pattern generated for the analysis compared very well with the actual crack pattern of the slab. To ensure the structural integrity of the slabs, the cracks were pressure grouted with epoxy adhesive, and a subsequent load test was performed on a portion of the slab. The analysis, repair, and testing of the slab are presented and discussed.

B-160 Carino, N. J., Woodward, K. A., Leyendecker, E. V., and Fattal, S. G. 1983 (Jul). "A Review of the Skyline Plaza Collapse," Concrete International: Design & Construction, Vol 5, No. 7, Detroit, MI.

On March 2, 1973, portions of the Skyline Plaza apartment building, under construction in Fairfax County, VA, collapsed. The failure resulted in the death of 14 workers; 34 others were injured.

This article summarizes the results of the failure investigation carried out by the National Bureau of Standards. Based on structural analyses and estimates of concrete strength at the time of collapse, NBS investigators concluded that the probable cause was a punching shear failure of the 23rd floor slab. The critical condition was attributed to: (1) premature removal of shoring below the 23rd floor slab at the time the 24th floor was being placed, and (2) the low strength of that portion of the 23rd floor which was unshored.

B-161 Kashino, N. 1983. "Evaluation System on Corrosion of Reinforcing Bars in Concrete," Conference on To Build and Take Care of What We Have Built with Limited Resources, CIB 83, The 9th CIB Congress, Stockholm, Sweden 15-19 Aug 1983, Vol 2, pp 101-111, National Swedish Institute for Building Research, Gavle, Sweden.

The durability of an actual reinforced concrete structure is governed to a great extent by the progressive nature (corrosion rate not less than 0.15 mm/yr) of corrosion of reinforcing bars in the concrete. Although there are various ways of investigating corrosion of internal reinforcing bars such as electrochemical methods, physical techniques, etc., a method of evaluating the state of corrosion by visual

observations in chipping investigations is proposed as a simple but sure procedure.

B-162 Currie, R. J. 1983. "Assessment of the Long Term Durability of Reinforced Concrete Structures," Conference on To Build and Take Care of What We Have Built with Limited Resources, CIB 83, The 9th CIB Congress, Conference Location: Stockholm, Sweden, 15-19 Aug 1983, Vol 2, pp 57-68, National Swedish Institute for Building Research, Gavle, Sweden.

A description is given of data related to reinforcement corrosion which has been obtained through site investigations of reinforced concrete structures. The evidence from these investigations is used together with research data obtained from exposure site tests to establish the likely time-scale to the onset of corrosion. This, in turn, enables structures to be categorized in terms of risk from reinforcement corrosion, using results from routine chemical analysis of the concrete.

B-163 Mullick, A. K. 1983. "Probabilistic Assessment of Service Life of Concrete Structures Based on Condition Survey," To Build and Take Care of What We Have Built with Limited Resources, CIB 83, The 9th CIB Congress, Stockholm, Sweden 15-19 Aug 1983, Vol 2, pp 159-170, National Swedish Institute for Building Research, Gavle, Sweden.

Prediction of service life of concrete structures is of interest for life cycle design and optimal planning of maintenance and repair actions. Design of concrete structures for durability is generally restricted to adherence to specifications of materials, mix proportions, and workmanship. The assignment of 'performance' of a structure built to such 'prescriptive' specifications is always difficult. Accelerated tests in the laboratories fail to simulate the random nature of the service environment and interaction of causative factors. An alternative, probabilistic approach to the assessment of service life of concrete structures, based on Markov Chain stochastic process model, is suggested.

B-164 Idorn, G. M., and Thaulow, N. 1983 (Sep). "Examination of 136 Year Old Portland Cement Concrete," Cement and Concrete Research, Vol 13, No. 5, pp 739-743, Elmsford, NY.

A piece of portland-cement concrete cast in England in 1847 was examined by advanced petrographic methods. The concrete was dense, well preserved, and air entrained. Unhydrated and hydrating fragments of the clinker components C_3S and C_2S are present in the cement paste. Residual ferrite phases seem to have remained unhydrated.

B-165 Wong, G. S. 1983 (Sep). "Evaluation of Concrete Cores, Caruthersville Floodwall," Miscellaneous Paper SL-83-17, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

Core drilling followed by laboratory testing provided petrographic and physical data on the concrete from the Caruthersville Floodwall. The

floodwall consisted of an old wall constructed before 1932 and a newer wall constructed in 1932. Concrete cores representing the old and newer concrete from various locations in the structure were tested to determine ultrasonic pulse velocity, compressive strength, and density.

The petrographic examination indicated the presence of an alkali-silica reaction product as isolated fillings in voids, coating some aggregate particles, and, in some instances, as coatings of cracked surfaces. No other deleterious chemical reaction product was identified in the concrete.

The compressional wave velocities had an average value of over 15,000 fps for the new concrete and over 14,500 fps for the old concrete. The average compressive strengths were 7,630 psi for the newer concrete and 3,790 psi for the old concrete. One specimen of old concrete tested had a low ultrasonic pulse velocity of 10,970 fps, which correlated to a low compressive strength of 2,020 psi. Concrete densities were all consistently near 150 lb/cu ft.

In general, the concrete appeared to be in acceptable condition. Only minor repairs involving monolith joints, isolated vertical cracks within monoliths, and areas of localized deteriorated concrete were recommended.

B-166 Chung, H. W., and Law, K. S. 1983 (Oct). "Diagnosing in Situ Concrete by Ultrasonic Pulse Technique," Concrete International: Design & Construction, Vol 5, No. 10, pp 42-49, Detroit, MI.

This article describes field applications of the ultrasonic pulse velocity technique in testing concrete, using the portable V-meter. Effects of mix proportions, reinforcing bars, and voids are examined. Methods of assessing the uniformity of concrete and detecting voids or honeycombs are discussed. A semiempirical approach is proposed for estimating concrete strength from pulse velocity measurement. A process is also suggested to approximately assess the fire damage of concrete.

B-167 Bungey, J. H. 1983 (Oct). "Non-Destructive Testing: Part 2," Concrete, Vol 17, No. 10, pp 49-50, London, England.

This article describes new strength assessment test methods, integrity tests, and potential durability assessment. Principal new strength tests only measure concrete in the surface region. They cause a limited amount of surface damage but directly measure a strength-related property. Calibrations are therefore not sensitive to such a wide range of variables as for the truly nondestructive test methods. The internal fracture tests, pullout tests, pulloff tests, penetration resistance tests, and breakoff tests are discussed.

Major developments in dynamic response testing that allow testing of dimensions and integrity of structures are overviewed. These include the pulse echo method, impact tester, and infrared thermography.

Halfcell potential assessments and resistivity measurement as methods of potential durability assessment are discussed.

B-168 Brillet, F., and Gothe, M. 1983 (Sep-Oct). "Seasonal Variations in the Adhesion of Pavements Measured with the SCRIM Apparatus" (in French), Bulletin de Liaison, No. 127, pp 37-52, Paris, France.

The SCRIM (Sideways force Coefficient Routine Investigation Machine) developed in Great Britain has been used in France since 1974 for examining the skid-resistance properties of the French highway network. This machine has continuously measured the sideways force coefficient (SFC) of a bald tire on a wet pavement at 60 km/hr. The article describes the studies conducted to better determine SFC variations due to factors not easily controlled. It draws practical conclusions with regard to the operational use of the measurements within the framework of the scheduling of pavement maintenance operations. The factors considered are the following: position of the machine cross section, horizontal alignment of the road, wear of the measurement tire, and climatic influences. Experiments make use of several methods including the computer processing of a large number of values (measurements distributed over 8 years) using statistical methods. The reproducibility of the measurements would be very good if it were possible to overcome seasonal variations due to climatic factors. Several correction methods are proposed for this purpose.

B-169 Clemena, G. G. 1983. "Nondestructive Inspection of Overlaid Bridge Decks with Ground-Penetrating Radar," Transportation Research Record 899, pp 21-32, Transportation Research Board, Washington, DC.

An ongoing study on the use of ground-penetrating radar for the nondestructive inspection of overlaid concrete bridge decks is described. The technique, which uses microwave pulses, should be particularly valuable in the inspection of box-girder and similar types of decks for which even the undersides are inaccessible for visual inspection. The study has indicated that radar can be used to survey the conditions of not only overlaid decks but also decks that have their original surfaces. It also has shown that delaminations in a concrete deck are manifested as irregularities, or recognizable signatures in recorded microwave reflection bands that result from reflections at the top mat of the reinforcing bars.

B-170 Hays, C. O., Jr., Fagundo, F. E., and Callis, E. C. 1983. "Study of Cracking of Composite Deck Bridge on I-75 Over Peace River," Transportation Research Record 903, pp 35-44, Transportation Research Board, Washington, DC.

When the Peace River Bridge on Interstate 75 near Punta Gorda, FL, started cracking, concern was raised about the possibility of high maintenance cost and the structural adequacy of the bridge system. The deck system consists of precast panels resting on soft fiberboard, which served as formwork for the road surface and later aided in carrying traffic loads. An investigation began involving an analytical

model using the finite element method and limited laboratory testing on beam specimens, indicating that although the Peace River Bridge is adequate to carry normal traffic, the shear stresses in the bridge deck are substantially higher than those of deck systems that have positive bearing at the end of the panels.

B-171 Beal, D. B. 1983. "Tests to Failure of the Hannocroix Creek Bridge," Transportation Research Record 903, pp 15-22, Transportation Research Board, Washington, DC.

This article describes the destructive testing of a 52-year-old bridge to evaluate the effects of concrete deterioration on load capacity. Test results showed that the deterioration noted has no significance on the load-carrying capacity of the structure. Based on theoretical arguments, it was concluded that deterioration sufficient for serious reduction in the structure's capacity would be manifested in a local collapse and that overall failure of reinforced concrete T-beam bridges should not be a concern.

B-172 Nazarian, S., Stokoe, K. H., II, and Hudson, W. R. 1983. "Use of Spectral Analysis of Surface Waves Method for Determination of Moduli and Thicknesses of Pavement Systems," Transportation Research Record 930, pp 38-45, Transportation Research Board, Washington, DC.

The spectral analysis of surface waves (SASW) method is a nondestructive method for determining moduli and thickness of pavement systems. By means of a transient impact on the surface of a pavement system (or soil deposit), a group of waves with different frequencies is transmitted to the medium. Seismic wave velocities and, eventually, elastic moduli and thickness of the various layers in the pavement system are determined from analysis of the phase information for each frequency determined between two receivers located on the surface. The method has several advantages: it is nondestructive, has a unique solution, and is capable of full automation. The results of three series of tests performed on an asphaltic concrete pavement, a continuously reinforced concrete pavement, and a natural soil occupying the median at the site are presented. Elastic moduli determined by using the SASW method are compared with those determined by means of crosshole seismic tests and dynaflect measurements. Moduli determined by the SASW method are in agreement with those from crosshole tests, whereas moduli back-calculated from dynaflect measurements compare rather unfavorably with moduli determined by the other two methods.

B-173 "Safety of Existing Dams: Evaluation and Improvement." 1983. National Academy Press, Washington, DC.

In May 1982, the Corps of Engineers reported that no remediation had been begun at 64 percent of the unsafe dams identified in its 4-year inspection program. The principal reason for this inaction was the owners' lack of financial resources. This report, prepared by a committee of experts in dam engineering and safety, provides guidance for assessing and remediating existing dams within financial restraints.

Emphasis is placed on risk-based decision analyses which allow for remedying deficiencies progressively while funding is being sought. The report includes case histories that are examples of economic solutions to specific problems. Topics covered are risk assessment techniques, stability of masonry and embankment dams and cheir foundations, hydraulic and hydrologic considerations, and instrumentation.

B-174 Smith, L., and Placido, F. 1983. "Thermoluminescence: A Comparison with the Residual Strength of Various Concretes," Fire Safety of Concrete Structures, SP-80, American Concrete Institute, Detroit, MI.

Conventional methods for the assessment of fire damaged concrete structures tend to be unreliable, since in post-real fire situations accurate estimates of the temperatures reached and the resulting distribution of damage are at present impossible. The thermoluminescence test gives a measure of thermal history of a sample of concrete. The residual compressive strength of various concretes has depended on the thermal exposure rather than just the maximum temperature reached in a fire. The correlation between the residual compressive strength of the concrete and the thermoluminescence signal remaining in small samples of quartz sand extracted from the concrete is described. This may allow a criterion to be established for the acceptance or rejection of fire exposed concrete where no obvious visual damage is apparent and would therefore provide us with information which would promote greater understanding of the residual condition of a fire damage concrete structure.

B-175 Gustaferro, A. 1983. "Experiences from Evaluating Fire-Damaged Concrete Structures," Fire Safety of Concrete Structures, SP-80, American Concrete Institute, Detroit, MI.

The author describes evaluations of structural damage caused by accidental fires to buildings, bridges and outdoor industrial structures constructed of reinforced concrete, cast-in-place posttensioned concrete, or precast prestressed concrete. Techniques for evaluating structural damage include visual inspections, nondestructive testing, laboratory tests of samples of steel and concrete, and load tests. Most damaged structures can be repaired by concrete restoration procedures, but it is sometimes more economical to replace damaged portions of structures.

1984

B-176 Jones, W. 1984 (Jan). "Inspection and Maintenance of Highway Structures," Municipal Engineer, Vol 111, No. 1, pp 16-19, Wales.

The aim of this paper is to outline the inspection procedures with regard to trunk road bridges and review the various methods employed in rectifying the more common faults associated with masonry arches and steel/concrete structures. The importance of sound inspection methods backed by adequate records is of prime importance. This enables defects to be detected at an early stage and effective repairs

implemented. The different repair techniques outlined in the paper are intended as a guide only, and the most appropriate solution must be found according to the particular circumstances.

B-177 Christory, J. P. 1984 (Jan-Feb). "Continuous Non-Destructive Inspection of Concrete Pavements: Aspects of the Method Employed in France for the Road Network Managed by the Administration" (in French), Bulletin de Liaison des Laboratoires des Ponts et Chaussees, No. 129, pp 99-109, Paris, France.

Defects in concrete slabs are rarely attributable to the cement concrete, but their evolution is mainly linked with the deterioration of their bearing conditions. The main purpose of nondestructive inspection is to assess these bearing conditions. Semirapid measuring instruments, some of which work under traffic at speeds above 50 km/hr, were developed for the most significant indicators (deterioration of slabs, shifting of slabs, and slab rocking).

GERPHO, the High Efficiency Unit for Photographic Surveying of Road Surface, continuously photographs pavement traffic lanes and the part of the hard shoulder for emergency stops at a speed of 50 km/hr. It is particularly good at detecting structural defects in concrete pavements, i.e., cracks and points where pumping phenomena occur between slabs.

The L.P.A. (Longitudinal Profile Analyzer) used with a special data processing version provides information on the shifting of slabs from measurements made at 72 km/hr.

The D.M.B.D. (Slab Rocking Measurement Instrument) works at a much slower speed of about 1 km/hr. Subject to a few precautions relating to temperature conditions, this instrument gives information on the bearing conditions of slabs before any visible defect occurs.

Apart from their contribution to pavement inspection and pavement maintenance programming, these instruments can be used operationally during actual road works, i.e., in applying certain techniques and remedial measures relating to slabs (injection, dowelling. etc.).

B-178 Sullivan, B. R., Pace, C. E., and Campbell, R. L. 1984 (Feb). "Condition Evaluation of Supersonic Naval Ordnance Research Track (SNORT)," Miscellaneous Paper SL-84-1, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

In December 1981, the Waterways Experiment Station, at the request of the Naval Weapons Center, began an evaluation of the condition of the Supersonic Naval Ordnance Research Track (SNORT) at China Lake, California. The evaluation included both theoretical analysis and field tests. The concrete, soil, and water were sampled and tested in the laboratory. Nondestructive tests were used to determine locations for coring concrete and to develop a condition profile for the structure.

B-179 Buck, A. D. 1984 (Feb). "Alkali-Silica Reaction in Concrete in a North Dakota Highway," Miscellaneous Paper SL-84-2, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

The North Dakota State Highway Department discovered cracking in concrete on Interstate Highway 94 east of Dickinson in about 1979 when the concrete was about 15 years old. While the cracking was primarily in the eastbound lanes where high-alkali portland cement had been used, it had the appearance of "D" cracking. The fine aggregate was local natural sand with a good service record, while the coarse aggregate was a mixed gravel from eastern Montana with no known service record. The question therefore was: "Is the cracking due to alkali-silica reaction, to freezing and thawing, or to both, or to some other factor or factors?"

Petrographic examination of concrete cores from the cracked pavement and dilation testing of some of these for resistance to freezing and thawing showed the presence of significant amounts of products of alkali-silica reaction and satisfactory frost resistance. It was concluded that the cracking was due to alkali-silica reaction.

B-180 Verhulst, K. 1984 (Mar). "Acoustical Inspection of Offshore Constructions" (in Dutch), Cement, Vol 36, No. 3, pp 173-176, The Netherlands.

This article describes acoustical inspection methods for determining durability of offshore underwater structures. Three techniques that have been demonstrated experimentally to detect surface cracking are discussed, as is the research directed toward developing methods for determining crack width and depth.

B-181 Claytor, T. N., and Ellingson, W. A. 1984 (Apr). State-of-the-Art Review of Acoustic Techniques for Application to the Nondestructive Evaluation of Refractory Concrete for Coal Gasification," Report ANL/FE-83-23, Argonne National Laboratories, IL.

Acoustic methods provide a promising approach to measuring the thickness and quality of concrete structures that are accessible from only one side, such as refractory linings of coal gasifier vessels. This report discusses the theoretical and practical factors that must be taken into account when designing acoustic systems for this purpose and gives a critical review of the systems that have been developed to date. Recommendations for the development of more effective acoustic systems are also presented.

B-182 (Deleted)

B-183 Schickert, G. 1984 (May-Jun). "Critical Reflections on Nondestructive Testing of Concrete," Materials and Structures, Research and Testing, Vol 17, No. 99, pp 217-223, Paris, France.

Sclerometer tests, the ultrasonic pulse velocity method, the acoustic emission technique, and combined nondestructive methods for testing

concrete properties are discussed. Examples and test results obtained by investigations with rigid and flexible loading platens show the efficiency of additional nondestructive testing. Finally, the nondestructive testing methods under consideration as independent testing tools are critically analyzed under several aspects.

B-184 Akman, M. S., and Guner, A. 1984 (May-Jun). "Applicability of Sonreb Method on Damaged Concrete," Materials and Structures, Research and Testing, Vol 17, No. 99, pp 195-200, Paris, France.

In damaged structures, a knowledge of the value of the residual concrete strength is needed as a basis for the decision of reconstructing or repairing and for the design of the repair project. In this work, the limits of applicability of the Sonreb method, a combination of the ultrasonic pulse velocity and the Schmidt index measurement, in the detection of damage caused by high temperatures and chemical attack by ammonium nitrate and ammonium sulfate is discussed. It is concluded that the Sonreb method can be used in assessing the fire-damaged concretes after making a classification of the degree of damage, the duration and the temperature of exposure to fire. In the case of chemical attack, a knowledge is required as to the duration of exposure and the prevailing process of corrosion.

B-185 Al-Hamed, A. H. M. S. 1984 (Jun). Evaluation of the Windsor Probe Test to Assess In Situ Concrete Strength," Proceedings, Institution of Civil Engineers, London, Part 2, Research and Theory, Vol 77, pp 167-194.

A comprehensive study on the use of the Windsor probe system to assess in situ strength of concrete is reported. The tests were carried out on slabs of normal weight and lightweight concrete having a strength of 5 to 70 N/mm2 up to about 1 year. The effect of aggregate type and aggregate size was also investigated. Results are related to pulse velocity, internal fracture, and core tests. If the Windsor probe system is used to evaluate absolute values of in situ strength, separate calibration charts are necessary to account for type of concrete, size of aggregate, aggregate type, and age. As a general method of nondestructive testing, the probe system estimated strength up to 28 days better than small-diameter cores, while the small-diameter cores better estimated strength of old concrete. In particular, the probe system appeared unable to identify low strength at 1 year.

B-186 Gamble, W. L. 1984 (Jun). "Bridge Evaluation Yields Valuable Lessons," Concrete International: Design & Construction, Vol 6, No 6, Detroit, MI.

Major shear cracking of both girders of a multispan reinforced concrete bridge occurred about 10 years after it was completed. Low-strength concrete was discovered in the failure region, but it also appears that axial tension was a very important factor. The bridge was evaluated and repaired and is in service today without load restrictions.

B-187 Carino, N. J., and Sansalone, M. 1984 (Jul). "Pulse-Echo Method for Flaw Detection in Concrete," Report NBS/TN-1199, National Bureau of Standards, Center for Building Technology, Washington, DC.

The basic principles of the pulse-echo method for the detection of internal flaws in concrete are presented. As the heterogeneous nature of concrete poses problems not encountered in pulse-echo evaluation of metals, progress in this area of concrete nondestructive testing has been slow. A review of past research shows that pulse-echo techniques have been used successfully to detect flaws within concrete; however, no standardized method currently exists for pulse-echo evaluation of concrete structures. Based on the current state of knowledge, areas of needed research are outlined.

B-188 Stowe, R. L., and Thornton, H. T., Jr. 1984 (Sep). "Engineering Condition Survey of Concrete in Service," Technical Report REMR-CS-1, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

Civil works structures must be continually evaluated for structural safety, stability, and operational adequacy. The overall objective of the investigation documented in the report is to develop information essential to the continued safety of concrete used in civil works structures such as flood control and multipurpose dams, navigation locks and dams, powerhouses and appurtenant structures, floodwalls, pumping stations, and similar structures. Specific objectives include (a) development and evaluation of materials and techniques for repair and rehabilitation of civil works structures, (b) development of engineering guidance to evaluate and monitor safety of structures, and (c) development of design and construction methods for rehabilitating older structures to comply with current structural design criteria.

B-189 (Deleted)

B-190 Di Leo, A., Pascale, G., and Viola, E. 1984 (Oct). "Core Sampling Size in Nondestructive Testing of Concrete Structures," Conference on In Situ/Nondestructive Testing of Concrete, Ottawa, Ontario, Canada, Oct 1984, SP-82, pp 459-477, American Concrete Institute, Detroit, MI.

In this paper a procedure aimed to assess the characteristic value of actual compressive strength of in situ concrete is presented. It involves: an evaluation of the homogeneity, which may suggest a subdivision of the structure in parts characterized by different estimated strength levels; a calibration of estimated strength values on the basis of a sample of cores. The experimental values obtained from cores can be utilized to modify the characteristic value of estimated strength: by means of an appropriate correcting coefficient; statistically through the Bayesian approach, according to which the mean value of the actual strength is considered as a random variable. Consequently, its characteristic value also becomes a random variable.

B-191 Prakash Rao, D. S. 1984 (Oct). "Some Pitfalls in the Ultrasonic Pulse Velocity Method of Testing Hardened Concrete," Indian Concrete Journal, Vol 58, No. 10, pp 254-273, Bombay, India.

Ultrasonic pulse velocity (UPV) method of testing hardened concrete is extremely simple and large amounts of data can be collected in a short time. However, interpretation of results is not always easy due to the large number of factors that affect the pulse velocity. The method and some of the problems in assessing the data from tests on concrete are discussed. It is emphasized that like most nondestructive techniques of testing, hardened concrete UPV can only supplement engineering judgment and cannot substitute for it.

B-192 Hillger, W., and Neisecke, J. 1984 (Nov). "Ultrasonic Pulse Technique for the Automatic Non-Destructive Quality Control of Precast Concrete Components" (in German and English), Betonwerk und Fertigteil-Technik, Vol 50, No. 11, pp 769-773, Weisbaden, Germany.

Ultrasonic measurements can be used to observe relative changes in concrete. Besides the pulse propagation time measurements commonly employed, amplitude or intensity measurements can be used with considerable advantage due to their great sensitivity.

B-193 Fookes, P. G., Cann, J., and Comberbach, C. D. 1984 (Nov). "Field Investigation of Concrete Structures in South-West England, Concrete, Vol 18, No. 11, pp 12-16, London, England.

A diagnosis of the alkali-aggregate reaction in set concrete, made solely from an examination of the surface effects, is not always accurate, since similar effects may sometimes be produced by, for example, sulphate attack, shrinkage, freezing and thawing, or structural cracking. For confirmation, it is necessary to make a laboratory examination of concrete samples taken from the diseased structures. As discussed in Parts 1 and 2, deterioration due to alkali-aggregate reactivity is often combined with other phenomena, which complicates field recognition. The following laboratory work normally is carried out: field inspection (megascopic); laboratory examination of cores and concrete samples (macroscopic; and (3) petrographic examination (microscopic). Additional supplementary laboratory tests if required are: chemical analyses; X-ray diffraction; electron probe analysis, and infrared spectrophotometry.

B-194 Andrade, C., Castelo, V., Alonso, C., and Gonzalez, J. A. 1984 (Nov). "The Determination of the Corrosion Rate of Steel Embedded in Concrete by the Polarization Resistance and AC Impedance Methods," Symposium on Corrosion Effect of Stray Currents and the Techniques for Evaluating Corrosion of Rebars in Concrete, ASTM Committee G-1 on Corrosion of Metals, Williamsburg, VA.

The polarization resistance Rp determination has been widely used by the authors to measure the corrosion rate of steel bars embedded in concrete in many different situations. The AC impedance measures have

now started to be used within the same system. In the present paper, we present the way to obtain accurate data by the Rp method. Comparison of the results of Rp with the weight losses determined gravimetrically and some of the results of the corrosion rates of steel bars embedded in concrete calculated by this method are presented. Also, presented here are results of AC impedance of the reinforcements obtained through a spectrum analyzer. Additionally, the different graphical methods for representing the results and the accuracy of this technique in comparison with those of the Rp method are discussed. Finally, some considerations about the use of both techniques are drawn.

B-195 "Specialized Concrete Evaluation and Testing." 1984 (Dec). Concrete Construction, Vol 29, No. 12, pp 1097-1100, Addison, IL.

This article presents problematic situations in concrete construction practices and the specialized testing services needed to remedy the particular problem. Standard methods for conducting tests used to evaluate concrete are discussed, including rebound, pullout, load testing, petrography, etc. A table listing some nondestructive test applications is provided.

B-196 Bhuyan, S., and Tracy, R. G. 1984. "Corrosion of Galvanized Steel Floor Slab Reinforcement," Transportation Research Record 962, pp 82-85, Transportation Research Board, Washington, DC.

A 17-year-old parking facility in metropolitan Detroit is experiencing floor slab deterioration. An investigation was performed to determine the nature and extent of deterioration and identify possible restoration alternatives. The investigation involved visual observation, materials testing, a chain-drag delamination survey, and determination of concrete cover to slab reinforcement.

The structural frame consists of a 12-in.-thick flat plate floor system spanning in two directions supported by columns approximately 30 ft on centers. Floor slab reinforcement in the top and bottom slab sections consists of galvanized steel bars.

The floor slab and ceiling deteriorated from corrosion-induced spalling; chain drag and coring surveys indicate that approximately 26 percent of exposed floor surfaces and 5 percent of ceiling surfaces are delaminated or spalled to a depth of about 2 in. Clear concrete cover is generally good, with a low cover of about 1.25 in. and an average cover of about 2.25 in.

The chloride content of the concrete, determined within the top 3 in. of the slab, ranged from 25.2 to 8.5 yd^3 of concrete. The average compressive strength of the floor slab is about 5,670 psi. The average air content of the concrete was determined to be 2.3 percent. Slab concrete pH ranges from 9.93 at the deck surface to 10.82 at the 3-in. depth. Reinforcement section loss of up to 20 percent was noted at isolated areas.

B-197 Valbuena, J. H. 1984. "Pathology of a Cracked Structure" (in Spanish), Technical Bulletin 74-75, pp 143-170, Central University of Venezuela, Institute of Structural Materials and Models, Caracas, Venezuela.

Within the context of the pathology of concrete structures, the cracking degradation of concrete is studied through a structure that exhibited severe cracking under extreme environmental conditions before being used. The numerous factors that point out the causes of damage are emphasized, and a very broad continuous symptomatology is established. These factors have been traced from the initial anomalies to the final diagnosis.

B-198 Yener, M., and Chen, W. F. 1984. "In-Place Strength of Concrete and Pullout Tests," Cement, Concrete, and Aggregates, Vol 6, No. 2, pp 90-99, Philadelphia, PA.

The current status of in-place strength evaluation of concrete is discussed. A literature survey regarding the controversy surrounding the assessment of concrete strength through field-cast laboratory-cured cylinder tests is presented. Inconsistencies associated with the drilling and testing of cores for determining in-place concrete strength are pointed out. On the basis of these arguments, the necessity of developing alternative nondestructive test procedures is emphasized. This is followed by a detailed discussion on the status of the pullout test method as a measure of compressive strength of in-place concrete, which appears to be a potentially feasible nondestructive test procedure.

B-199 Haksever, A., and Krampf, L. 1984. "Possibilities to Value Subsequently Temperatures Which May Have Occurred Within Concrete Building Elements During a Fire," Deutscher Ausschuss fur Stahlbeton, Bulletin 352, pp 35-65, Berlin, Germany.

This article presents information to help the engineer who is forced to decide if a reinforced or prestressed concrete structure damaged by a fire can be reused after repair or if the building must be demolished. A catalog of circumstances and vestiges which can be found when the affected building is visited and which allow conclusions concerning the intensity of the fire and the resulting value of damages to the structural elements is given. General information concerning the development of natural fires and the parameters influencing it is also given. The thermodynamic basis to calculate the temperature rise in concrete cross sections is explained. Information concerning residual changes of material properties due to temperature influences is also provided.

B-200 "Repair of Concrete Damaged by Reinforcement Corrosion." 1984. Concrete Society, Technical Report CS/TR-26, London, England.

This report is an authoritative guide to the investigation and repair of concrete damaged by reinforcement corrosion. The three principal factors which cause deterioration to reinforcement - low cover to

steel, permeable concrete, high chloride levels - are described. Detailed guidance on diagnosis of the cause of corrosion and on inspection of concrete structures is given, together with advice on carrying out in situ and laboratory tests. The general principles of concrete repair, the stages in the repair process, operational factors, and choice of method are discussed in detail. Guidance is given on the main systems currently used; recasting; sprayed concrete and mortar; hand-applied plain and polymer-modified cementitious mortars; hand-applied resin-based mortars; repair of cracks; coatings. Aspects of the conditions of contract, specification and measurement are discussed. An extensive list of references and sources of further information is included.

B-201 Koerner, R. M., Leaird, J. D., and Welsh, J. P. 1984. "Uses of Acoustic Emissions as a Non-Destructive Testing Method to Monitor Grouting," Innovative Cement Grouting, SP-83, American Concrete Institute, Detroit, MI.

The detection and monitoring of subsurface flow phenomena, such as seepage, grouting, and hydrofracturing, are significant and largely unsolved problem areas. As a nondestructive testing technique, the acoustic emission (AE) method seems to be a likely candidate technique for application to these problems.

This paper describes the AE method, in general, and a particular AE system which holds significant promise in this regard. It is a multichannel AE system which will eventually source locate the emissions in three dimensions and in real time on a CRT screen. A series of laboratory tests, where equipment selection and proper system tuning were made, are described. Two field tests where chemical and cement grouts were being injected were also monitored with positive results, indicating the technical feasibility of the method. Computer software is presently being developed and, when complete, further field tests will be forthcoming.

B-202 Zoldners, N. G., and Soles, J. A. 1984. "An Annotated Bibliography on Nondestructive Testing of Concrete, 1975-1983," In Situ/Nondestructive Testing of Concrete, SP-82, American Concrete Institute, Detroit, MI.

Nondestructive concrete testing methods provide construction engineers and concrete technologists with useful tools for quality control of concrete and for evaluating the strength and durability of existing structures. This annotated bibliography, chronologically arranged, compiles literature published from 1975 to 1983 on innovations and modifications of nondestructive methods used for the testing of concrete. Attention was focused on the new methods used for monitoring concrete deterioration, crack development, and corrosion of reinforcement.

The journals, symposia, and books selected for review have international stature, and contain state-of-the-art experimental works from diverse laboratories. Authors' abstracts or their translations are

included, when possible, to assist the concrete engineer in determining the applicability of a method to provide needed data.

The study was made possible with a Canadian government contract awarded to the senior author.

B-203 Okada, K., Kobayashi, K., and Miyagawa, T. 1984. "Corrosion Monitoring Method of Reinforcing Steel in Offshore Concrete Structures," In Situ/Nondestructive Testing of Concrete, SP-82, American Concrete Institute, Detroit, MI.

The half cell potential method can be used to assess the progress of reinforcing steel corrosion. The numerical model analysis proposed in this paper can estimate the macro cell corrosion rate and its distribution along the length of reinforcing steel. Applicability of this method, however, is limited because of disturbance of electrical circuit caused by water on the concrete surface. The polarization resistance method can also estimate the corrosion rate of steel in concrete structures exposed to various environmental conditions. But the application of this method on site requires embedment of a small steel specimen into the structures. In this study, the square wave current polarization with compensation for concrete resistance is used to measure the polarization resistance of steel in a model specimen. The results indicate that both monitoring methods make up for the disadvantages of each other and can be utilized as the corrosion monitoring techniques, their effectiveness depending upon the environmental conditions of the off-shore concrete structures.

B-204 Tamura, H., and Yoshida, M. 1984. "Nondestructive Method of Detecting Steel Corrosion in Concrete," In Situ/Nondestructive Testing of Concrete, SP-82, American Concrete Institute, Detroit, MI.

This paper presents a new nondestructive detecting method of corrosion of reinforcing steel in concrete. The state of corrosion of steel can be electrochemically estimated by using not only natural potential, but also polarization and electrolyte resistance. These three kinds of electrochemical values can be measured with a polarization resistance meter and a two-electrode probe set on the surface of concrete above any measuring point of steel. These values obtained from the surface of concrete are only apparent, being composed of the values in both anodic and cathodic sites. The authors, therefore, analyzed the relationship between the measured apparent values and real values in an equivalent electric circuit reflecting the corrosion phenomenon in concrete. Furthermore, the relationship among the various kinds of electrochemical characteristics was evaluated by a numerical study. In situ application of the new nondestructive method is also presented.

B-205 Uomoto, T., and Kobayashi K. 1984. "In Situ Test to Determine Fiber Content of Steel Fiber Reinforced Concrete by an Electro-Magnetic Method," In Situ/Nondestructive Testing of Concrete, SP-82, American Concrete Institute, Detroit, MI.

To control the quality of steel fiber reinforced concrete (SFRC), determination of fiber content is one of the most important matters in practice. Although SFRC is often assumed to be satisfactorily mixed by any concrete mixer, uniform fiber content cannot always be obtained if mix proportions and mixer design are unsuitable. To deal with the problem of nonuniform fiber contents, a simple in situ test is needed to check the quality of SFRC before it is cast.

Determination of the fiber content of SFRC can be accomplished by using techniques such as X-ray image analysis, separation by washout analysis, and an electro-magnetic method. However, some of these techniques are too troublesome to be used as in situ tests.

The special electro-magnetic method described herein is not only applicable to hardened concrete but also to fresh concrete. Measurement of fiber content can be done within a few minutes whether the test is performed in the laboratory or on the job. The proposed method of measuring fiber content is discussed from the point of view of practical problems such as the effects of distribution and orientation of fibers, etc. This method has been introduced as a standard test of SFRC in Japan.

B-206 Takabayashi, T., and Ishida, H. 1984. "Measurement of Thickness of Concrete Pavement and Structural Members," In Situ/Nondestructive Testing of Concrete, SP-82, American Concrete Institute, Detroit, MI.

This paper describes a method of measuring the thickness of pavement concrete and other concrete structural members. A particular feature of this method involves the combined usage of the ultra-sonic pulse and resonance methods to compute the thickness of concrete by measuring the sonic velocity and resonance frequency of concrete.

B-207 Roper, H., Baweja, D., and Kirkby, G. 1984. "Towards a Quantitative Measure of Durability of Concrete Structural Members," In Situ/Nondestructive Testing of Concrete, SP-82, American Concrete Institute, Detroit, MI.

Brief consideration is given to the uses of a quantitative measure of durability of concrete structural members. A classification scheme of structures, elements, and causes and effects is reviewed by the use of examples. Any quantitative measure of durability of in situ structural members must be based on data gathered using nondestructive test methods. For any phenomenon such as cracking, corrosion, or spalling which influences durability, three factors must be considered, viz. a method of measurement of the phenomenon, the intensity of the phenomenon, and its distribution over the observed area.

B-208 Cantor, T. R. 1984. "Review of Penetrating Radar as Applied to Nondestructive Evaluation of Concrete," In Situ/Nondestructive Testing of Concrete, SP-82, American Concrete Institute, Detroit, MI.

Practical experiences in the use of downward looking penetrating radar as applied to nondestructive evaluation (NDE) of masonry structures such as bridge decks, roadways, and tunnels are described. Various configurations of radar and data presentation are considered along with theoretical operational concepts. Specific operational examples are cited including automatic signal analysis and processing. Discussion of void and other defect detection is included. The ability of radar to rapidly gather data while moving in traffic at speeds in the neighborhood of 10 miles per hour is reviewed, and its implications for pavement management systems are commented on. Case histories are presented.

B-209 Carino, N. J. 1984. "Laboratory Study of Flaw Detection in Concrete by the Pulse-Echo Method," In Situ/Nondestructive Testing of Concrete, SP-82, American Concrete Institute, Detroit, MI.

A study was performed to evaluate the applicability of using the echoes from mechanically produced impact to locate hidden defects within concrete. The expected interactions of spherical waves with concrete-air interfaces are reviewed, and the results of experiments using artificial flaws in a large concrete slab are summarized. The following aspects were studied: type of impact source; distance from impact point to receiver; type of receiving transducer; depth of reflecting interfaces; and diffraction effects by sharp edges. The contact time of the impact is shown to be an important parameter for the success of the technique. The influence of the concrete thickness from impact point to the reflecting interface is an area of needed research.

B-210 Munday, J. G. L., and Dhir R. K. 1984. "Assessment of In Situ Concrete Quality by Core Testing," In Situ/Nondestructive Testing of Concrete, SP-82, American Concrete Institute, Detroit, MI.

Cores are cut from structural members to establish the quality of in-situ concrete, particularly in terms of uniaxial compressive strength. Although the strength test itself is simple enough, the procedure used has to be carefully established and well understood as numerous factors can affect the measured value and hence the judgement on the quality of concrete. Some of the important factors have been considered in this paper, namely: the diameter of core; its slenderness ratio (?/d), direction in relation to placing of concrete and location in the structure; curing; cube/core strength relationship and soaking of cores prior to testing. The results obtained are discussed and recommendations put forward which could extend the role of core testing, as well as improve the reliability of the test and the interpretation of the results. The existing ASTM and BSI procedures for core testing are examined in the light of the results obtained. A procedure for the determination of in situ concrete cube strength is described and it is suggested that the estimation from core strength

values of the potential strength of concrete as measured by standard cube tests could give very misleading information and should be avoided.

B-211 Murphy, W. E. 1984. "The Interpretation of Tests on the Strength of Concrete in Structures," In Situ/Nondestructive Testing of Concrete, SP-82, American Concrete Institute, Detroit, MI.

The results of tests on concrete in in situ or precast elements are only of value if they contribute to the making of valid and useful conclusions relating either to the quality of the concrete mix supplied or to the performance of the structure in service. The paper indicates how these objectives might be achieved by expressing the strength of the concrete in the structure in terms of an in situ cube strength. This may be used as a basis for assessing both the standard cube strength of the concrete in a structural element and a design strength which may be used to estimate the performance of the structural element in service.

B-212 Dahl-Jorgensen, E., and Johansen, R. 1984. "General and Specialized Use of the Break-Off Concrete Strength Testing Method," In Situ/ Nondestructive Testing of Concrete, SP-82, American Concrete Institute, Detroit, MI.

A reliable in situ testing method such as breakoff provides a more accurate estimate of the concrete strength of the structure than site-cured and laboratory-cured standard specimens. Considerable discrepancy was observed between strength measured in the structure and on separate specimens cast from the same mix.

The test method also proved to be useful when testing bonding strength of concrete overlays and epoxy coating to concrete.

B-213 Samarin, A., and Dhir, R. K. 1984. "Determination of In Situ Concrete Strength: Rapidly and Confidently by Nondestructive Testing," In Situ/Nondestructive Testing of Concrete, SP-82, American Concrete Institute, Detroit, MI.

The determination of concrete properties using theoretical and/or empirical relationships is commonly used in the design and construction of concrete structures. It is argued that, at best, all such estimates could only be approximate, given the varied nature of concrete due to its intrinsic makeup and workmanship, as well as such factors as environmental conditions and age. The use of nondestructive testing of concrete should be assessed against this background. The current position on the testing of in situ concrete is briefly reviewed and the potential application of the nondestructive tests discussed. A method combining the rebound hammer and pulse velocity readings is explained. Both tests are very simple and rapid to perform, and from the studies undertaken in Australia and Scotland, it would appear that the combined method approach could help to further increase the confidence in estimating the strength of in situ concrete.

B-214 Facaoaru, I. 1984. "Romanian Achievements in Nondestructive Strength Testing of Concrete," In Situ/Nondestructive Testing of Concrete, SP-82, American Concrete Institute, Detroit, MI.

This paper summarizes Romanian experience concerning in situ concrete strength estimation by nondestructive methods. The methods presented include "classical" nondestructive methods such as ultrasonic pulse method and rebound method. The philosophy of transforming the measured property into concrete strength, taking into account concrete composition and maturity, is given. Details about original developments of nondestructive methods for concrete strength estimation are also presented. Such developments are:

a) Combined SONREB method based on pulse velocity and rebound index measurements

b) Sonic coring method, an immersion method using radial transducers, adapted for the inspection of deep foundations

c) Acoustic method by shock based on the measurement of the natural period for the quality control of precast units.

B-215 Tanigawa, Y., Baba, K., and Mori, H. 1984. "Estimation of Concrete Strength by Combined Nondestructive Testing Method," In Situ/Nondestructive Testing of Concrete, SP-82, American Concrete Institute, Detroit, MI.

The purpose of the present paper is to obtain a practical expression for estimating the compressive strength of concrete. The nondestructive testing method is used, combining rebound number with ultrasonic pulse velocity to discuss its applicability to the evaluation of the strength of concrete members or structures.

Experimental investigations were carried out to examine the effects of factors such as water-cement ratio, the maximum size and volume fraction of coarse aggregate, and the curing condition and age of concrete. Accuracies of the prediction expressed in various types of empirical formulae are examined by multiple regression analysis, and practical equations for estimating the concrete strength are proposed. The equations are applied for evaluating the strength distribution in a concrete column and in an existing concrete building.

B-216 Malhotra, V. M. 1984. "In Situ/Nondestructive Testing of Concrete - A Global Review," In Situ/Nondestructive Testing of Concrete, SP-82, American Concrete Institute, Detroit, MI.

During the past 40 years in situ/nondestructive testing of concrete has achieved increasing acceptance for the evaluation of existing concrete structures with regard to their uniformity, durability, and other properties. This paper reviews critically the available in situ/nondestructive tests for estimating concrete strength and for determining properties other than strength and discusses their implications. The

methods discussed for estimating concrete strength include surface hardness and penetration resistance tests, pullout, ultrasonic pulse velocity, breakoff, combined methods, and maturity techniques. The tests reviewed for determining properties other than strength include magnetic, electrical, radioactive, pulse echo, radar, microwave absorption, acoustic emission, nuclear, infrared thermography, and permeability methods.

B-217 Bungey, J. H. 1984. "The Influence of Reinforcement on Ultrasonic Pulse Velocity Testing," In Situ/Nondestructive Testing of Concrete, SP-82, American Concrete Institute, Detroit, MI.

Embedded reinforcement may have a significant effect on ultrasonic pulse velocity measurements taken through structural concrete members. Reliable corrections are essential if test locations cannot avoid the influence of the steel. Extensive laboratory experimental work demonstrates major shortcomings in all currently accepted allowance procedures and confirms that bar diameter is an essential variable to be incorporated. The effect of bars passing across the pulse path is less than for bars of similar size running along the path. A correction procedure is proposed which can meet many practical combinations of bar size, bar orientation, and concrete properties with significantly greater accuracy than possible by established methods.

1985

B-218 Koelliker, E. 1985 (Jan). "Method for Microscopic Observation of Corrosion Layers on Concrete and Mortar," Cement and Concrete Research, Vol 15, No. 1, pp 100-104, Elmsford, NY.

A method of observation by thin-section microscopy has been developed to observe the growth of corrosive layers on concrete and mortar. A detailed description of the procedure is followed by results.

B-219 Nishimura, A., Fujii, M., and Miyamoto, A. 1985 (Jan). "Damage Assessment of Reinforced Concrete Slabs for Highway Bridges," Journal of the Society of Materials Science, Vol 34, No. 376, pp 40-46, Kyoto, Japan.

Systematization of maintenance, diagnosis, repair, and rehabilitation of existing bridges has been widely discussed. This study provides an objective and quantitative basis for rating and evaluating serviceability of cracked reinforced concrete slabs. The factors used to judge serviceability of slabs are selected and rated quantitatively, and the applicability of the reciprocal averaging method and the fuzzy analysis were tested as the synthetic rating method. The results obtained are summarized as follows:

1. The current rating method based on crack density could not evaluate the extent of crack penetration into the slab, and the crack density did not correspond to the load carrying capacity of the slab when it exceeded a certain degree.

2. The reciprocal averaging method as one of the synthetic rating methods was found to be effectively used by taking more than three evaluating factors. It was possible to evaluate quantitatively the relative serviceability by selecting the upper and lower limits.

3. The fuzzy analysis may be used to estimate the type of damage in reinforced concrete slabs and to rate accurately without trying extra measurements.

B-220 Pommersheim, J., and Clifton, J. 1985 (Jan-Feb). "Prediction of Concrete Service Life," Materials and Structures, Research and Testing, No. 103, pp 21-30, Paris, France.

This article discusses development of accelerated tests and mathematical models for predicting durability of concrete. Durability, service life, and degradation factors are defined and accelerated test methods are contrasted with comparable conventional methods. Factors and mechanisms of concrete degradation are reviewed, as are efforts to qualify these phenomena. Deterministic and stochastic models are discussed, and procedures for developing accelerated tests are presented and applied to a hypothetical example involving freeze-thaw damage. Advantages and disadvantages of accelerated testing and mathematical modeling are discussed in terms of the degradation mechanisms affecting concrete. Examples given of the modeling approach and service life prediction include the prediction of strength and maturity of concrete, acid attack on cement, sulfate attack, and the effect of scaling and corrosion on the load-bearing capacity of concrete.

B-221 Page, C. L., and Havdahl, J. 1985 (Jan-Feb). "Electrochemical Monitoring of Corrosion of Steel in Microsilica Cement Pastes," Materials and Structures, Research and Testing, No. 103, pp 41-47, Paris, France.

The corrosion behavior of steel in hardened cement pastes containing various proportions of microsilica and sodium chloride has been studied by corrosion potential and linear polarization measurements. Replacement of increasing proportions of portland cement and microsilica in pastes of constant total chloride and water content caused the ratio of free chloride ion concentration to hydroxyl ion concentration in the pore water to increase. This tended to destabilize the passivity of steel during the early stages of hydration, but the effect became less significant as the curing progressed. It is suggested that the growth of anodic pits may be restrained in microsilica cement pastes owing to the fine pore structure of the material, which limits the mobility of chloride ions near the surface of embedded steel.

B-222 Keiller, A. P. 1985 (Feb). "Assessing the Strength of In Situ Concrete: An Investigation of Test Methods," Concrete International: Design & Construction, Vol 7, No. 2, pp 15-21, Detroit, MI.

A number of tests for assessing the strength of in situ concrete have been developed in recent years. Although some of these tests cause minor damage to the surface of the concrete, they do not generally

impair the load-carrying capacity of the structure and may, therefore, be thought of as nondestructive. Research was performed at the Cement and Concrete Association to compare and evaluate some of these test methods and to determine their usefulness in assessing the strength of concrete in structures.

B-223 Jenkins, R. S. 1985 (Feb). "Nondestructive Testing-An Evaluation Tool," Concrete International: Design & Construction, Vol 7, No. 2, pp 22-26, Detroit, MI.

The use of nondestructive test procedures to evaluate problems or failures of concrete materials can result in a certain amount of uncertainty in determining the in-place strength of the concrete. Although regression data can be analyzed for the best fit correlation, there is a rather large magnitude of uncertainty in the determined strength due to inherent variability in the test procedures. Nondestructive test procedures utilizing rebound hammer testing, penetration testing, or ultrasonic testing may allow a degree of uncertainty as great as 600 to 900 psi (4.1 to 6.2 MPa) in the strength determination.

B-224 Hindo, K. R., and Bergstrom, W. R. 1985 (Feb). "Statistical Evaluation of the In-Place Compressive Strength of Concrete," Concrete International: Design & Construction, Vol 7, No. 2, Detroit, MI.

Recent advances in the world of concrete have resulted in remarkable progress in the field of quality control. Considerable research effort has been directed toward developing reliable, nondestructive methods for testing the strength of concrete in place. These methods have created the need for a valid statistical analysis to evaluate test results with a prescribed level of confidence. However, ACI does not provide statistical analysis for evaluating compressive strength of in-place concrete. In view of the foregoing, it is timely that a statistical method be developed to properly evaluate the in-place test results of concrete. Present ACI compressive strength evaluation criteria have been modified to utilize a statistical analysis which has yielded satisfactory results.

B-225 Stone, W. C., and Giza, B. J. 1985 (Feb). "The Effect of Geometry and Aggregate on the Reliability of the Pullout Test," Concrete International: Design & Construction, Vol 7, No. 2, Detroit, MI.

A series of tests were performed to investigate the effect of changes in the geometry of the test apparatus and the effect of various concrete aggregate properties on the reliability of the pullout test. Key geometric variables included the apex angle and the depth of embedment of the 1-in. (25-mm) insert. Also investigated were the effects on reliability of nominal maximum aggregate size and the type of aggregate. The results indicate that for a fixed value of cylinder compressive strength, the scatter in the pullout ultimate load decreases nonlinearly with increasing apex angles and with decreasing depth of embedment. The presence of aggregate raises the scatter in the ultimate load and also raises the average ultimate pullout load. However,

there appears to be no significant difference in scatter, or in the mean ultimate load among the aggregate sizes tested. The four aggregate types showed no effect on the reliability of the test.

B-226 Hillger, W., and Neisecke, J. 1985 (Mar). "Ultrasonic Pulse Technique for the Automatic Non-Destructive Quality Control of Precast Concrete Components, Part 2," Betonwerk und Fertigteil-Technik, Vol 51, No. 3 pp 165-169, Weisbaden, Germany.

Ultrasonic measurements on concrete can be utilized for observing relative changes in this material or in concrete structure. Besides the pulse propagation time (transit time) measurements hitherto commonly employed, amplitude or intensity measurements can be used with considerable advantage since they have greater sensitivity. The conditions for making this technique a practical proposition have been established in the research described in this article, more particularly in that an automatic amplitude measuring technique within a time slot and a method of checking the effectiveness of the coupling of the transducers to the test specimen have been developed, and the necessary equipment has been constructed. Defectoscopic ultrasonic tests with a high-informative content can be performed on concrete only if the measuring set up is suited to the special requirements and the necessary optimizations have been performed.

B-227 Thornton, H. T., Jr. 1985 (Mar). "Corps-BuRec Effort Results in High-Resolution Acoustic Mapping System," The REMR Bulletin, Vol 2, No. 1, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

A high-resolution acoustic mapping system for performing rapid, accurate surveys of submerged horizontal surfaces has been developed as part of a joint research and development effort of the Corps of Engineers and the US Bureau of Reclamation. The system makes possible, without dewatering of the structure, comprehensive evaluation of top surface wear on such horizontal surfaces as aprons, sills, lock chamber floors, and stilling basins, where turbulent flows carrying rock and debris can cause abrasion-erosion damage.

The high-resolution acoustic mapping system is designed to operate in water depths of 5 to 40 feet and produce accuracies of ± 2 inches vertically and ± 1 foot laterally. The system has been used successfully to survey the stilling basin floor of Folsom Dam, a BuRec project near Sacramento, CA, and the stilling basin of Ice Harbor Dam in the Corps' Walla Walla District near Richland, WA. A detailed description and specifications of the system are available.

B-228 Rewerts, T. L. 1985 (Apr). "Safety Requirements and the Evaluation of Existing Concrete Buildings," Concrete International: Design & Construction, Vol 7, No. 4, pp 50-55, Detroit, MI.

Existing structures don't always behave as they were designed to behave. This fact creates significant uncertainty for evaluating the strength of an existing concrete structure. A symposium at the 1984

ACI annual convention addressed this problem with 19 presentations describing test methods, case histories, and statistical approaches in determining the existing condition and remaining life of a structure.

B-229 McDonald, J. E., and Campbell, R. L., Sr. 1985 (Apr). "The Condition of Corps of Engineers Civil Works Concrete Structures," Technical Report REMR-CS-2, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

The Corps of Engineers currently operates and maintains 536 dams and 260 lock chambers at 596 sites. Sixty percent of these hydraulic structures are over 20 years of age, more than forty percent are more than 30 years old, and approximately one-third are more than 40 years old. With the relatively limited number of new constructions anticipated, many of these structures are being and will continue to be kept in operation well beyond their original design lives. The primary objective of this study was to develop quantitative information on the present condition of the concrete portions of these structures.

Two computerized data bases, (a) structure-description and (b) damage and repair were compiled. The structure-description data base contains basic information (location, category, age, purpose, etc.) on 766 projects. The damage and repair data base contains information on the current condition of the concrete in the Corps' civil works structures as determined through detailed reviews of over 2,000 periodic inspection reports.

To assist in the analysis, a number of computer programs were developed to manipulate and search the data bases. This analysis concentrated on the types of deficiencies observed, the cause (if reported), location within the structure, and degree of damage. Also, if the deficiency had been repaired, the material or technique, or both, that were used and the performance were analyzed.

This identification and assessment of problems relating to evaluation, maintenance, and repair of concrete will provide guidance in developing and establishing priorities for research in the Repair, Evaluation, Maintenance, and Rehabilitation Research Program.

B-230 LLoyd, J. P., and Heidersbach, R. H. 1985 (May). "Use of the Scanning Electron Microscope to Study Cracking and Corrosion in Concrete," Concrete International: Design & Construction, Vol 7, No. 5, pp 45-50, Detroit, MI.

The scanning electron microscope (SEM) has become a standard analytical tool used by a wide range of investigators to analyze materials failures of many types. The SEM can be used for postmortem analyses of corrosion and cracking problems in a variety of metal-reinforced concrete systems. Applications to research and forensic analysis are discussed.

B-231 Tellander, S. 1985 (May). "Florida Initiates State of the Art Bridge Testing," AASHTO Quarterly, Vol 64, No. 2, American Association of State Highway Transportation Officials, Washington, DC.

Florida DOT is entering a new era of bridge testing and research as it launches a state-of-the-art bridge testing program using an instrumentation vehicle equipped with an electronic data acquisition system. It is estimated that the approximately $500,000 cost of the testing equipment will be recovered in savings on the first two projects.

B-232 Koga, F., et al. 1985 (May). "Simple Method for Testing the Quality of Concrete Structures" (in Japanese), Cement and Concrete, No. 459, pp 23-34, Tokyo, Japan.

The authors discovered a simple method of estimating concrete quality on the construction site, a method that presents the characteristic of allowing evaluation of concrete chloride content, strength, and carbonation, according to the following process: 1) A hole is drilled in concrete. Concrete dust produced during this operation is collected, mixed with water, agitated. The chloride content is then measured with a chlorine ions concentration meter. 2) An anchor is inserted in the hole, and pullout tests, allowing estimation of concrete strength, are carried out. 3) The concrete test pieces collected during the pullout tests are used for estimating, with phenolphtalein, concrete carbonation. The article describes in detail the previously mentioned testing method and the results of tests carried out for estimating its accuracy, which proved to be comparatively good.

B-233 Shrive, N. G., and El-Rahman, M. 1985 (May). "Understanding the Cause of Cracking in Concrete: A Diagnostic Aid," Concrete International: Design & Construction, Vol 7, No. 5, pp 39-44, Detroit, MI.

An understanding of the cause of cracking in concrete is necessary if correct diagnosis is to be made of the macroscopic conditions which induce the distress. Plain concrete is shown to behave like other so-called brittle materials under different states of stress. It is shown that the development of tensile stresses around voids initiates cracking. This simple theorem is confirmed by comparing experimental results with predicted behavior in terms of cracking for a variety of stress states, including compression.

B-234 Mikhailovsky, L., and Scanlon, A. 1985. "Nondestructive Test Methods for Evaluation of Existing Concrete Bridges," Official Proceedings - 2nd Annual International Bridge Conference, Pittsburgh, PA, USA, 17-19 Jun 1985, pp 115-120, Engineers' Society of Western Pennsylvania.

Structural evaluation of an existing concrete bridge requires an assessment of concrete quality, particularly the variation of concrete strength within the structure, and identification of any areas of low-quality concrete. This paper presents results of a test program to assess the applicability of two commonly available test methods,

ultrasonic and rebound hammer, in conjunction with data from compressive tests on cores, for evaluation of concrete quality.

B-235 Yen, T., and Chu, M. S. 1985. "Investigation and Analysis of Concrete Strength and Reinforcement on Old Existing Structures," Proceedings of the 1985 SEM Spring Conference on Experimental Mechanics, Las Vegas, NV, USA, 9-14 Jun 1985, Society for Experimental Mechanics, Brookfield Center, CT.

A test method involving a rebound hammer, an ultrasonic test instrument, and a coring machine is proposed with analytical derivation for the determination of the representative concrete strength in old existing structures. An R-meter with the aid of a multimeter is applied for the detection of the reinforcement.

B-236 Meneghetti, F., and Meneghetti, T. 1985 (May-Jun). "Non-Destructive Testing to Evaluate In Situ Maturity on Prestressed Concrete Members," Materials and Structures, Research and Testing, Vol 18, No. 105, pp 171-180, Paris, France.

This article reports results of an investigation on steam-curing prestressed reinforced concrete beams. The "maturity" concept is used to estimate the in situ cube compressive strength of concrete.

During the investigation, it was possible to evaluate the characteristics of concrete in situ, particularly at chosen critical points, without referring to specimens which, having a remarkably different heat inertia from that of the structure they relate to, are not suitable for reliably evaluating maturity.

As a result of this investigation, optimization of the curing cycle in the yard was achieved by reducing steam-flow time from 9 to 5 hr, saving considerable energy.

B-237 Poulin, R. M., Cupitt, P., and Latheef, A. 1985. "Instrument Reliability Monitoring the Data from the Idukki Arch Dam," Fifteenth International Congress on Large Dams, 24-28 Jun 1985, Paris, France.

The Idukki arch dam is situated in the Periyar River in the State of Kerala, South India. The dam features a nonoverflow, double curvature, parabolic concrete arch dam 169 m high, and was constructed in 1969-1974.

This report on the reliability of 11 types of instruments embedded in the dam summarizes the results of 10 years of monitoring the conditions of Idukki.

A computer system was developed over a period of 6 years to process the data from 18 instrument groups. More recently, it became possible to process the field data with a programmable pocket calculator. This enables the field engineer to process the data directly at the site as it becomes available.

The reservoir level, the pendulums, the crest collimation, rock targets, and the clinometer are all parameters measured by instruments that give reliable and consistent results and, as such, they are regarded as a true commentary of the conditions within the arch dam.

The other instruments are buried in the concrete in the dam, some data obtained is questionable, and the values cannot be confirmed. But, by recording the data for each parameter continuously throughout each year, a regular pattern develops in which any particular irregularities or sudden changes in values can be noted and acted upon.

The dam continues to react to the water loading as expected, and a comparison of the data shows good correlation with visual observation.

B-238 Kovari, K. 1985 (Jun). "Detection and Monitoring of Structural Deficiencies in the Rock Foundation of Large Dams," Fifteenth International Congress on Large Dams, 24-28 Jun 1985, Paris, France.

A simple and highly accurate measuring technique is discussed to determine the complete distribution of strain along boreholes both in the rock foundation and in the concrete structure. For this purpose, the portable Sliding Micrometer probe is applied to measure the strain with a base length of 1.00 m between consecutive points along a casing. The boreholes may be oriented arbitrarily in space and their length may exceed 100 m. The detailed knowledge of strain development is crucial when causes of unexpected dam behavior have to be elucidated. Measuring results from large-scale applications at the Albigna gravity dam (Switzerland) and at the Kolnbrein Arch dam (Autria) are discussed in detail.

B-239 Satak, Y., Kiho, K., and Yasufuku, S. 1985. "The Borehole Television (BTV) Observation of Existing Concrete Dams and Foundation Rock," Fifteenth International Congress on Large Dams, 24-28 Jun 1985, Paris, France.

The durability of concrete dams, for which many years has elapsed after the construction, should be tested by suitable methods for safety. Some engineering techniques, such as coreboring, uniaxial test of specimens, and seismic prospecting of the concrete of the dams should be applied.

In the case of Soyama (h=73 m) and Miura (h=86 m) dams in Japan, both of concrete gravity type and which were constructed in 1930 and 1945, respectively, the strength of the concrete of the two dams has been inspected by previously mentioned methods, as well as by the BTV. The BTV, which pictures inside wall of drilled holes, is very effective for the detailed observation of cracks of concrete, the joints between concrete, and foundation rock and conditions in the foundation rock.

As a result, no cavity was found in the concrete of the two dams by the BTV survey. The interface between the concrete and the foundation rock is cohesive for both dams. The foundation rocks of Soyama and Miura

dams consist mainly of granodiolite and rhyolite, respectively. Some cracks in foundation rock are filled with grout mix.

Under the circumstances, the BTV survey proves to be effective for evaluating the safety of existing dams through direct observation of boreholes in the dam and foundation rock.

B-240 Matsumoto, N., Yasuda, N., Ogawa, M., and Iwata, M. 1985 (Jun). "Investigations of Cracks in an Asphaltic Concrete Facing and Comparison between Observed Cracking and Predicted Behaviour by Earthquake Analysis," Fifteenth International Congress on Large Dams, 24-28 Jun 1985, Paris, France.

The paper describes the results of investigations of cracks in theasphaltic concrete facing of Magosawa Dam, which is a 16.5-m-high small earthfill dam.

The authors were informed of the cracking in the upstream impervious membrane of this dam after the Off Miyagi Earthquake of 1978, field investigations in November, 1982, and September, 1983, and laboratory tests for dynamic properties of fill materials.

Results of these investigations indicate that e causes of cracks of an asphaltic concrete facing can be classified ıto opening of construction joints, differential settlement, creep flow of asphaltic concrete, and earthquake motion. Only one crack had been caused by the earthquake.

Further investigations were carried out for the crack caused by the earthquake. Those investigations include the estimation of the ground motion at the foundation of Magosawa Dam from the accelerograms recorded at a nearby dam and the numerical dynamic analysis of the dam by using the deformation properties obtained from laboratory tests of fill materials. The results of analysis show that excessive shearing stresses occurred in the impervious membrane during the earthquake as a result of the constraints of the sloping intake structures.

B-241 Guerreiro, M., and Del Hoyo, R. 1985. "Bringing Up-to-Date Monitoring Systems on Existing Concrete Dams," Fifteenth International Congress on Large Dams, 24-28 Jun 1985, Paris, France.

The situations that usually lead to updating or improving the monitoring system of a concrete dam are presented in this paper. Two case histories of monitoring systems for gravity dams constructed before 1950, two case histories of double curvature arch dams in which their monitoring systems were improved by new equipment (with the purpose of improving the information on its behavior), and two case histories of monitoring systems on gravity dams and arch dams which were built in the last 20 years are also presented. These six case histories concern dams built during the last 40 years and give the reader an idea about the evolution and improvements that monitoring systems have had during this time.

B-242 Cummins, P. J., Smith, B. R., and Evans, R. C. 1985. "Rehabilitation of Goulburn Weir Foundations and Superstructures," Fifteenth International Congress on Large Dams, 24-28 Jun 1985, Paris, France.

Goulburn Weir, constructed in 1890, controls the diversion of waters released from Eildon Dam down the Goulburn River to supply the Major Goulburn-Murray Irrigation District in Northern Victoria, Australia, through three major irrigation canals from the weir pool.

The 15-m-high weir is a graite step-faced concrete gravity structure with 21 cast iron gates which are lowered into slots in the structure.

The safety and surveillance program for major structures controlled by the Rural Water Commission identified this structure as a high priority for rehabilitation in regard to structural stability and deterioration and the vital importance of this weir to irrigation supplies.

Scour holes in the river bed at the time of construction have eroded to a 10-m depth exposing joint planes in the sedimentary rock foundations under the weir, which dip toward the scour hole. Tests and stability analyses indicated a high potential for a foundation slip. The foundations have been stabilised by the installation of 53 prestressed, monitorable ground anchors, each of 400-ton load capacity, angled upstream and bearing onto a concrete plinth which was constructed across the toe of the weir.

The investigations also indicated severe deterioration of the cast iron by graphitic corrosion in both the piers and gates, requiring complete replacement of the superstructure.

B-243 Seifart, L. A., Szpilman, A., and Piasentin, C. 1985. "Itaipu Structures, Evaluation of their Performance," Fifteenth International Congress on Large Dams, 24-28 Jun 1985, Paris, France.

The present paper describes the performance of the structures of the Itaipu hydraulic powerplant during the filling of the reservoir, which started in 1982 and was concluded in May 1984.

The evaluation of the behavior of the dam was carried out through the analysis of the instrumentation readings and visual inspections of the works.

The system of instrumentation installed allowed close monitoring of the behavior of the key blocks and interpolating the performance of the other blocks.

The interpretation of more than 1 year of data and observation allowed drawing some conclusions regarding stresses and displacements of structures, influence of temperature, piezometric levels at rock-concrete contact, seepage flows through concrete, and hydraulic performance of spillway.

B-244 Mahasandana, T., and Mahatharadol, B. 1985. "Monitoring Systems of Khao Laem Dam," Fifteenth International Congress on Large Dams, 24-28 Jun 1985, Paris, France.

This paper describes the instrumentation installed in the structures and foundation of Khao Laem Multipurpose Project in Thailand. Khao Laem Dam is a 90-m-high concrete faced rockfill dam constructed on a karstic limestone foundation.

The design criteria used for the instrumentation in monitoring the dam and its foundation is described. The type, quantity, and distribution of instruments are detailed together with a brief description of the project features and construction methods.

Results of the monitoring during construction, prior to reservoir filling are presented and discussed.

B-245 Santa Clara, J. M. A., and Izzett, I. P. 1985. "The Dam and Foundation Monitoring System at Kariba," Fifteenth International Congress on Large Dams, 24-28 Jun 1985, Paris, France.

At Kariba, the dam and foundation monitoring systems have been in operation for up to 25 years. This paper describes the instrumentation which is installed and the various analyses which have been carried out on the data obtained from the instrumentation. General results and conclusions of the analysis are given. Various lessons can be derived from the experiences at Kariba, and these are briefly outlined in the conclusions.

This paper attempts, by describing experiences and results, to communicate with those who may have similar problems so that dialogue may be opened to the mutual benefit of the parties. It is beyond the scope of the paper to outline all problems, remedies, and results obtained and gained.

B-246 "Evaluation Techniques Ease Restoration Choices." 1985 (Jul). Roads & Bridges, Vol 23, No. 7, pp 40-42, Des Plaines, IL.

Confident restoration or reconstruction of a damaged or deteriorated pavement can proceed only when dependable information on pavement structure is available. Quality control involves all participants in the paving process from the design engineer to the finisher, requires up-to-date equipment, well-trained operators, and current design.

The increased use of nondestructive testing allows state highway departments to attack the multifaceted problem of concrete pavement distress by attending to the causes, rather than the symptoms, of failure to repair existing or prevent future damage.

B-247 Stark, D. C. 1985 (Jul). "Alkali-Silica Reactivity in Five Dams in Southwestern United States," Technical Report REC-ERC-85-10, US Bureau of Reclamation Engineering and Research Center, Denver, CO.

Concrete samples from five dams in the Southwestern portion of the United States (Coolidge, Friant, Matilija, Parker, and Stewart Mountain Dams) were tested for alkali-silica reactivity. This investigation was intended to study the state of alkali-silica reactivity in the concrete and to determine the potential for additional reactivity.

The four procedures used in this investigation were selected to determine whether the concrete contained potentially reactive silica or enough moisture to cause expansion. These procedures were relative humidity measurement, petrographic examinations, length change measurements, and osmotic cell tests. Test results showed that the extent of alkali-silica reactivity and the potential for its occurrence varied not only between dams but also between sample locations within each dam.

B-248 Berke, N. S., and Philip, S. 1985 (Sep). "Evaluating and Testing for Corrosion Resistance," Concrete International: Design & Construction, Vol 7, No. 9, pp 42-47, Detroit, MI.

Potentiostatic anodic polarization is an important technique used in evaluating the performance of anodic corrosion inhibitors. A description of the technique, an explanation of the curves generated, and examples of its application to steel in concrete-type environments are given. Also presented are polarization data which confirm the effectiveness of calcium nitrate as a corrosion inhibitor for steel in concrete over a broad range of chloride concentrations and Cl^-/NO_2^- ratios.

B-249 Koelliker, E. 1985 (Sep). "Method for Microscopic Observation of Corrosion Layers on Concrete and Mortar," Cement and Concrete Research, Vol 15, No. 5, pp 909-913, Elmsford, NY.

This article develops a method to study the growth of corrosive layers on concrete and mortar by measuring their original thickness in the aqueous liquid. The method is based on the use of plaster of Paris as an embedding material. A detailed description of the procedure is followed by examples of results.

B-250 "Underwater Inspection and Repair of Hydraulic Structures." 1985 (Mar). The REMR Bulletin, Vol 2, No. 1, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

Seventeen presentations were given at a workshop on underwater inspection and repair of hydraulic structures held in St. Louis, MO. Videotapes of the workshop proceedings are available for loan.

B-251 Dufay, J. C., and Piccardi, J. 1985 (Sep-Oct). "Scorpion: The First High-Energy Televised Radioscopy System for the Non-Destructive Control of Prestressed Concrete Civil Engineering Structures" (in French), Bulletin de Liaison des Laboratoires des Ponts et Chaussees, No. 139, pp. 77-83, Paris, France.

The Blois Regional Laboratory of the LPC specializes in the nondestructive control of hydraulic concrete structures using x-rays or gamma rays. The laboratory has researched televised radioscopy and the method is now operational. The method was developed in two stages. The first stage led to the development of an instrument to convert x-rays or gamma ray photons onto light photons. This convertor makes it possible to obtain, in place of radiographic images, images recorded by a highly sensitive camera and displayed on a television monitor. In the second stage, a 250-kg linear accelerator was built. It allows investigations to be made to a thickness of 80 cm of concrete using radioscopy and to 1.2 m using radiography, with exposure times not exceeding 30 minutes. This new instrument makes about 90 percent of prestressed concrete accessible to radiographic or radioscopic controls.

B-252 Laloux, R., and Robert, J. L. 1985 (Sep-Oct). "Acoustic Emission Techniques Applied to Civil Engineering Structures" (in French), Lab Central des Ponts et Chaussees, Service de Physique, No. 139, pp 93-98, Paris, France.

Acoustic emission is a phenomenon of creation and propagation of transitory elastic waves resulting from internal local micro-displacements in a material. The detection and analysis of these waves provide information on the physical mechanisms which generated them. Acoustic emission techniques have been employed for a twofold purpose: (a) the monitoring of structures in service to detect the failure of strands in prestressing cables and the cracking of concrete; and (b) the study of the mechanisms of the cracking of concrete, carried out on test samples in the laboratory. A specific item of equipment has been developed for the monitoring of structures, but the earliest results obtained, though encouraging, show that the method is not yet sufficiently reliable and gives no absolute certainty to the evolution of deteriorations in a structure. In the study of concrete cracking, acoustic emission has made it possible to define the dimensions of the damaged area of a sample subjected to tensile cracking test. On the whole, acoustic emission techniques have produced positive results in some respect, but are still an area of research.

B-253 Mather, K. 1985 (Oct). "Preservation Technology: Evaluating Concrete in Structures," Concrete International: Design & Construction, Vol 7, No. 10, pp 33-41, Detroit, MI.

There is a need to evaluate the condition of the concrete in a structure whenever a question is raised regarding: (a) the significance of visible evidence of changes (such as cracking); (b) the suitability of the structure for rehabilitation, adaptive reuse, or enlargement or

extension; or (c) the future uses of the structure. Such evaluation may involve visual examination, in situ nondestructive testing, sampling, and laboratory evaluation of these samples. Laboratory examination techniques include the polarizing microscope, X-ray diffraction, chemical tests, and physical tests.

B-254 Zia, P. 1985 (Oct). "Causes and Remedies of Distress - Three Case Histories," Concrete International: Design & Construction, Vol 7, No. 10, Detroit, MI.

A combination of design and construction errors caused the partial collapse of a shopping center roof, the torsional cracking of edge beams of a parking deck, and the extensive cracking of the corbels of a three-story parking structure. The investigations of the causes of failure and the corrective measures taken in each of these three cases are described.

B-255 Libby, J. R. 1985 (Oct). "Critique of a Post-Tensioned Roof Slab Failure," Concrete International: Design & Construction, Vol 7, No. 10, Detroit, MI.

After 5 years of service, a failure occurred in a corner of a posttensioned, sand-lightweight concrete flat slab roof. The failure at first appeared to have been caused by a single, nearly horizontal crack at the level of the tendon anchors. The appearance of the crack suggested vertical tensile stresses in the concrete caused by the products of corrosion of embedded materials. Subsequent investigation revealed a second, approximately horizontal crack below the originally visible crack, and the almost complete absence of corrosion. The fact that the second crack found was determined to have existed for a considerably longer period of time than the first observed crack was considered significant in forming the mechanism that caused failure. Structural analysis led to the conclusion that the failure was the result of fatigue in the concrete in the area where splitting tensile stresses in the anchorage zone combined with flexural tensile stresses due to the variation in moments in the structural frame.

B-256 Schickert, G. 1985 (Nov). "Infrared Thermography as a Possible Tool to Detect Damaged Areas in Buildings," Durability of Building Materials, Vol 3, No. 2, pp 87-99, Amsterdam, The Netherlands.

Infrared thermography has, in recent years, become important for detecting heat transfer or thermal leakages in outer walls of buildings. The opportunities are good, also, for application of thermography as a nondestructive testing method for well-timed and repeated inspection of concrete and structures with respect to damage perception. The procedures of both classical infrared thermography and infrared reflectography are briefly explained and possibilities are discussed for their application. Because in this field development is just beginning, only some examples are given. The localization of defects and the critical surface condensation are regarded as well as the detection of moisture in masonry.

B-257 Lemoine, L., Raharinaivo, A., and Tache, G. 1985. "Corrosion of Reinforced Concrete in Marine Environments--Methods of Inspection" (in French), 8th European Congress of Corrosion, Nice, France, 19-21 Nov 1985, Vol 1, Centre Francais de la Corrosion, Societe de Chimie Industrielle, Paris, France.

Reinforced concrete is a material widely used for building in marine environments. Its durability is excellent if corrosion of rebars does not occur. It is necessary, for the safety of structures, to detect corrosion before severe defects are present. For this reason, methods including nondestructive or destructive test are available and are described. Diagnosis needs a good understanding of corrosion phenomena occurring on a concrete structure in an aggressive environment. Behavior of rebars is mainly dependent on the properties of the concrete cover. Present defects as cracks, local concentration of gravels, insufficient cover thickness, and high chloride concentration are the main factors of the corrosion initiation. In marine environments, cracks can result from the hydrodynamic loading due to wave action.

B-258 Ollivier, J. P. 1985 (Nov). "Non-Destructive Procedure to Observe the Microcracks of Concrete by Scanning Electron Microscopy," Cement and Concrete Research, Vol 15, No. 6, pp 1055-1060, Elmsford, NY.

The study of microcracking is crucial to understand concrete behavior under loading. Direct observation by a scanning microscope (SEM) is not suitable because the concrete is subject to drying shrinkage. An indirect method of using the SEM is proposed which uses a single replica and can observe microcracking in concrete at any loading levels with a resolution of 0.5 μm or better.

B-259 Berthelot, J. M., and Robert, J. L. 1985 (Nov-Dec). "Application of Acoustic Emission to Mechanisms of Concrete Damage" (in French), Bulletin de Liaison des Laboratoires des Ponts et Chaussees, No. 140, pp 101-111, Paris, France.

The technique of acoustic emission has been used to follow the evolution of concrete damage in various tests (double cantilever beam, crackline wedge loading, and compact tension). These tests all lead to similar results. Using a technique of triangulation (a special geometrical arrangement of detectors placed on two perpendicular axes), acoustic emission makes it possible to localize the damage in the course of a test. Furthermore, a discrimination of the signal amplitudes makes it possible to propose a model of the failure of a sample. The damage is progressive along the crack. Three zones of damage may be defined: a microcracked zone at the head of the crack, a macrocracked zone whose front is the front of the crack proper, and a zone that may be considered as completely broken. The damage in each zone may be characterized by a general coefficient that can be introduced into a concept of structural design calculation. During a test, acoustic emission makes it possible to follow the evolution of these various zones of damage in samples of concrete.

B-260 Muller, K. F. 1985 (Nov-Dec). "Possibility of Evolving a Theory for Predicting the Service Life of Reinforced Concrete Structures," Materials and Structures, Vol 18, No. 108, pp 463-472, Paris, France.

The development in recent years of increasing air pollution, increasing need for energy saving, and, last but not least, the growing number of damage in old structures leads to a rising demand to calculate the durability of structures, too. The paper has been prepared by request of the RILEM Technical Committee 45-LTO to show that, in principle, it is possible to evolve a theory for predicting the service life of r.c. structures and to sketch how that could be achieved. Necessary basic data can be found scattered in the literature.

B-261 Akashi, T., and Amasaki, S. 1985 (Dec). "State-of-the-Art on Nondestructive Testing of Concrete" (in Japanese), Concrete Journal, Vol 23, No. 12, pp 11-20, Tokyo, Japan.

There are many methods for nondestructive testing of concrete. This paper describes the available nondestructive tests for evaluation of existing concrete structures with regard to their strength and other properties and the future of nondestructive tests. The methods discussed include surface hardness and penetration tests, ultrasonic pulse velocity, breakoff, pullout, and combined methods.

B-262 Stoll, U. W. 1985 (Dec). "Compressive Strength Measurement with the Stoll Tork Test," Concrete International: Design & Construction, Vol 7, No. 12, pp 42-47, Detroit, MI.

The Stoll Tork Test (STT) is a new, nondestructive means for assessing the compressive strength within a concrete structure. The prototype device is comprised of a special bolt extension and a small, removable, cleated spindle which is positioned in the plastic concrete. The configuration assures that at the desired moment, a small aliquot of hardened concrete mortar can be subjected to a semiconfined compressive stress via a twisting force applied by a conventional torque wrench with a memory dial.

B-263 Russell, H. G., and Rowe, T. J. 1985 (Dec). "Collapse of Ramp C," Concrete International: Design & Construction, Vol 7, No. 12, pp 32-37, Detroit, MI.

A ramp of the Cline Avenue Extension Expressway collapsed during construction in 1982. Prior to collapse, the ramp was supported on a falsework system consisting of timbers, steel beams, jackscrews, steel towers, and concrete pads. Results of an investigation by Construction Technology Laboratories showed that collapse of a section of the ramp could have been initiated by differential movements at a tower base caused by cracking of a concrete pad or by instability of the system of upper jackscrews and steel beams. This summary describes the investigation including field inspection, review of drawings, determination of construction loads, laboratory and field tests, and analysis of the falsework system.

B-264 Gross, K. P., and von Cramon, W. 1985. "Investigation into the Crack Development and Joint Rotation of Reinforced Concrete Structures," 2nd International Technical Symposium on Optical and Electro-Optical Applied Science and Engineering, Proceedings of SPIE - The International Society for Optical Engineering, Vol 599, pp 211-215, Bellingham, WA.

The experimental investigation of the reinforced concrete construction problems mentioned in the title is described, making use of the Laser-Speckle-Photography optical measurement method. Proceeding from the material-conditional particularities and the high demands on the accuracy of the measurement values, a semiautomatic working device was developed for analyzing the Laser-Speckle photographs. The method of working with this device, the statistical routines applied in the process, and the attainable accuracy are reported on. Moreover, reference is also made to the strains in a reinforced concrete member and the crack formation. In the last section, the results of measurements of the joint rotation on the inner support of a two-span beam of reinforced micro-concrete, as well as the shear bearing behavior observed in this context, are described.

B-265 Hughes, B. P , Soleit, A. K. O., and Brierley, R. W. 1985 (Dec). "New Technique for Determining the Electrical Resistivity of Concrete," Magazine of Concrete Research, Vol 37, No. 133, pp 243-248, London, England.

An improved method has been developed for measuring the electrical resistivity of concrete which eliminates difficulties due to polarization effects and capacitative reactance. Typical results for fresh and hardened concrete obtained with the proposed technique are also presented and compared with results using more conventional techniques.

B-266 Tamura, H., and Yoshida, M. 1985. "Evaluation of Corrosion of Reinforcing Steel in Concrete by Non-Destructive Method," Transactions, Japan Concrete Institute, Tokyo, Vol 7, pp 189-194, Tokyo, Japan.

The study considers a microcircuit and a macrocircuit as an equivalent circuit expressing corrosion of steel in concrete. Also, investigations were made on the effect of moisture conditions of concrete surface on the values of natural potential, measured on the concrete surface by numerical studies using a finite macrocircuit. Qualitative features of the effect were clarified and also confirmed by measured examples of a nondestructive test of corrosion of steel in an existing reinforced concrete column.

B-267 Seki, H., Matsui, K., Matsushima, M., and Kaneko, Y. 1985. "Estimation of Fracture Probability Due to Deterioration of Reinforced Concrete," Transactions, Japan Concrete Institute, Tokyo, Vol 7, pp 203-210, Tokyo, Japan.

A simple life prediction model is established to examine a life of reinforced concrete beam considering deterioration of materials as well

as the reduction of a cross-sectional area of reinforcing bars due to corrosion. Normal distribution is assumed on variations of initial strength of materials and other parameters contributing to its strength reductions. Assuming a failure will take place by bending, the method of Monte Carlo Analysis is introduced to estimate the change of beam strength through passage of time based on a failure probability.

B-268 American Society for Testing and Materials. 1985. "Corrosion Effect of Stray Currents and the Techniques for Evaluating Corrosion of Rebars in Concrete," V. Chaker, ed., ASTM STP-906, Philadelphia, PA.

Nine papers address new causes for reinforcing bar corrosion and ideas and techniques to identify, control, and monitor this type of corrosion. This problem can be responsible for structural failures that provoke loss of life and large financial losses. Highway bridges in regions exposed to ice, snow, and chlorides are the structures at the highest risk.

B-269 Wiseman, G., Greenstein, J., and Uzan, J. 1985. "Application of Simplified Layered Systems to NDT Pavement Evaluation," Transportation Research Record 1022, pp 29-36, Transportation Research Board, Washington, DC.

Presented are nondestructive testing (NDT) deflection measurements on flexible, rigid, and composite pavements obtained with two vibratory devices, the Pavement Profiler and the WES 16-kip vibrator, and one impulse loading device, the falling weight deflectormeter (FWD). The deflection bowls are analyzed in terms of the elastic parameters of layers using the Hogg, the Burmister, and the Odemark-Ullidtz approximation to linear layered elastic systems models. The results are compared with those obtained using more exact solutions and are found to be satisfactory. The evaluated elastic parameters were similar for all three NDT devices for the subgrade and the surface layers of the pavement. Lower elastic moduli were found for the base course with deflection bowls produced by the FWD than for those produced by the other two vibratory devices. Most pavement evaluation is done on pavements that have been in service for many years and have a varied history of maintenance and overlaying. The resulting lack of homogeneity must be considered in developing a strategy for meaningful pavement evaluation.

B-270 Sakata, Y., and Ohtsu, M. 1985. "Ultrasonic Filter Characteristics of Concrete Members with Cracks," Transactions, Japan Concrete Institute, Tokyo, Vol 7, pp 65-72, Tokyo, Japan.

In the field of concrete engineering, deterioration and cracking of concrete members provide significant problems in a number of structures constructed. Therefore, a testing method which can evaluate structural integrity of concrete promptly is urgently required. We are currently studying an evaluation method by using ultrasonic filter characteristics of concrete members. This paper is a summary of results obtained by several experiments concerning crack evaluation and restoration. These include in situ measurement of crack-repairing effects in a

concrete structure, freezing and thawing tests of specimens with hair-crack-nets which were cut out from steam cured U-blocks, and experiments of model specimens with artificial cracks and hair-cracks due to drying.

B-271 Tamura, H., Hoshino, Y., Takahashi, T., and Saitoh, H. 1985. "Proposal of Test Method on Rapid Identification of Alkali Reactivity of Aggregate (GBRC Rapid Method)," Transactions Japan Concrete Institute, Tokyo, Vol 7, pp. 119-126, Tokyo, Japan.

The authors propose the GBRC Rapid Method as a new method for the identification of the alkali reactivity of aggregate. According to this method, the alkali reactivity of aggregate can be judged in a short time, by observing the cracking of mortar specimens or by measuring either the ultrasonic pulse velocity or dynamic Young's modulus of specimens, which are of high alkali content and kept in boiling water in a high-pressure vessel for 2 hours after curing for 2 days. By this method, 61 samples of aggregate in Japan and several kinds of aggregate picked from two deteriorated concrete structures were tested. The test results showed that the GBRC Rapid Method seemed to be applicable.

B-272 Kaneko, S., Nagano, H., Sakurai, H., and Yasu, S. 1985. "Chloride Content and Cement Hydrate Minerals in Concrete in Sea Environment," Transactions of the Japan Concrete Institute, Tokyo, Vol 6, pp 147-154, Tokyo, Japan.

A series of investigations for clarifying the properties of existing concrete structures in sea environment and for evaluating the deterioration and the durability of the marine structures concerned are presented in this paper. It consists of quantitative chemical analysis for chlorine and calcium oxide, X-ray diffraction analysis, differential thermal analysis and infrared absorption analysis for calcium carbonate, and scanning electron microscopy.

B-273 Kostrencic, Z., Bjegovic, D., and Balabanic, G. 1985. "Mathematical Evaluation of the Quality of Repairs on Concrete Specimens," Cement Concretes, and Aggregates, Vol 7, No. 2, pp 95-99, Philadelphia, PA.

By comparing ultrasound pulse velocities before and after repairs on concrete and reinforced concrete structures, it is possible to assess the efficiency of repairs. Two statistical ways to assess repairs shown in the paper are: (1) comparing the velocities and using t-test, and (2) the chi-square test. The former is good in application when individual repairs are considered, and the latter is good when a great number of repaired places are under consideration, and the success and the stability of the hole structure is assessed. The methods were applied on bridge prestressed beams and the advantages of each are shown in examples.

B-274 Cohen, E., Dobbs, N., and Combs, W. 1985. "Inspection, Analysis, and Restoration of MIT Kresge Auditorium," Rehabilitation, Renovation, and Preservation of Concrete and Masonry Structures, SP-85, pp 31-93, American Concrete Institute, Detroit, MI.

This paper describes the engineering procedures involved in the renovation of Kresge Auditorium which is located at the Massachusetts Institute of Technology in Boston. Described are inspection procedures used to determine any structural deterioration which may have occurred since the building's inception. These procedures included visual inspection to determine cracking and other aspects which would possibly reduce the strength of the structure, pulse-echo test, and chemical and petrographic tests of the concrete in the structure, as well as continuous monitoring of structure motions during remedial construction. To assist in this remedial work, a series of finite element analyses were performed to determine stress levels within the structure. These analyses considered initial construction stresses as well as increased stresses due to structure deterioration. Based on the above, a series of structural modifications were developed and implemented in the restoration of the structure.

B-275 Di Maio, A. A., Traversa, L. P., and Giovambattista, A. 1985. "Nondestructive Combined Methods Applied to Structural Concrete Members," Cement, Concrete, and Aggregates, Vol 7, No. 2, pp 89-94, Philadelphia, PA.

Strength evaluation of structural members has been done with such nondestructive methods as ultrasonic pulse velocity, hammer rebound, and localized pressure, either individually or by combining methods. The effects of the mineralogical composition of the coarse aggregate, moisture content, and age of concrete on pulse velocity and rebound number is reported. Standard cylindrical specimens cured at 100 percent relative humidity were tested for compressive strength. Regression equations thus obtained were used to estimate the in situ compressive strength of reinforced prisms measuring 0.15 x 0.15 x 1.00 m. The prediction error is calculated from the comparison of the estimated strength and the strength determined on drilled cores.

B-276 Chung, H. W., and Law, K. S. 1985. "Assessing Fire Damage of Concrete by the Ultrasonic Pulse Technique," Cement, Concrete, and Aggregates, Vol 7, No. 2, pp 84-88, Philadelphia, PA.

When a concrete member is exposed to fire, the exterior of the member is heated drastically while the interior remains at a relatively low temperature. Only a thin surface layer of the concrete is subjected to severed damage. It is most useful to the engineer to know the extent of damage for estimating repair work. Thickness of the damaged layer can be expediently assessed by measuring the velocity of ultrasonic pulses along the surface. The accuracy of this technique has been assessed with a series of tests in which the concrete was heated to various temperatures; results indicate that the technique is relatively accurate. However, extensive cracking of concrete at very high

temperatures may make the ultrasonic measurements very difficult to obtain and hence limit the applicability of this technique.

B-277 Mizrokhi, Y. K., et al. 1985. "Standard Relative to an Ultrasonic Method to Determined Concrete Frost-Resistance" (in Russian), Beton i Zhelezobeton, No. 4, pp 28-29, Moscow, USSR.

Introduction of the ultrasonic method to control and estimate frost resistance according to GOST 26124-84 permits reducing the number of tested samples of 2.5 times and testing duration of 40 percent while it increases control result truth. This method ruled by GOST 26134-84 gives not only frost resistance of tested concrete but also a real value of frost resistance.

B-278 Clifton, J. R. 1985. "Nondestructive Evaluation in Rehabilitation and Preservation of Concrete and Masonry Materials," Rehabilitation, Renovation, and Preservation of Concrete and Masonry Structures, Publication SP-85, American Concrete Institute, Detroit, MI.

This paper describes nondestructive evaluation (NDE) methods that can be used in assessing the condition of concrete and masonry materials and components in structures being rehabilitated or preserved. Metal reinforcement is also included. The appropriate use of NDE methods is discussed and a recommended approach to selecting NDE methods for specific situations is given.

NDE methods are briefly described based on their principle of operation, information they provide, applications, expertise required to use them, and advantages and limitation of their use.

B-279 Ozbeki, M. A., Kilareski, W. P., and Anderson, D. A. 1985. "Evaluation Methodology for Jointed Concrete Pavements," Transportation Research Record 1043, pp 1-8, Transportation Research Board, Washington, DC.

Many interstate and other major highways constructed with jointed portland-cement concrete pavements have reached their design life and consequently are deteriorating significantly. Few transportation agencies have an effective method for evaluating the structural adequacy of transverse joints. Most pavement rehabilitation programs now underway are based on subjective engineering judgment. A more objective evaluation procedure is presented. A newly developed finite element program, JSLAB, was used in a parametric study to determine which variables have the most significant effect on the performance of transverse joints. It was concluded that the variables that most significantly affect pavement deflections and stress are the modulus of subgrade reaction and the modulus of dowel-concrete interaction. On the basis of this study, it was concluded that a rigid pavement system can be structurally evaluated if the modulus of subgrade reaction and the dowel--concrete modulus are known. Charts were developed to determine these moduli and subsequently to evaluate in-service pavements.

B-280 Clarke, J. N. 1986 (Jan). "Testing Concrete Durability-Work of the Concrete Society," Concrete, Vol 20, No. 1, pp 29-30, London, England.

A Concrete Society member highlights current work of the Society's technical Steering Groups relating to testing concrete durability. There are two main reasons for investigating and testing concrete: to check compliance with a specification during construction, and to investigate performance after a period in service. The Concrete Society has been actively involved in both of these areas since its formation nearly 20 years ago and has contributed, directly and indirectly, to the revision and improvement of many British standards.

B-281 Orantie, K., and Punakallio, E. 1986 (Jan). "Verification of Strength Properties of Concrete Structures by Nondestructive Methods" (in Finnish), Research Report 389, Technical Research Centre of Finland, Espoo.

The purpose of this research was to verify the compliance of in situ concrete structures with strength requirements using such nondestructive testing methods as the rebound hammer, the ultrasonic pulse technique, and a combination of the two. The influence of wetting of the concrete surface on the accuracy of test results was considered, and the reliability of methods for testing frozen concrete was appraised.

B-282 Rengaswamy, N. S., et al. 1986 (Jan). "Nondestructive Testing of Concrete by Electrical Resistivity Measurements," Indian Concrete Journal, Vol 60, No. 1, pp 23-27, Bombay, India.

The scope of electrical resistivity measurements as a nondestructive testing technique for concrete structures is examined. There is a linear relationship between resistivity and compressive strength and the resistivity measurements can be used to continuously monitor strength development in concrete. Porosity of concrete can also be assessed by measuring resistivity in the dry and water- saturated conditions. An important observation is that a highly porous concrete, in spite of its low strength, can have a very high-resistivity value. This study also shows that a battery-operated portable resistivity meter can be conveniently used as a nondestructive testing tool for in situ measurements on concrete structures.

B-283 Reichverger, Z. 1986 (Feb). "Using an Impact Device with Sliding Drop Collar for In Situ Evaluation of Compressive Strength of Insulating Cellular Concrete," Journal of Testing and Evaluation, Vol 14, No. 2, Israel.

This paper describes the efforts of the Central Building Laboratory of the Standards Institute of Israel to develop a relatively simple method for in situ nondestructive evaluation of the compressive strength of lightweight cellular concrete used for thermal insulation of roofs.

The idea of the developed impact device with sliding drop collar is similar in principle to the well-known soil test method of drop-weight penetration, ordinarily used for field determination of compacted soil density.

Test results show that the depth of penetration is influenced by two main parameters: compressive strength of the concrete and its density. If the unit weight of the cellular concrete is known or predetermined, its compressive strength can be estimated by means of the impact device with a sufficient degree of accuracy. Thus the drop-collar penetrometer may find useful application in in situ quality control of lightweight cellular insulating concretes.

B-284 Smith, A. P. 1986 (Feb). "Underwater Nondestructive Testing of Concrete: An Evaluation of Techniques," Technical Note N-1747, US Naval Civil Engineering Laboratory, Port Hueneme, CA.

Three commercially available instruments for testing concrete above water were successfully modified for underwater use and evaluated in laboratory and field tests. Each instrument represents a different technique for evaluating concrete structures. Instruments for the following methods were tested: a magnetic reinforcing bar locator that can be used to locate reinforcing bars in concrete structures and measure the amount of concrete cover over the bar; a Schmidt hammer that can be used to evaluate the surface hardness of the concrete and obtain a general condition assessment; and ultrasonic test equipment that can be used to estimate compressive strength, detect cracks, and provide a general condition rating of the concrete based on sound velocity measurements.

Laboratory and field tests did not reveal any problems with the fundamental operation of each instrument. Only the Schmidt hammer showed a shift in output data (23 percent) as a result of the modifications. This shift can be eliminated by modifying the design. Modification for underwater operation did not affect data from the other two instruments, and all instruments were easily operated by a diver.

B-285 Berke, N. S. 1986 (Mar). "Corrosion Rates of Steel in Concrete - Why Worry?" ASTM Standardization News, Vol 14, No. 3, pp 57-61, Philadelphia, PA.

When large potholes and widespread steel delamination from the concrete are present there is little difficulty in assessing the condition of a reinforced concrete structure. Yet, because of the inaccessibility of reinforcing steel, a reliable, nondestructive means is needed to determine the corrosion rate of steel in structures that are still sound. Two nondestructive electrochemical techniques to determine corrosion rates of steel in concrete are polarization resistance and alternating-current (a-c) impedance. Sufficient detail will be provided to demonstrate their usefulness in this application. More detailed examples of the use of these techniques applied to steel in concrete can be found.

B-286 Domone, P. L., and Castro, P. F. 1986 (Mar). "Expandable Sleeve Test for In Situ Concrete Strength Evaluation," Concrete, Vol 20, No. 3, pp 24-25, London, England.

Research work on the ESCOT (Expanding Sleeve Concrete Test) is outlined. A research program, sponsored by the Brazilian National Council for Scientific Technical Development, has been carried out at University College, London, to develop a suitable test. The test is limited in that it measures only the properties of a relatively small volume of concrete close to the surface. There is increasing recognition that the cover zone has the major influence on the overall durability of the concrete element; therefore, the testing may be valuable.

B-287 Vietro, P. D. 1986 (Mar). "Monitoring a Bridge's Pulse," Civil Engineering, Vol 56, No. 3, pp 54-55, American Society of Civil Engineers, New York, NY.

Five years after the collapse of Florida's Sunshine Skyway Bridge, a replacement, possibly the longest cable-stayed bridge in the United States, is under construction. Over 500 gages are closely monitoring the construction and will continue to do so after construction. Instruments are installed in the bridge segments before the concrete is cast: 534 gages are being used-228 concrete strain meters and 306 temperature sensors.

B-288 Dixon, D. E. 1986 (Mar). "Sampling for Attributes," Concrete International: Design & Construction, Vol 8, No. 3, pp 53-55, Detroit, MI.

It is often necessary to determine the properties of reinforced concrete in existing structures. Routine sampling and testing satisfies the requirements. Sometimes it is necessary to determine both an overall property and its variations, such as compressive strength and standard deviation of compressive strength. Through the use of a case history, the sampling requirements and procedures for the testing program and the procedures used to determine the appropriate sample size are discussed. The procedures include cover for reinforcing steel and slab thickness for several multistory parking garages. The statistical analysis procedures used are also presented.

B-289 Randal, D. 1986 (Apr). "Measuring Corrosion of Reinforcement in Concrete Structures," Indian Concrete Journal, Vol 60, No. 4, pp 109-110, Bombay, India.

Corrosion of reinforcement in reinforced concrete and of the tendons in prestressed concrete structures, although undesirable, is a common phenomenon. If the corrosion process goes undetected, the safety of the structure may become endangered, leading even to collapse. The measurement of corrosion in the structures is, therefore, a dire necessity. Two modern systems of measuring corrosion-the "potential wheel" and the "pathfinder"-are described briefly.

B-290 Snell, L. M., Wallace, N., and Rutledge, R. B. 1986 (Apr). "Locating Reinforcement in Concrete," Concrete International: Design & Construction, Vol 8, No. 4, pp 19-23, Detroit, MI.

An evaluation of the cover and spacing of reinforcement in an existing concrete structure is usually performed by selective testing and statistical determination. There are two similar, but distinctly different, reasons why reinforcement cover and spacing may be required: to determine if the reinforcement is in compliance with the contract specifications and to analyze a building for which the contract documents are not available. This paper illustrates techniques that can be used to analyze both types of structures. The paper also presents the types of statistical information that must be considered in the evaluation of an existing concrete structure.

B-291 Matti, M. A. 1986 (Apr). "Frozen Concrete," Concrete International: Design & Construction, Vol 8, No. 4, pp 34-41, Detroit, MI.

A structural concrete slab placed with inadequate protection from winter weather was inadvertently exposed to freezing conditions at an early age. The principal concern was whether it could be rehabilitated or should be totally rejected. Nondestructive techniques were used to determine the quality of the concrete and to reach conclusions about the factors affecting concrete strength development at low temperatures. Accepting or rejecting frozen concrete should be determined only after all relevant information is examined. Subjecting concrete to freezing temperatures at an early age is certainly not advised; however, if it happens it should not be cause for summarily rejecting the concrete.

B-292 (Deleted)

B-293 De Sitter, W. R., et al. 1986 (Apr). "Acoustic Inspection and Monitoring of Prestressing Tendons and Bars in Concrete Structures," CUR Report No. 124, Centre for Civil Engineering Research, Codes and Specifications for Concrete, Grouda, The Netherlands.

Concrete is relatively new as an offshore construction material. Severe demands are made by the marine environment on the integrity of offshore structures and their extended service life. A major risk is corrosion attack of reinforcing steel and, in particular, prestressing tendons. To minimize the danger of major structural damage, efficient inspection methods are required. As part of the research program, echo-acoustic methods have been developed for locating and measuring surface cracks, which allow inspection of concrete structures, both above and underwater. Under adverse weather conditions, exterior inspection is not possible. Therefore, other means for increasing the confidence level in the security of the structure and for giving an early warning of potential damage can be useful. Two such methods have been investigated and are detailed.

B-294 Barlow, M. 1986 (May). "Investigation of High-Rise Structures-Access Versus Cost," Construction Repairs & Maintenance, Vol 2, No. 3, pp 15-16, London, England.

The first step in organizing repairs to the exteriors of modern structures is to identify the nature and extent of the problem, but high costs often make close inspection prohibitive. This article describes a low-cost method of inspection. By employing fixed ropes and easy-to-control variable friction devices and, borrowing from long-established mountaineering practice, a trained inspector is afforded easy and rapid access to any location, rendering platforms and scaffolding unnecessary. On a typical high-rise building inspection program, inspectors examine and hammer sound all external surfaces. Every defect is measured, coded, and the location marked on an elevational drawing. Selected faults are photographed. Data gleaned by such a preliminary survey provide a cost-effective means of determining additional selective test programs designed to monitor structural integrity.

B-295 Shibuya, T., et al. 1986 (May). "Petrographical Investigation on Alkali-Reactive Aggregates in Japan" (in Japanese), Journal of the Society of Materials Science, Vol 35, No. 392, pp 496-501, Kyoto, Japan.

As the first step of investigation to avoid alkali-silica reaction, a study was carried out on the characteristics of reactive rocks in Japan, especially andesites of the tertiary and quarternary periods.

The test methods were as follows: observation under a microscope, x-ray diffraction analysis, and ASTM C 289 Standard Test method for potential reactivity of aggregates (chemical method).

The rocks containing a large quantity of reactive silica (such as cristobalite, tridymite, and amorphous silica) were susceptible to alkali-silica reaction. Most of the andesites of the quarternary were classified as "deleterious." Many cracks and cavities, which occurred during the cooling of the magma, were observed at the inner part of andesite aggregates in deteriorated concrete structures.

B-296 Santhakumar, A. R., et al. 1986 (May). "Semi-Destructive Methods of Testing In-Situ Concrete," Indian Concrete Journal, Vol 60, No. 5, pp 127-133, Bombay, India.

Various semidestructive methods of testing in situ concrete are discussed briefly. An experimental investigation on concrete through pullout tests with a separately fabricated device is also presented.

B-297 Curtin, B., and Thelwell, J. 1986 (May). Structural Surveys and Repairs of High-Rise Systems," Construction Repairs & Maintenance, Vol 2, No. 3, pp 6-10, London, England.

Structural surveys and repairs of high-rise concrete buildings are

discussed. The basic three C's of concrete (cement content, cover, and compaction) are suggested to determine if the buildings are structurally sound and whether they can be repaired and maintained economically. The deterioration of high-rise concrete structures is addressed, suggesting that it is not the material, but rather its handling, that is the root of the problem.

B-298 Mani, K., and Lakshmanan, N. 1986 (Jul). "Determining the Extent of Damage Due to Fire in Concrete Structures by Ultrasonic Pulse Velocity Measurements," Indian Concrete Journal, Vol 60, No. 7, pp 187-191, Bombay, India.

A fire in a concrete structure causes damage to various structural components, the extent of which depends upon the intensity and duration of the fire. There are few analytical methods available at present to estimate the core strength and depth of damage to the exterior faces. Ultrasonic pulse velocity measurements are extensively used in evaluating fire-damaged structural elements. A method has been proposed to estimate the core strength as also the depth of damage in a fire-damaged environment of reinforced concrete structures using ultrasonic pulse velocity measurements.

B-299 Rajagopal, C., et al. 1986 (Jul). "Use of Electrochemical Techniques in Corrosion Monitoring of Reinforced Concrete Structures-State of the Art," Journal of Structural Engineering, Vol 13, No. 2, pp 65-70, Madras, India.

The latest electrochemical techniques that are reported in literature for determination of the corrosion rate of reinforced concrete structures are reviewed.

B-300 Jambor, J., Zivica, V., and Kucka, J. 1986 (Jul). "New Method of Study of State of Steel Concrete Reinforcement and Development of its Corrosion" (in Czechoslovakian), Stavebnicky Casopis, Vol 34, No. 7, pp 541-556, Bratislava, Czechoslovakia.

This article describes an improved method of electric resistance to be used for the study of corrosion of steel reinforcement embedded in concrete. The method involves a concrete steel specimen to be included in a so-called "corrosion pickup" that is embedded in concrete to record the state of the steel reinforcements. For measurements using this pickup, equipment was developed and a suitable method of obtaining results was suggested. Verification tests show that the method allows nondestructive investigations with substantially higher reliability and less labor consumption.

B-301 Headquarters, US Army Corps of Engineers. 1986 (Jul). "Evaluation and Repair of Concrete Structures," EM 1110-2-2002, Washington, DC.

This manual provides guidance on evaluating the condition of the concrete in a structure, relating the condition of the concrete to the underlying cause or causes of that condition, selecting an appropriate

repair material and method for any deficiency found, and using the selected repair method. Guidance is also included on maintenance of concrete and on preparation of concrete investigation reports for repair and rehabilitation projects. Considerations for certain specialized types of rehabilitation projects are also given.

B-302 Brackett, R. L. 1986 (Aug). "Underwater Inspection of Waterfront Facilities," The Military Engineer, Vol 78, No. 509, pp 442-445, Alexandria, VA.

Over two-thirds of the facilities of the Naval Shore Establishment are over 35 years old (nearly twice their original design life) and require increasing amounts of maintenance and repair to remain operational. Underwater inspection of these facilities is now essentially limited to visual observations, with a minimal amount of nondestructive testing using instruments originally developed for terrestrial applications. Specialized inspection procedures and equipment are required to gather concise and objective data on the internal and external condition of the structural elements of critical facilities.

The most common causes of damage to concrete waterfront structures is cracking and loss of material or cross section due to spalling. Currently, visual underwater inspections of concrete structures are conducted to locate cracks, spalls, or rust stains. Data from these inspections are generally inadequate to accurately assess the overall condition and load-bearing capacity of the entire structure. Six techniques developed to test the condition of terrestrial concrete structures appear most adaptable to underwater use: surface hardness testing, penetration techniques, pullout tests, magnetic reinforcing-bar location, coring, and ultrasonic testing. These were evaluated at NCEL and three were selected for further development: the Schmidt hammer surface hardness tester, a magnetic reinforcing-bar location system, and a low-frequency through transmission ultrasonic testing technique.

B-303 El-Sayed, H. A., El-Didamony, H., and Ali, A. H. 1986 (Aug). "Case Histories of Premature Failures of Concrete Structures Due to Reinforcement Corrosion Under Different Environmental Conditions," Corrosion Prevention & Control, Vol 33, No. 4, pp 88-92, Bucks, England.

The present study investigated the factors that were responsible for the corrosion of steel reinforcements in five structures in Egypt subjected to rural, urban, and industrial environments leading to concrete cracking and diminishment of the durability of the structures. The investigation included chemical analysis of concrete and its surrounding medium (water and/or soil), and X-ray analysis of the concrete. The investigation disclosed that proper workmanship, low concentration of aggressive ions, high alkalinity, relative low C and S contents of the steel and a nonaggressive surrounding atmosphere establish the ideal conditions for reinforcement passivity and hence maintaining the durability of the structures.

B-304 Vesikari, E. 1986 (Aug). "Service Life of Concrete Structures" (in Finnish), Valt Tek Tutkimuskeskus Tutkimuksia, Vol 417, Espoo, Finland.

Service life is the period of time during which a building or a structure preserves the esthetic and functional requirements established for it. The main deteriorating factors that affect the service life in Finland are the frost scaling of concrete and the corrosion of reinforcing steels. The service life of a structure with regard to frost resistance can be evaluated by means of a mathematical model, where environmental and material-related factors have been separated. The effect of the material is taken into account in the form of a frost-resistance index. It can be determined using a direct method of frost-resistance testing or evaluated by indirect methods. The service life of a structure with regard to the corrosion of reinforcements can be evaluated by means of a mathematical model where the influencing factors are the thickness of the concrete cover, the quality of the concrete, and environmental conditions. The initiation time of corrosion is determined by the carbonation or chloride penetration into the concrete cover. The service life is normally considered to be finished when the concrete cover is spalled as a result of corrosion.

B-305 Nagano, H., and Naito, T. 1986 (Sep). "Diagnosing Method for Chloride Contaminated Concrete Structures," International Conference on Concrete in the Marine Environment, London, England, 22-24 Sep 1986, Concrete Society, pp 211-222, London, England.

In Japan, deterioration of chloride contaminated structures in early ages has become a serious problem in recent years, and the establishment of measures to solve this problem is a matter requiring immediate attention. Since concrete is a porous material, chloride dissolves into the extremely small quantities of capillary water which fill minute voids and slowly move inside. This phenomenon may be simulated as diffusion into a semi-infinite body. A diagnosing method for contaminated concrete structures was established, which consists of: (i) determination of physical coefficients relating to diffusion, (ii) concrete surface sampling method, (iii) prediction of extent of chloride contamination inside concrete, and (iv) diagnosis of deteriorated structures.

B-306 Perez Caballero, J. 1986 (Sep). "Practical Guide for the Structural Evaluation of Damaged Buildings" (in Spanish), Revista IMCYC, Vol 24, No. 184, pp 15-28, Mexico.

This paper has the main objective of serving as a practical guide for the structural inspection and evaluation of damaged buildings. It intends both to tell what to do and how to do it. At the beginning, general evaluation procedures are given and several significant concepts are described. Later on the paper presents criteria and formats for the registration and interpretation of the information obtained.

B-307 Naderi, M., Cleland, D. J., and Long, A. E. 1986 (Sep). "Insitu Test Methods for Repaired Concrete Structures," Adhesion Between Polymers

and Concrete, Bonding, Protection, Repair, Proceedings of an International Symposium, RILEM Technical Committee 52-Resin Adherence to Concrete and Laboratoire Central des Ponts et Chaussees, Paris.

The repair and maintenance sector of the construction industry has become a growing sector in recent years. In the market there are many repair systems which have made the choice of the appropriate system very difficult. As far as the repair is concerned, achieving a good bond between the repair and the original concrete is essential. To date, a few methods of testing the bond strength between the repair and original concrete have been suggested, but mainly these are tests which must be carried out under laboratory conditions. In addition, there is the question of the applicability of laboratory test results to actual site conditions. This paper describes in situ testing methods which can be used to determine the tensile and shear bond strengths between the repair and original concrete. Comparisons have been made between these methods and a compression/shear method.

B-308 "Materials Research: New Way to Measure Corrosion on Highway Bridges." 1986 (Sep). NBS Update, Gaithersburg, MD.

A system for highway engineers to measure the corrosion rate of steel reinforcing bars in concrete has been developed by NBS (Gaithersburg, Maryland) researchers. The system will offer engineers a way to evaluate the effectiveness of various surface coatings and sealers applied to bridge decks to reduce internal corrosion. Developed for the Federal Highway Administration, the new technique uses a portable, computerized system for making nondestructive spot measurements within a matter of minutes. It eliminates that need to bore holes in concrete to inspect steel reinforcing bars. The system consists of a small computer, a data logger, and two probes for sending and receiving electrical impulses. Measurements are obtained by placing the probes on a bridge deck to make contact with internal steel reinforcing bars. One of the probes is used to polarize the steel bars and the other is used to measure voltage change. Applications for the new system include inspection of buildings, parking garages, and other concrete reinforced structures subject to corrosion.

B-309 Bieger, K. W., Lierse, J., and Spanke, H. 1986 (Oct). "Testing of the Structural Behavior and Deformations Using In-Situ Measurements, Demonstrated on a Repaired Hollow Slab Bridge" (in German), Bauingenieur, Vol 61, No. 10, pp 459-467, Berlin, Germany.

Proven methods of measurement have been further developed so that on existing concrete structures, deflections, strains, and crack widths can be registered with extremely great accuracy. Using this nondestructive method, it is possible to reliably register the actual behavior concerning the structure and its deformations. Test loading with a 390 kN tank and deformation measurements on a partly cracked prestressed hollow slab bridge are reported.

B-310 Babaei, K. 1986 (Nov). "Evaluation of Half-Cell Corrosion Detection Test for Concrete Bridge Decks," Report WA-RD-95.1, Federal Highway Administration, Olympia, WA, Washington Div., Washington State Dept. of Transportation, Olympia, Washington.

The first chapter of the report discusses the corrosion of steel in concrete and provides information on the half-cell corrosion detection technique. In the second chapter, WSDOT's use of the test is reviewed, its concerns with the test are discussed, and the reliability of data collected is determined based on the field tests conducted. In the third chapter, a systematic procedure is developed with which to incorporate half-cell data into the WSDOT's bridge deck repair priority and protective system selection program. The findings of the work support the use of the half-cell test on bridge decks for classifying their overall condition.

B-311 Ainso, H., and Tronzo, T. M. 1986. "Survey and Rehabilitation of Parking Garage Decks-A Case Study," Concrete in Transportation, SP-93, American Concrete Institute, pp 671-694, Detroit, MI.

Concrete parking decks are subject to several unique problems which can initiate or aggravate deterioration. These include negative-moment cracking, cold joint cracking, cracking due to embedded conduit runs, and other water-related damage. This paper deals with problems encountered during the rehabilitation of the parking decks in a three-story, 28-year-old garage. This structure was not maintained for its entire life, except for the installation of a waterproofing membrane on the top deck about 8 years ago. The topics covered are inspection and testing - what to look for and specific test procedures and causes and recommendations for the repair of some of the problems encountered.

B-312 Suprenant, B. A. 1986. "Investigating Concrete Failures - Clues from Hardened Concrete," Structural Engineering Practice: Analysis, Design, Management, Vol 3, No. 2, pp 113-131, New York, NY.

The structural engineer is usually the head of the investigative team organized to determine the cause and division of responsibility of a failure. When investigating a concrete structure collapse, the hardened concrete can provide many clues concerning the source or initiation of failure. Crack patterns, assessment of corrosion deterioration, and methods of analyzing constituents of hardened concrete provide information or 'clues' to the mechanism of concrete damage. General information on obtaining 'clues' is presented as an aid to the structural engineer shouldering the responsibility of leading the investigative team.

B-313 Carleton, H. R., and Muratore, J. F. 1986 (Nov). "Ultrasonic Evaluation of Concrete," IEEE, 1986 Ultrasonics Symposium - Proceedings, Williamsburg, VA, 17-19 Nov 1986, IEEE, New York, NY.

Ultrasonic analysis techniques have been developed for evaluating the internal structure of concrete and related materials. The penetration

of ultrasound into concrete has been evaluated at a wide range of frequencies where the penetration follows a linear inverse dependence on frequency. From this information it is possible to establish both the maximum penetration and the spatial resolution of ultrasonic analysis. Using backscattering from a concrete block, stochastic scattering from the internal structure is illustrated. Signal enhancement is obtained by using weighted deconvolution to obtain wideband pulse analysis from which axonometric plots of internal structure can be derived.

B-314 Lindsey, J., Edwards, D., Keeter, A., Payne, T., and Malloy, R. 1986. (Dec). "Instrumentation Automation for Concrete Structures; Instrumentation Automation Techniques," Technical Report REMR-CS-5, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

This report is a guide to determining the requirements for and the subsequent design, assembly or fabrication, installation, checkout, operation, and maintenance of data acquisition and reduction systems for use at or in large concrete hydraulic structures. It is a companion to two other reports in the series: Report 2, "Automation Hardware and Retrofitting Techniques," and Report 3, "Available Data Collection and Reduction Hardware." The report describes automation techniques and requirements for maintaining automated instrumentation in a generic fashion. It focuses on system concepts and describes the steps necessary for implementing automated instrumentation monitoring systems suitable for use in or at large concrete hydraulic structures.

B-315 Persson, S., and Ostman, E. 1986a. "Use of Computed Tomography in Non-Destructive Testing of Polymeric Materials," Aluminum and Concrete: Part 1 - Basic Principles, Polymer Testing, Vol 6, No. 6, pp 407-414.

During the first 50 years of the 20th century, X-ray technology developed slowly. It is only within the last decade that growth in imaging technology in the range of techniques available has been rapid. In the 1970's computed tomography (CT) was discovered by A. M. Cormack and G. N. Hounsfield. This article describes the principal differences between X-radiography and computed tomography.

B-316 Persson, S., and Ostman, E. 1986b. "Use of Computed Tomography in Non-Destructive Testing of Polymeric Materials," Aluminum and Concrete: Part 2 - Applications, Polymer Testing, V. 6, No. 6, pp 415-446.

Computed tomography has been used to detect imperfections in polymeric products such as airplane tires, rubber shock absorbers, and fiber-reinforced materials of various types and shapes. Computed tomography also can be used to investigate aluminum and concrete. There is some evidence which indicates that computed tomography can be used to measure cross-link density gradients in polymeric products, e.g., thick-walled rubber products such as dynamic springs and dampers.

B-317 "Inspection and Maintenance of Reinforced and Prestressed Concrete Structures." 1986. FIP Guide to Good Practice, Thomas Telford Ltd., London, England.

Concrete load-bearing structures are subjected to many types of environmental influence. To keep the structures in a good state, they have to be inspected regularly and maintained. When designing concrete structures, it is important to consider the requirements for proper inspection and maintenance. This guide deals mainly with inspection, which is a major part of preventive maintenance.

1987

B-318 Nasser, K. W., and Al-Manaseer, A. A. 1987 (Jan). "New Non-Destructive Test," Concrete International: Design & Construction, Vol 9, No. 1, pp 41-44, Detroit, MI.

It is a common practice in the construction industry to remove concrete forms as soon as the concrete has attained a safe minimum strength. To evaluate this required strength, an economical and efficient field test is needed that is simple and rugged enough for handling by construction personnel. For this, a simple device has been developed which is described in this paper.

The apparatus can grip a pin with a length of 30.5 mm, a diameter of 3.56 mm, and a tip machined at an angle of 22.5 deg. The pin is held by a hammer shaped shaft that is encased within the body of the tester. The hammer is activated when it is tightened against the spring by rotating and forcing its handle through the loading bolt. The spring stiffness is 49.7 N/mm and the apparatus is built to store about 108 N/m of energy.

B-319 McCleese, W. F. 1987 (Jan). "Proceedings of REMR Workshop on Assessment of the Stability of Concrete Structures on Rock," Repair, Evaluation, Maintenance, and Rehabilitation Research Program, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

Presented are the Proceedings of the Workshop on Assessment of the Stability of Concrete Structures on Rock. The workshop was conducted to define problems with the Corps' current stability criteria and procedures, and to identify research needs that would address these problems. The proceedings provide a summary of the papers presented and the activities, conclusions, and recommendations of five working groups. Each working group was assigned one of the following subject areas.

1. Shear strength selection procedures and the use of these parameters for evaluating the stability of existing concrete structures.

2. Foundation exploration procedures for acquiring test samples and identifying weakness in the foundation for evaluating the stability of existing concrete structures.

3. Computation of forces and methods of analysis for evaluating the stability of existing concrete structures on rock.

4. Instrumentation and monitoring procedures for the purpose of evaluating the stability of existing concrete structures on rock.

5. Procedures for selecting and designing systems to improve stability.

B-320 "Evaluation of Reinforced Concrete Parts After Fire Attack" (in German). 1987 (Feb). Technische Uberwachung, Vol 28, No. 2, Germany.

A new process evaluating the feasibility of restoring reinforced concrete structures after fire attack has been developed by the German RWTUV. The technique is based on on-site sampling of the microstructure of reinforced concrete parts. It concludes metallographic preparation of reinforcing steel, etching, preparation of a replica, and subsequent analyses by means of optical microscopy or SEM. It is recommended to follow up each microstructural investigation by nondestructive hardness testing. So far, the new method has been successfully applied to microstructural evaluation of steel structures, large vessels, and pipelines.

B-321 Lange, Y. V., Ustinov, E. G., Shlyaktsu, M. I., Abramovskii, V. R., and Vityuk, P. S. 1987 (Feb). "IPB-10UTs Instrument for the Nondestructive Strength Evaluation of Concrete by the Impact Method," Soviet Journal of Nondestructive Testing, Vol 23, No. 2, pp 120-124, USSR.

An instrument for impact testing of the strength of concrete is described. The structure of the measurement transducer is discussed, and a block diagram is given for digital processing of the measurement results. The instrument is tested on concrete samples of various strengths.

B-322 Luong, M. P. 1987 (Jan-Feb). "Detection of Mechanical Damage in Concrete by Infrared Thermography" (in French), Mecanique-Materiaux-Electricite, No. 419, pp 30-33, Paris, France.

With reference to thermomechanical coupling, infrared thermography offers the possibility of a contactless nondestructive test for revealing the degradation of concrete. It allows a quantitative evaluation of the rate of growth of thermal dissipation and facilitates the recording and interpretation of mechanical damage of the material. This technique accurately detects the threshold of unstable crack propagation and/or defect coalescence and reveals weakened zones, when irreversible microcracking occurs under vibrational loading. It is also a convenient means of in situ inspection and evaluation of stress concentration on loaded concrete structures, particularly in zones where serious defects or weaknesses are most likely to occur.

B-323 Irwin, R. W. 1987 (Mar). "Deterioration of Concrete by Carbonation," New Zealand Concrete Construction, Vol 31, pp 3-11, Porirua, New Zealand.

The mechanism of concrete deterioration due to carbonation is well documented, and a number of test procedures are known that determine the depth of carbonation. However, these tests do not give an overall assessment of the state of the structure nor do they enable the useful life of the structure to be projected. This paper outlines a new technique of simple site testing: the Merminod Program, developed in 1979. Subsequent correlation of test results and rate of decay projections are made possible using EDP equipment. Additionally, the various effects on future decay rates of different remedial treatments are illustrated with computer graphics.

B-324 Kettle, R. J., and Sadegzadeh, M. 1987 (Mar). "Field Investigations of Abrasion Resistance," Materials and Structures: Research and Testing, Vol 20, No. 116, pp 96-102, Paris, France.

An extensive field investigation has been undertaken to assess the abrasion resistance of concrete floors on industrial premises. The performance was expressed in terms of the depth of wear produced by an accelerated abrasion machine that simulated the damage mechanisms in a typical warehouse or factory. The results were used to compare site and laboratory practices, and this demonstrated that results obtained solely with laboratory methods may not be applicable to industrial concrete floor slabs.

A comparison between the results obtained from the accelerated abrasion test and subjective assessments of service wear showed a general agreement and indicated that the apparatus provides a means for assessing the quality of concrete floor slabs in terms of abrasion resistance.

B-325 Zelenevskii, Z. L., Draginich, V. V., and Draginich, G. O. 1987 (Mar). "Long-Term Service Checking of the Concrete of the Chirkey Dam," Hydrotechnical Construction, Vol 21, No. 3, pp 164-167, Consultants Bureau, New York, NY.

The new instruments introduced on the concrete arch dam of the Chirkey hydrostation can be recommended for wide use in nondestructive methods of service checking on the state of the concrete of hydraulic structures when evaluating their reliability and safety. The adopted method of nondestructive testing of the physical and mechanical characteristics of concrete with time objectively reveals their change. It is recommended for on-site investigations of the condition of concrete of all sections of the Chirkey dam.

B-326 Sowers, G. F. 1987 (May). "Investigating Failure," Civil Engineering, Vol 57, No. 5, pp 83-85, American Society of Civil Engineers, New York, NY.

Investigating the failure of a structure is a critical task, demanding

the cooperation of engineers, architects, builders, and owners. As a group, they must determine the facts, cause, corrective measures, and procedures for preventing future problems. The article offers advice on gathering evidence, administering investigation responsibilities, and evaluating and reporting the data. A sidebar examining the right and wrong ways to conduct an investigation is included.

B-327 Price, H. R., and Swaffar, K. M. 1987 (Jun). "Condition Surveys of Large Diameter Concrete Lined Tunnels," Concrete International: Design & Construction, Vol 9, No. 6, pp 58-64, Detroit, MI.

A methodology for performing condition surveys of large diameter concrete-lined tunnels is presented. Possible environmental constraints and causes of concrete lining deterioration are discussed, and case histories of two tunnel inspection programs are reviewed.

B-328 Berkeley, K. G. C. 1987 (Jun). "Negative Approach to Rebar Corrosion," Chartered Mechanical Engineer, Vol 34, No. 6, pp 28-30, Institution of Mechanical Engineers, London, England.

There have been a number of reports recently in the daily press of concrete bridges deteriorating due to corrosion of the reinforcing steel. Deicing salt applied to the roads in winter has been blamed, but this is only part of the story since the mechanism is electrolytic. Civil and structural engineers are much concerned with this problem, but it can also touch mechanical engineers concerned with plant life since it can affect any buried or immersed surface. This article describes the process and outlines new methods of survey and system application which enable electrochemical principles to be adapted to assess the condition of reinforced concrete structures, such as water-retaining basins, storage tanks and pipelines, open channel intakes, cooling towers, or indeed any reinforced construction where the steel is in direct contact with the concrete.

B-329 Paul, M. J. 1987 (Jun). "Brandywine Shoal Lighthouse," Concrete International: Design & Construction, Vol 9, No. 6, pp 46-53, Detroit, MI.

A variety of destructive and nondestructive tests were used to evaluate existing conditions and the extent of deterioration of Brandywine Shoal Lighthouse. Founded atop a hazardous shoal next to a busy shipping channel in Delaware Bay, this historic concrete structure has deteriorated severely in the harsh marine environment. The recommended repairs utilize the full spectrum of concrete types, including shotcrete, preplaced-aggregate, tremie, precast, and cast-in-place.

B-330 Holt, F. B., and Eales, J. W. 1987 (Jun). "Nondestructive Evaluation of Pavements," Concrete International: Design & Construction, Vol 9, No. 6, pp 41-45, Detroit, MI.

Infrared thermography and ground-penetrating radar are two proven tools in the growing inventory of pavement management procedures. These

nondestructive tests can be used to detect and evaluate various pavement defects, including delaminations in steel-reinforced concrete pavements, debonding of asphalt and concrete overlays, changes in overlay thickness, subsurface deterioration of joints and cracks, and subsurface voids. This article describes the equipment and test procedures used to evaluate each of the equipment and test procedures used to evaluate each of these pavement defects. Case studies are outlined to demonstrate the speed and accuracy of the procedures under operational conditions.

B-331 Kriviak, G. J., and Scanlon, A. 1987 (May-Jun). "Estimation of Compressive Strength of Concrete in Existing Structures Based on In Situ Test Data," ACI Materials Journal, Vol 84, No. 3, pp 235-245, Detroit, MI.

A Bayesian statistics approach is presented for combining compressive strength data from cores and nondestructive test data such as pulse velocity and rebound number, as well as subjective data, to estimate the mean compressive strength of concrete in an existing structure. The procedure is illustrated through a parametric study using core data and nondestructive data from an existing bridge structure. The sensitivity of the analysis to various factors is discussed.

B-332 Nymand, K. K. 1987 (Jun). "Damage to Prestressed Bridges in the Nordic Countries," Nordisk Betong, Vol 31, No. 6, pp 33-35, Stockholm, Sweden.

The Nordic Road Engineering Association has studied the extent of damage to prestressed bridge designs in the Nordic countries. An account is given of existing methods of investigation and repair with respect to prestressed material. The report is subsequently supplemented by evaluations of the causes and extent of damage as well as by a review of experiences gained.

B-333 Sentler, L. 1987 (Jul). "Service Life Predictions of Concrete Structures," Durability of Building Materials, Vol 5, No. 1, pp 81-98, Amsterdam, The Netherlands.

The durability of reinforced concrete structures depends on the possible influence of loads, the effects of environmental agents, or a combination of the two. Stochastic methods are presented where the change in material properties due to loads and environmental agents can be described as a function of time. This enables the expected service life to be estimated-taking into account damage accumulation due to loads, deterioration due to environmental agents, or a combination of both.

B-334 El-Sayed, H. A., Abd El-Wahed, M. G., and Ali, A. H. 1987 (Jul). "Some Aspects of the Corrosion of Reinforcing Steel in Concrete in

Marine Atmospheres," Durability of Building Materials, Vol 5, No. 1, pp 13-25, Amsterdam, The Netherlands.

Seven deteriorated reinforced concrete structures exposed to marine environmental conditions in Egypt were inspected. Chemical analysis of collected concrete, soil, and water samples revealed that salty water had probably been used for concrete mixing and for aggregate washing. Also, most likely, the concrete components were originally contaminated with salts and/or salt dredged due to contact with saline water or soil at the site. The extent of carbonation in the concrete as well as carbonate content were determined. X-ray analysis of the concrete revealed the formation of expansive reaction products, i.e., ettringite, in some cases. Determination of the corrosion rate of steel in concrete in the coastal areas of Egypt indicated that it varies between 0.06 and 0.1 mm per year. Microscopic examinations performed on the obtained reinforcing steels revealed that pitting corrosion was the essential mode of attack in the investigated cases. However, transgranular corrosion cracking of steel reinforcement has been found in one case as a result of the combined effect of stress and the aggressive ions in the medium.

B-335 Thornton, H. T. Jr., and Alexander, A. M. 1987 (Aug). "Nondestructive Tests of Concrete Structures," Military Engineer, Vol 79, No. 516, pp 432-434, Alexandria, VA.

More attention has been focused on inspecting and evaluating completed civil works structures to assess their condition and performance capabilities. These structures should be evaluated in place, nondestructively, and in real time. Therefore, research and development work has been ongoing in sonic and ultrasonic pulse-echo, impact-resonance, and vibration signature. Systems for dry and underwater nondestructive tests have been developed. Some of these include an ultrasonic pitch-catch and pulse-echo system; impact-resonant vibration signature; and an underwater acoustic mapping system.

B-336 Tovey, A. 1987 (Sep). "Repair of Structures Damaged by Fires" (in Spanish), Revista IMCYC, Vol 25, No. 196, pp 21-28, 31-33, Mexico.

A number of publications advise on the assessment of the effect of fire on concrete structures. The most comprehensive, with regard to concrete structures, is the Concrete Society's Technical Report 15, 'Assessment of Fire-Damaged Concrete Structures and Repair by Gunite.' This publication is currently being revised by the Fire Resistance Committee of the Concrete Society. The major changes are presented in this article. The revised report has been available since 1986.

B-337 Nasser, K. W., and Al-Manaseer, A. A. 1987 (Sep-Oct). "Comparison of Non-Destructive Testers of Hardened Concrete," ACI Materials, Vol 84, No. 5, Detroit, MI.

This paper presents a comparative study of five nondestructive apparatuses for testing hardened concrete in place. The apparatuses are

the ultrasonic pulse velocity, the rebound hammer, the pullout tester, the penetration probe, and a new pin penetration tester. Mainly in the Morse tests, the performance of new pin penetration tester was evaluated in comparison to the other four testers.

The tests were carried out on 150-mm by 300-mm cylinders and 460- by 610 by 100-mm slab blocks at the ages of 1, 2, 5, 7, 14 and 28 days. The cylinders and blocks were made from mixes that contained portland cement. Manual and light weight aggregates and air-entraining admixtures were used in the mixes and the water-cement ratio varied between 0.53 and 0.66. The authors found out that the linear and power regression equations were best suited to fit most of the data and to relate it to the compressive strength of the concrete. The tests covered compressive strength in the range of 3.1 to 24.1 MPa.

B-338 Berra, M., and Baronio, G. 1987. "Thaumasite in Deteriorated Concretes in the Presence of Sulphates," Concrete Durability-Katharine and Bryant Mather International Conference, SP-100, pp 2073-2090, American Concrete Institute, Detroit, MI.

Some different degrees of alteration have been found in a concrete tunnel lining affected by dissolved calcium sulfate in water due to the oxidation and solubility of the pyrites contained in the rock. In some cases the damage has been so extensive that the concrete has changed into a plastic mass. Measurements taken inside the tunnel over many years showed a range of temperature from 4 to 6° C. The chemical analysis of the concrete, the diffractomeric analysis, and the scanning electron microscope analysis performed on some alteration products clearly showed the presence of thaumasite and calcite, while no ettringite was found. The recorded thermal conditions, the presence of silica due to feldspar alteration, and the free carbon dioxide in the water lead to the conclusion that the ettringite has been transformed completely into thausmasite.

To understand this transformation, some laboratory tests were carried out on mortar immersed in a water mixture containing calcium sulfate, calcium carbonate, calcium hydroxide, and amorphous silica in an environment rich in carbon dioxide, at 5 and 20° C, respectively.

B-339 Gjorv, O. E., and Vennesland, O. 1987. "Evaluation and Control of Steel Corrosion in Offshore Concrete Structures," Concrete Durability-Katharine and Bryant Mather International Conference, SP-100, pp 1575-1602, American Concrete Institute, Detroit, MI.

To provide a better basis for evaluation and control of steel corrosion in offshore concrete structures, a comprehensive research program was carried out a few years ago at the Norwegian Institute of Technology. In this paper, the most important findings of this program are briefly presented.

For corrosion of embedded steel the importance of considering the concrete as an electrolytic system is emphasized. If the passivity of the

embedded steel is broken, either by chloride penetration or by carbonation, the electrical resistivity and the availability of dissolved oxygen are the main controlling factors for corrosion to occur. In the present program basic information on these electrolytic factors was obtained for typical environmental conditions prevailing in the oceans. The effect of cracks and cathodic protection was further investigated. A system for field control and corrosion monitoring was also developed.

B-340 Kumar, S., and Heidersbach, R. 1987. "Corrosion of Metals in Concrete: Lessons Learned by Examination of Field Failures," Concrete Durability-Katharine and Bryant Mather International Conference, SP-100, pp 1727-1742, American Concrete Institute, Detroit, MI.

The corrosion of metals in concrete has become a multibillion dollar problem in the United States. Most of the research into the problem has been concerned with highway structures, primarily bridges, exposed to deicing salts and similar chemicals. Corrosion problems in buildings, concrete pipelines, and similar structures are seldom discussed in the open literature. One of the reasons for this is that many of these corrosion problems are associated with privately owned buildings and other structures involved in lawsuits.

This paper presents the results of forensic failure analyses on a variety of masonry and concrete structures. Analyses using the scanning electron microscope, the Raman microprobe, and other analytical techniques are presented and compared with the highway-oriented corrosion-in-concrete literature. Instances where corrosion has occurred under conditions not addressed by the highway-structure literature are discussed. The means of preventing or controlling corrosion in existing concrete and masonry structures are also discussed.

B-341 Stark, D. C., and De Puy, G. W. 1987. "Alkali-Silica Reaction in Five Dams in Southwestern United States," Concrete Durability-Katharine and Bryant Mather International Conference, SP-100, pp 1759-1786, American Concrete Institute, Detroit, MI.

The Bureau of Reclamation and Construction Technology Laboratories are conducting a joint program to study the effects of alkali-silica reactivity in concrete dams and to determine the remaining potential for further reactivity in the structures. The first phase of the study covers Coolidge Dam, near Globe, AZ; Friant Dam, near Fresno, CA; Matilija Dam, near Ventura, CA; Parker Dam, near Lake Havasu City, AZ; and Steward Mountain Dam, near Phoenix, AZ.

The three requirements for expansive alkali-silica reactivity are sufficient alkali, availability of moisture, and the presence of potentially reactive silica. The procedures used in this investigation include field measurements of the relative humidity of the concrete to determine if sufficient moisture is available to sustain a continued reaction, expansion measurements of cores immersed in water and in an NaOH solution, petrographic examination of the cores to identify

reactive aggregate particles, and osmotic cell tests of aggregate particles to determine potential reactivity.

B-342 Kerckaert, P., et al. 1987. "In Situ and Laboratory Investigation of the Degradation of an Old Concrete Quay Wall," Concrete Durability-Katharine and Bryant Mather International Conference, SP-100, pp 31-48, American Concrete Institute, Detroit, MI.

A complete study of the old concrete harbor dam at Zeebrugge, Belgium, is presented. As a basis for material examination, an anamnesis study was executed to establish details of construction techniques, requirements and composition of materials, and structure. Mechanical characteristics were determined by diagraphic drilling and by coring. The concrete samples were chemically analyzed to determine the cement content and the extent of corrosion. On the basis of the laboratory results and observations on the site, the repair procedures were determined and subjected to preliminary site tests.

B-343 Lach, V. 1987. "Deterioration of Alumina Cement Concrete," Concrete Durability-Katharine and Bryant Mather International Conference, SP-100, pp 1903-1915, American Concrete Institute, Detroit, MI.

It has been stated that some structures failed due to the use of alumina cement. This failure was connected with the physical and chemical changes of concrete. The reason for this effect has been studied on the samples prepared from a concrete structure that collapsed suddenly after 30 years of use without any symptoms of defects. Various methods of examination were used, e.g., chemical and thermal analysis, X-ray diffractometry, scanning electron microscopy, besides mechanical tests. The failure was attributed to a combination of two main factors. First, the hydrated alumina cement was converted and then carbonated so that gibbsite and calcite, which have slight binding properties, were formed. The highly converted and carbonated concrete lost considerable strength and could not sustain the stress in the construction.

B-344 Fournier, B., Berube, M. A., and Vezina, D. 1987. "Condition Survey of Concrete Structures Built with Potentially Alkali-Reactive Limestone Aggregates from the Quebec City Area (Quebec, Canada)," Concrete Durability-Katharine and Bryant Mather International Conference, SP-100, pp 1343-1364, American Concrete Institute, Detroit, MI.

This paper reports the results from the condition survey of about 300 concrete structures of the Quebec City area, with a significant proportion of them showing signs of deterioration commonly associated with alkali-aggregate reactions. Each component of these structures has been described according to the more common defects affecting concrete structures and to exposure conditions. Core samples have been taken in about 70 structures and investigated for physico-mechanical properties and air and chloride contents. Each sample has also suffered a petrographic examination. This study has been done to determine the present condition of these structures, to recognize the occurrence and the

severity of the major defects affecting them, and mainly to establish the influence of the alkali-aggregate reactivity on deterioration.

B-345 Kazakavich, V. 1987. "Condition Survey of Modular Expansion Joint Performance on Hoosick Street Bridge," Joint Sealing and Bearing Systems for Concrete Structures, SP-94, pp 943-954, American Concrete Institute, Detroit, MI.

The principal cause of deterioration to the superstructure and substructure are the expansion joint systems. Bridge engineers and maintenance personnel have long advocated longer spans with fewer and maintenance-free expansion joints. With longer spans, expansion joints have become greater.

In 1978, the New York State Department of Transportation invited manufacturers of six different types of modular expansion systems to install their devices on a new structure crossing the Hudson River at Troy, N.Y.

This paper is an up-to-date condition survey of the performance conducted on a regular basis of the six different modular expansion joints.

B-346 Litvan, G. G., and Bickley, J. A. 1987. "Durability of Parking Structures: Analysis of Field Survey," Concrete Durability-Katharine and Bryant Mather International Conference, SP-100, pp 1503-1526, American Concrete Institute, Detroit, MI.

A total of 215 garages in Toronto, Ottawa, and Montreal, Canada, have been surveyed to various extents by assessing delamination, half-cell potential, depth of cover, and component condition. In addition, tests were carried out on cores, in which chloride content, compressive strength, and chloride permeability were determined, and the air void system was analyzed. The evidence indicates that durable garages can be built and that poor performance must be attributed to design and construction practices, the effectiveness of which falls short of that required by the environment.

It follows that almost all previously built garages will eventually require repair unless upgraded before the chloride concentration of the concrete reaches a critical level. Repair by the patch and waterproof method was found to decrease the rate of corrosion of deteriorated garages by approximately 70 percent. Detrimental effects following installation of a waterproofing membrane over concrete with elevated chloride concentration were not observed. No relation was detected between extent of delamination and crack density or compressive strength. Half-cell potential did not prove more sensitive than the chain-drag test in detecting delamination.

B-347 Novokschchenov, V. 1987. "Investigation of Concrete Deterioration Due to Sulfate Attack-A Case History," Concrete Durability-Katharine and

Bryant Mather International Conference, SP-100, pp 1979-2006, American Concrete Institute, Detroit, MI.

In coastal areas of Saudi Arabia underground reinforced concrete structures are frequently exposed to aggressive action of saline water and sulfate-bearing groundwater. The extent of deterioration varies from negligible to very severe depending on the type of exposure and the concentration of sulfates and chlorides, as well as the quality of concrete. Deterioration of concrete is due mainly to aggressive action of magnesium sulfates, mitigated by chloride ions, and the decomposing effect of calcium sulfates from sulfate-bearing groundwater.

The procedures employed to evaluate nature, extent, and rate of deterioration consisted of a condition survey, chemical analysis of groundwater and water-borne precipitates, petrographic analysis of concrete cores, and structural evaluation of the in-place concrete. After unsound concrete is replaced and deficiencies repaired, protection from further deterioration can be achieved by tanking the surfaces with several layers of hot-applied coal tar reinforced with felt and by the installation of a subsurface drain system.

B-348 Tanaka, R., Takahashi, T., and Okada, T. 1987 (Nov). "Concrete Strength of Damaged Reinforced Concrete Buildings in the 1985 Mexico City Earthquake" (in Japanese), Journal of Structural and Construction Engineering, No. 381, pp 35-42, Tokyo, Japan.

In the Mexico Earthquake, many reinforced concrete buildings in Mexico City were severely damaged. This paper is a report on the results of the concrete strength measurements made by the Architectural Institute of Japan (AIJ) and the Japan International Cooperation Agency (JICA), who measured the concrete strength of 30 damaged buildings using the Schmidt hammer test and the concrete core test.

A tendency for destroyed or severely damaged buildings to have a particularly low concrete strength could not be recognized; a specific relation between the damage rank of the building and concrete strength was not found; a tendency for the concrete strength of damaged columns to be lower than undamaged columns could not be seen; no large difference was found between the concrete strength of upper floors and that of lower floors; and neither could a large difference be seen between different locations (columns, beams, slabs, etc.) on the same floor. Concrete strength values obtained using the concrete core test were larger than those obtained using the Schmidt hammer test, and the average concrete density was 2.06 t/m^3.

B-349 Dahlquist, M. S. 1987 (Nov). "Nondestructive Testing of Foundation at Lock No. 2, Mississippi River," The REMR Bulletin, Vol 4, No. 3, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

The US Army Engineer District, St. Paul, developed a nondestructive testing (NDT) program to locate voids beneath concrete lock structures, a drilling program to confirm the NDT results, and a grouting program

to fill any voids or areas of unconsolidated material beneath the lock floor slab, miter gate sills, and lock wall monoliths.

The NDT program employed two testing methods: pulse echo and ground-penetrating radar. Two methods were specified because conditions in the dewatered lock chamber would be variable. Surface conditions ranged from snow, sand, and ice to standing water or slush to bare concrete. The concrete thickness varied also, from 18 in. in the slab to over 9 ft at the miter gate sills.

As a measure of the effectiveness of the testing program, the drilling and grouting contractor attempted to correlate the NDT results with the results of the drilling. Reported correlation was over 80 percent.

During the course of the project, refinement of the testing procedure and data interpretation increased the correlation between the NDT and the drilling programs. It became possible to distinguish between solid and soft materials as well as to identify voids at various levels. Overall, the nondestructive testing program was successful in achieving the desired results.

B-350 Thornton, H. T., Jr., and Alexander, A. M. 1987 (Dec). "Development of Nondestructive Testing Systems for In Situ Evaluation of Concrete Structures," Technical Report REMR-CS-10, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

The need for additional capability to nondestructively evaluate concrete in large structures is similar for both the US Army Corps of Engineers (CE) and the US Bureau of Reclamation (USBR). In view of this mutual need, the CE and the USBR entered into a cooperative program of research and development designed to increase the nondestructive testing evaluation capabilities of these two organizations, with each agency sharing the program planning and financial support.

Literature reviews were conducted for the five tasks outlined in this investigation, and staff members of organizations known to be engaged in the development of applicable systems or technology were contacted.

An effort was made to develop an ultrasonic pulse-echo system for the investigation and evaluation of the interior of concrete structures. The large pulse-echo transducer fabricated at Ohio State University (OSU) was obtained for study. Experimental transducers were fabricated and bandwidths were altered and optimized. Transducer area and frequency of operation were determined and various piezoelectric materials were studied; acoustic and electrical matching were employed to optimize signal strength and signal-to-noise (S/N) ratio. The final prototype transducers were constructed of lead metaniobate (EC-82) and lead zirconate titanate (PZT-5H). The transducer area and mass was reduced by 90 percent and the S/N ratio was increased by 200 percent when compared with the OSU transducer. The pitch-catch prototype configuration was used to successfully measure the thickness of a 9-1/4-in. concrete test slab with a S/N ratio of 18. The system is presently useful for

making thickness measurements on concrete pavements and floor slabs. Limited tests have shown that a metal plate and a plastic pipe can be located in a concrete slab of 9-in. thickness or less. Also, a thickness measurement was made on concrete by generating wideband acoustic (sonic and ultrasonic) energy by an impact hammer and detecting the echoes with a low Q resonant receiver centered at 180 kHz.

B-351 Denes, T., and Buck, A. D. 1987. "An Experiment to Investigate Chloride Intrusion on Construction Joints in Concrete," Cement, Concrete, and Aggregates, Vol 9, No. 2, pp 80-81, Philadelphia, PA.

A field experiment was conducted to investigate the extent of chloride intrusion along the construction joint between later-placed, cement-based grout and concrete in instrumented precast concrete breakwater elements (dolosse). Experimental blocks were cast, grouted, and submerged in seawater. Upon retrieval, the construction joint between the grout and the concrete was evaluated for chloride intrusion from seawater using X-ray diffraction (XRD) and energy dispersive X-ray analysis (EDX) of scanning electron microscope (SEM) samples. No detectable intrusion occurred, indicating that the planned instrumentation of dolosse in a field experiment should be secure from significant seawater intrusion.

B-352 Thornton, H., and Alexander, A. 1987. "Development of Impact/Resonant Vibration Signature for Inspection of Concrete Structures," Concrete Durability-Katharine and Bryant Mather International Conference, SP-100, American Concrete Institute, Detroit, MI.

Sinusoidal vibration and impact loading techniques have been tested in the laboratory and on field structures. An impact system has been tested which has proven more economical and versatile than the more commonly used sinusoidal system. With transient loading, a broad band of frequencies (including the resonant frequencies) is applied to the structure simultaneously rather than sweeping through each frequency one at a time. The resonant frequency of a structure is directly related to its dynamic Young's modulus and, hence, its mechanical integrity. Factors that influence the soundness and safety of a structure such as continuity and boundary conditions also directly affect the resonant frequency. With the availability of digital Fourier analyzers, mathematical functions such as spectra, coherence, and transfer relationships permit the analysis of the behavior of large structures under dynamic conditions in-place and in real-time.

Results of laboratory and field tests established the feasibility of determining mechanical properties and assessing other factors that influence the soundness and safety of concrete structures using this nondestructive testing technique.

B-353 Mutti, R. A., Sudol, J. J., and Love, B. W. 1987. "Void Detection and Rigid Pavement Undersealing in Indiana: A Comprehensive Approach,"

Transportation Research Record 1109, National Research Council, Washington, DC.

The Indiana Department of Highway (IDOH) has been undersealing concrete pavements with bituminous materials since the late 1940's. Most early rigid pavements were constructed directly on soil subgrades and were subject to severe pumping. Thus, early undersealing operations involved treating entire sections of roadway. As pavement designs improved, severe pumping became less prevalent and a method of identifying only those areas that required undersealing became necessary. The approach taken by IDOH personnel was global in nature. Because it was impractical to locate and treat specific voids, a method was developed to identify and treat the most severely distressed areas. The method of void detection presented herein uses Dynaflect deflections measured at regular (100-ft) intervals within each contract section. Decision criteria based on midslab deflections are established for each contract; Sensor 5 is the primary indicator variable. Because decision criteria are obtained independently for each contract section, the method is applicable to both jointed and continuously reinforced concrete sections and to previously overlaid sections. When the areas that require undersealing have been identified, all cracks and joints within each area are treated. The procedure involves carefully monitoring slab motion during material injection with a sensitive deflection gauge developed specifically for that purpose. Furthermore, injection time limits are observed to minimize material losses due to blowouts. Data are presented that demonstrate both the validity of the void detection method and the joint deflection improvements that can be expected from the undersealing procedure. The economic feasibility of the method is discussed in terms of the savings that have been realized since the implementation of the method.

B-354 Clemena, G. G., Sprinkel, M. M., and Long, R. R., Jr. 1987. "Use of Ground-Penetrating Radar for Detecting Voids Under a Jointed Concrete Pavement," Transportation Research Record 1109, National Research Council. Washington, DC.

A survey of a jointed, reinforced concrete pavement with ground-penetrating radar indicated that radar provides a nondestructive inspection technique that can be used at a minimum rate of 5 lane-miles of pavement per hour with only minimal interference with traffic. The coring of some slabs and subsequent use of a devised water test revealed that the radar was effective in detecting voids deeper than 1/8 in. but considerably less effective in spotting shallow voids. The overall accuracy was approximately 68 percent, which indicates that the sensitivity of the equipment needs to be improved. The location component used with the radar unit showed insufficient accuracy. A regression analysis of the recorded quantities of grout used daily in subsealing portions of the pavement versus the total linear feet of voids detected under the slabs grouted each day yielded only a 51-percent correlation. However, the regression was found to be significant at a 95-percent probability level. It is believed that if the width and depth of each void can be conveniently estimated so that the extent of voids can be

expressed in terms of volume instead of length alone, an even more successful method of estimating grout quantities would be available. It has been shown that information derived from a radar survey can be useful in developing a sound and cost-effective slab stabilization operation in which grout holes are properly placed.

B-355 Montenegro, F. M., and Sinha, K. C. 1987. "Development of a Procedure for Assessing Routine Maintenance Needs of Highways," Transportation Research Record 1109, National Research Council, Washington, DC.

In this paper is described a procedure that can be used to estimate routine maintenance work loads by highway section for a coming year or season. Although the approach can also be extended for use in maintenance budget planning, the primary area of application of the proposed procedure is in determining the amount of maintenance work that is to be undertaken on what highway sections within a subdistrict subject to the constraint of a given maintenance budget. The procedure is based on periodic surveys of highway distress by unit foremen and subsequent use of a set of quantity standards, termed "present quantity standards." These standards were developed by relating the foremen's subjective ratings of road conditions to objective field measurements of distress and subsequently transforming the subjective ratings to expected work loads. A statistical regression analysis was used to develop the necessary relationships. The field data were collected from 18 maintenance units in Indiana.

B-356 Theberge, P. E. 1987. "Development of Mathematical Models to Assess Highway Maintenance Needs and Establish Rehabilitation Threshold Levels," Transportation Research Record 1109, National Research Council, Washington, DC.

Recent developments in methods of managing pavement investments have emphasized the importance of communication between the various subsystem components of a pavement management system. Historically, the maintenance element has been difficult to integrate. A systematic and objective means of assessing maintenance needs would improve the likelihood that funds would be optimally expended. This study was undertaken to examine the mathematical relationship between a variety of pavement attributes and other quantifiable variables, on the one hand, and maintenance needs and priority evaluations made by district area supervisors, on the other. A secondary objective was to establish threshold levels for preventive maintenance, capital maintenance, and rehabilitation. Descriptions, which conform to the Maine Department of Transportation's operations, were included to categorize various rehabilitation and maintenance strategies as well as to define various types of maintenance. A simple questionnaire was employed to obtain the required subjective input from maintenance staff. Measures of pavement distress routinely collected by trained observers and appropriately weighted, using a Delphi technique, proved to correlate the best. Roughness measured by a response-type road measurement device and correlated with the Quarter Car Index also proved significant, but to a lesser degree. A series of other variables made only nominal

improvements in the models. A model to predict repair categories from similar data was also developed. Recommendations are offered for providing tabulated information to maintenance personnel to use as a "tool" in establishing priorities.

B-357 Ksaibati, K., and Sinha, K. C. 1987. "Development of a Routine Pavement Maintenance Data Base System," Transportation Research Record 1109, National Research Council, Washington, DC.

When a routine maintenance management system is developed, the creation of a meaningful data base should be considered. This paper presents the development of a microcomputer data base that can be used at different maintenance management levels of the Indiana Department of Highways. To determine what type of data to include in the data base, the relationship between roughness and level of routine maintenance expenditure was analyzed. Condition survey information, based on unit foremen's evaluation of highway deficiencies, may be included in the proposed data base. The condition survey information along with roughness measurements can be used in two ways. First, the Central Office can use the information in programming maintenance and rehabilitation activities. Second, the data can be used by subdistricts to set priorities for routine maintenance work on highway sections within their jurisdictions. Information on rehabilitation activities, such as resurfacing, was included in the data base to increase the level of coordination between the programming of major maintenance and routine maintenance activities. This coordination may result in substantial savings in pavement maintenance and rehabilitation. Some other supplementary information, such as average daily traffic, contract number, county, subdistricts, and pavement type, was included in the data base. A pilot implementation plan is proposed. Performance of the data system in pilot implementation should be evaluated to provide the feedback necessary to assess the value of the information included in the data base.

B-358 Saraf, C. L., McCullough, B. F., and Aslam, M. F. 1987. "Rutting of Asphalt Concrete Overlays on Continuously Reinforced Concrete Pavements in Texas," Transportation Research Record 1109, National Research Council, Washington, DC.

Rutting history data on asphalt concrete pavement (ACP) overlays on rigid pavements are being collected by the Center for Transportation Research (CTR) to study ACP overlay behavior under the traffic and environmental conditions of Texas. The available data were analyzed recently for this purpose. Overlaid sections located in three counties of the state were selected for this study. These sections were originally built as continuously reinforced concrete pavement (CRCP). Using the limited data available at the present time, it was observed that the rate of rutting was maximum in the first year because of the initial compaction of material in the wheelpath. In the second year, the material between the wheelpaths experienced more compaction than that in the wheelpath themselves, and therefore rutting was observed to decrease in the second year. However, rutting increased in the years

following full compaction of the lanes. A regression equation was developed to characterize the rutting behavior of ACP overlays on CRCP. The analysis of available data indicated that overlay thickness was an important predictor of rutting in overlays. The age of the overlay was not very significant in the regression equation. This may be due to the brief history of rutting data available at the present time. The rutting of the overlays in different counties was affected by the locations of the overlaid sections. Apparently the materials of construction and construction-related items, which may be different in each county, affected the performance of overlays.

B-359 Mysyk, W. K. 1987. "Petrological Studies on Carbonate Aggregate Responsible for Pavement D-Cracking in Southern Manitoba, Canada," Transportation Research Record 1110, National Research Council, Washington, DC.

Petrographic evaluation of aggregate in portland-cement concrete from Winnipeg International Airport was conducted to determine the characteristic composition, texture, and porosity of nondurable carbonate aggregate associated with D-cracking. Aggregate in the concrete is from the glaciofluvial Birds Hill esker complex northeast of Winnipeg. Carbonate rocks (limestone and dolomite) constitute 75 to 85 percent (by volume) of aggregate in the recovered drill cores, with granite and basalt the only other significant rock types. Polarizing microscope, scanning electron microscope, and X-ray diffraction analyses of the carbonate aggregate resulted in the following conclusions: (a) All major fracturing in the concrete is associated with coarse carbonate aggregate greater than 1/4 in. in diameter; (b) Composition of nondurable carbonate aggregate is one of the following types: pure end member limestone, dolomite, or a chalky white silicified limestone; (c) Texturally, the carbonate rocks are massive, micritic-to-finely crystalline mudstone to packstone. Layering does not occur and clay minerals are noted in trace amounts only; (d) The uniform grain size and shape results in a narrow pore size range in the carbonate rocks mainly as intergranular porosity; and (e) The expansive alkali-carbonate rock reaction is not a factor in the concrete deterioration as neither the composition nor the texture of the carbonate rocks corresponds to the documented characteristic of susceptible rock types. Also, the map-cracking characteristic of the deterioration does not occur on the apron. The few carbonate particles with reaction rims display a good bond between the cement and aggregate.

B-360 Halavanja, I., et al. 1987. "Identification of Deterioration of Reinforced Concrete Structures" (in Slavic), Nase Gradevinarstvo, Vol 41, No. 10, pp 11-15, Belgrade, Yugoslavia.

To identify the condition of already damaged structures or to follow up the changes in concrete conditions, the following procedures are recommended: observation, investigation, diagnosis, damage, classification, and therapy.

This paper describes research on the diagnosis and damage classification. Diagnosis deals with the cause and the possible types of damage. Damage classification has been done in 5 degrees for three basic causes: aggressive environment, earthquake and other causes (errors of design, construction, and services), and fire. Each degree is elaborated in detail according to types of damage and criteria for each type of damage. The objective was to achieve uniform criteria in the particular damage degree regardless of causes.

B-361 Maage, M., and Sellevold, E. J. 1987. "Effect of Microsilica on the Durability of Concrete Structures," Concrete International: Design & Construction, Vol 9, Detroit, MI.

Cores taken from concrete structures, both with and without microsilica, were tested by mechanical and microscopic methods. Results indicate no significant detrimental changes in long-term properties for concrete containing microsilica.

1988

B-362 "Taking The Pulse of A Structure." 1988 (Jan). Concrete Construction, Vol 33, No. 1. Addison, IL.

Dancing makes your pulse go up and stresses your body. Dancing also stresses the floor beneath you. Many people dancing to the same beat may send a rhythmic vibration through the floor, causing more stress. Just as a doctor may take your pulse to test your response to stress, an engineer can take the pulse of a structure to see how it's doing. The engineer uses modal analysis. This method of testing shows how large complex structures such as high-rise buildings respond to induced or ambient vibrations such as traffic or wind. It's done without disturbing people working in the building.

B-363 Buck, A. D. 1988 (Jan-Feb). "Characterization of Radioactive Concrete by Petrographic and Physical Methods," ACI Materials Journal, Vol 85, No. 1, Detroit, MI.

Portions of a core drilled from radioactive concrete in a dismantled German nuclear reactor were examined by petrographic methods and physical tests. While there was some indication of radiation damage by some of the physical testing, it was concluded from results of the petrographic examination that this was a specimen effect and that there was no radiation damage to the concrete.

B-364 Kinugasa, H., and Nomura, S. 1988 (Feb). "Damage Estimation of R/C Members Based on Energy Absorption" (in Japanese), Journal of Structural and Construction Engineering, No. 384, pp 68-79, Tokyo, Japan.

Reinforced concrete beams subjected to various cyclic loadings are investigated by using nonlinear finite element method analysis to clarify the characteristics of energy absorption. A few conclusions are discussed.

1. The energy absorption obtained within the maximum deformation experienced so far under cyclic loading is quite different from that obtained beyond the former maximum deformation.

2. The energy absorption obtained beyond the former maximum deformation under cyclic loading is very similar to that obtained under monotonic loading.

A method of evaluating structural damage in reinforced concrete members under arbitrary cyclic loading is proposed on the basis of the analysis, where it is assumed that the energy absorbed by concrete is closely connected with damage of reinforced concrete members.

B-365 Thornton, H. T., Jr., and Alexander, A. M. 1988 (Mar). "Ultrasonic Pulse-Echo Measurements of the Concrete Sea Wall at Marina Del Rey Los Angeles County, California," The REMR Bulletin, Vol 5, No. 1, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

A new improved prototype ultrasonic pulse-echo system for concrete evaluation has been developed by Waterways Experiment Station (WES) researchers. This system uses piezoelectric crystals for both signal generation and detection. The 200-kilohertz two-transducer system has a signal-to-noise ratio (SNR) of 18. The weight and dimensions of the improved system have been reduced by 90 percent from the prior state-of-the-art system. The WES system, which has the shortest pulse length on record, works well in making thickness measurements of portland-cement concrete (≤12 in.) and can indicate the presence of reinforcing steel, voids, and inferior quality concrete.

Results of the preliminary tests with the prototype ultrasonic pulse-echo system at Marina Del Rey indicate that the system facilitates delineation of sound concrete, concrete of questionable quality, and deteriorated concrete. The presence or absence of backwall echo, the noise preceding the backwall echo, and the SNR are all significant factors in making these delineations.

Preliminary test results indicate the system is also capable of detecting interfaces between sound concrete and reinforcing steel, interfaces between sound concrete and voids or cracks, and interfaces caused by corrosion product.

B-366 Bevins, T. L., Chiarito, V. P., and Hall, R. L. 1988 (Mar). "Vibration Test of Richard B. Russell Concrete Dam After Reservoir Impoundment," Technical Report SL-88-14, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

The Richard B. Russell Dam has recently been completed by the US Army Corps of Engineers approximately 170 miles from the mouth of the Savannah River between Georgia and South Carolina. The crest of the concrete gravity dam is 1,884 ft long and is composed of 13 nonoverflow, 8 intake, and 11 spillway monoliths, the tallest of which is approximately 200 ft high. To experimentally determine the dynamic properties

of the dam with and without hydrodynamic interactions, forced vibration tests were conducted before and after reservoir impoundment. The average reservoir elevation during the test following reservoir impoundment was 470 ft. This is an increase of 127 ft above the upstream elevation during the first test.

The structure was excited at three locations by a crest-mounted 17,000-lb inertial mass that was driven by an electrohydraulic servo-controlled actuator. The force input was computed as the product of the measured acceleration and the mass. Servo accelerometers with sensitivities ranging from 0.25 to 5.0 volts per g (gravitational force) were used to measure the horizontal motion of all 32 monoliths and the distributions of horizontal acceleration with elevation in the three drive-point monoliths. Dynamic pressures at the dam-reservoir interface were measured at the upstream face of the tallest nonoverflow monolith. Piezoelectric pressure transducers with a charge sensitivity of approximately 150 picocoulombs per psi measured the dynamic pressure.

The results determine the dynamic parameters of the dam with hydrodynamic interactions. The natural frequencies, damping estimates, and mode shapes were determined. Comparisons with the first test before impoundment indicated: (a) natural frequencies were reduced (approximately 10 percent for the fundamental frequency and 2 percent for the fifth mode), (b) damping estimates were increased by approximately 0.4 percent of critical, and (c) there was a reasonable agreement in the first three mode shapes between the two tests. The hydrodynamic pressures were of low magnitude but were in agreement with analytical predictions and earlier test results from forced vibration tests.

B-367 Okada, K., Kobayashi, K., and Miyagawa, T. 1988 (Mar-Apr). "Influence of Longitudinal Cracking Due to Reinforcement Corrosion on Characteristics of Reinforced Concrete Members," ACI Structural Journal, Vol 85, No. 2, pp 134-140, Detroit, MI.

The results of an investigation taking into account longitudinal cracks due to reinforcement corrosion as the limit state in durability design are reported in the paper. First, an application of nondestructive methods for detecting the longitudinal cracks is examined. Then, the effects of various repair methods applied to the beams after longitudinal cracking and the fundamental structural behavior of reinforced concrete beams with longitudinal cracks are investigated.

B-368 Sansalone, M., and Carino, N. J. 1988 (Apr). "Impact-Echo Method," Concrete International: Design & Construction, Vol 10, No. 4, pp 38-46, Detroit, MI.

The impact-echo method for nondestructive testing of concrete was successfully used to locate honeycombed concrete and an ungrouted metal duct and to determine the depth of vertical surface-opening cracks in concrete. The studies were carried out on laboratory specimens that contained artificial flaws at known locations. Frequency analysis of

recorded surface displacement waveforms was used to determine the location of the various flaws. Finite element studies of the transient impact response of a solid containing simulated honeycombing were also carried out to gain an understanding of transient wave propagation through such a solid.

B-369 Knab, L. I., and Spring, C. B. 1988 (Apr). "Evaluation of Test Methods for Measuring the Bond Strength of Portland-Cement Based Repair Materials to Concrete," Report NBSIR-88/3746, National Bureau of Standards, Gaithersburg, MD.

Three bond strength test methods were evaluated for screening and selecting repair materials used in overlaying and patching portland-cement concrete. Bond strengths of three repair materials to base concrete were investigated using two uniaxial tensile bond strength test methods and a slant shear bond strength test method. The differing strengths of the repair materials caused different failure patterns, which had to be considered in the analyses of the failure stresses. Substantial differences in the failure stresses of the uniaxial tension and slant shear test methods were attributed to their different geometries and loading conditions. These differences emphasized the need to select test method(s) with geometry and loading conditions which are anticipated for the in-service repair material. For the two higher-strength repair materials investigated, the relative precision (repeatability) of the slant shear and one of the uniaxial tensile test methods (pipe nipple grips) were comparable and relatively good (coefficient of variation values were about 5 percent).

B-370 Bahlis, J. B., and Mirza, M. S. 1988 (Apr). "Structural Integrity of a Damaged Building," Concrete International: Design & Construction, Vol 10, No. 4, Detroit, MI.

The structural integrity and safety of a 24-story reinforced concrete building damaged by an explosion are investigated using finite element analysis and load tests. Repair of the damaged areas is described.

B-371 Siemes, A. J. M. 1988 (Sep). "Carbonation Damage Repair," Cement, Vol 40, No. 9, pp 16-21, The Netherlands.

Reinforcement corrosion as a result of carbonation of the concrete covering is described. This well-known type of damage will be considered in the light of preventive maintenance of buildings. This article considers a building where corrosion damage has occurred to balcony and gallery plates and causes the reinforcement to rust and the concrete covering to chip. It is important to detect the damage at a sufficiently early stage; equally, regular and on-time inspection is of great importance for maintenance. First, the areas under threat are selected and measured to see whether the corrosion damage is the result of carbonation. Other causes of damage may also have to be evaluated. At the most corroded spots and those of most importance from the structural point of view, an image must be built up of the remaining reinforcement section. Then a decision has to be made as to whether repair

is to be carried out and, if so, what kind. Alternatives are considered in relation to cost and the remaining life expectancy. Carrying out the repair is the last phase. In the case considered, the corroded concrete covering is removed, the reinforcement is derusted and given a base layer for the new mortar, then the new covering is applied and the surface can be protected using a coating or paint layer.

B-372 Shroff, A. C. 1988 (May). "Evaluating a 50 Year Old Concrete Bridge," Concrete International: Design & Construction, Vol 10, No. 5, pp 56-62, Detroit, MI.

To select a rehabilitation scheme for a 50-year-old concrete bridge, an in-depth inspection was followed by testing to determine the strength and quality of existing concrete. The adequacy of the structure was also evaluated, and several rehabilitation alternatives were considered.

B-373 Al-Tayyib, A. J., and Khan, M. S. 1988 (May-Jun). "Corrosion Rate Measurements of Reinforcing Steel in Concrete by Electrochemical Techniques," ACI Materials Journal, Vol 85, No. 3, pp 172-177, Detroit, MI.

This paper presents the findings of a laboratory investigation in which the applicability of Tafel plot and linear polarization resistance techniques in the corrosion rate measurements of reinforcing steel in concrete have been evaluated. The use of these electrochemical techniques in concrete is in a developing stage. Corrosion rates of reinforcing steel in concrete specimens made from three different mix proportions and immersed in salt solution for 2 years have been measured and compared with that obtained from metal loss determination.

B-374 Fintel, M., and Ghosh, S. K. 1988 (Jul). "Distress Due to Sun Camber in a Long-Span Roof of a Parking Garage," Concrete International: Design & Construction, Vol 10, No. 7, Detroit, MI.

Distress in a nine-story cast-in-place concrete parking garage is described. A detailed account is given of field observations, measurements, and computations leading to a definite diagnosis for the distress. A repair procedure that accommodates unavoidable movements of the structure is outlined.

B-375 Stroud, C., and Gardner, P. 1988 (Jul-Aug). "High-Rise Structures--Current Experience of Investigation and Repair," Construction Repair, Vol 2, No. 4, Berkshire, England.

This article discusses of the British methods and experiences of inspecting and maintaining the external structure of their high-rise housing stock.

B-376 Fetherston, N. W. 1988 (Aug). "NDT Solution-Computerized In-Service Inspection Programs," Materials Evaluation, Vol 46, No. 9, Columbus, OH.

Personal computers are revolutionizing the way we all conduct business. In this article, the author gives his experience in using personal computers for information retrieval for in-service inspections.

B-377 Lozen, K. M. 1988 (Aug). "Detecting Invisible Corrosion In Concrete," Concrete Construction, Vol 33, No. 8, pp 757-758, 760, Addison, IL.

Corrosion of reinforcing steel is an electrochemical process. Both a flow of electricity and a chemical change are involved. The difference in electrical potential at various points on the steel generates a flow of current from one point (anode) to another (the cathode), forming galvanic cells and leading to corrosion. Any salt solution in the concrete in contact with the steel aggravates the process by acting as an electrolyte through which ions migrate and electric current flows.

Detecting and measuring this current flow helps us assess the degree of unseen corrosion activity. To record this information, half-cell procedures have been developed. These procedures have proven to be valuable aids in the investigation of reinforced concrete deterioration. Article looks into this further.

B-378 (Deleted)

B-379 Wong, G. S., and Stowe, R. L. 1988 (Aug). "Condition Survey of Locks and Dam 3; Monongahela River, Miscellaneous Paper SL-88-6, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

A condition survey was performed at Locks and Dam No. 3 on the Monongahela River in Pennsylvania to evaluate the concrete condition at the locks and dam and to make a projection of the concrete condition of selected project features to approximately year 2010. Data from the original construction of the locks and major rehabilitation of the locks and dam between 1978 and 1980 were evaluated. A visual field investigation was conducted to determine the present concrete condition in the locks. Freezing and thawing of the older nonair-entrained concrete is the major deteriorating mechanism in the structure. A maximum vertical rate of deterioration for exposed original concrete was calculated to be 1.06 in. per year; a horizontal rate of deterioration of 0.90 in. per year was determined with a new concrete overlay serving as low-permeability cover. Where original concrete is exposed on vertical faces, the worst case damage of an additional 32 in. is estimated by the year 2010. Sections of the walls refaced with high quality air-entrained concrete should be serviceable until the year 2010, while local high stress areas may require repairs as deficiencies are formed.

B-380 Wong, G. S., Stowe, R. L., Ahlvin, J. C., and Tom, J. G. 1988 (Aug). "Condition Survey of Lock No. 2; Monongahela River, Miscellaneous Paper SL-88-7, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

A condition survey was performed at Locks and Dam No. 2 on the Monongahela River in Pennsylvania to determine the extent of possible concrete damage, processes causing distress of the concrete, selected physical and mechanical properties of the concrete and foundation materials, and the ability of the concrete to perform satisfactorily under anticipated conditions of future service. The field investigation included a visual inspection of the structure to determine the general condition of the concrete, and drilling operations to recover concrete and foundation core. Results of the field investigation and laboratory tests indicated that the concrete is generally in good condition, with dissolutioning of carbonate aggregate particles giving the appearance of exposed aggregate to the concrete. Some popouts, scaling, and spalling are also present. The near surface concrete contains some cracking not associated with any apparent chemical reaction. The cracks do not appear to be active. The concrete in this structure should remain serviceable for a period of 50 years from the date of this investigation.

B-381 ACI Committee 228. 1988 (Sep-Oct). "In-Place Methods for Determination of Strength of Concrete," ACI Materials Journal, Vol 85, No. 5, pp 446-471, Detroit, MI.

The state of the art in the use of methods for determining the in-place compressive strength of concrete is reported. The methods covered include the rebound hammer, probe penetration, pullout, ultrasonic pulse velocity, maturity, and cast-in-place cylinder. The underlying principles and inherent limitations of each method are discussed. Repeatability of test results is reviewed, and recommendations are given for developing the correlation relationship for each test method. Recommendations are given for the number of tests, and statistical techniques for interpretation of test results are described.

B-382 Gabriel, D. 1988 (Sep-Oct). "Lasers In Structural Monitoring," Construction Repair, Vol 2, No. 5, Berkshire, England.

Structural monitoring comes in a variety of forms, ranging from the simple to the complex, from visual examinations for signs of deterioration to computer enhanced ultrasonic testing for signs of internal weakness. This article discusses a new structural monitoring system, one that involves lasers in a simple yet effective way.

B-383 Chew, M. Y. L. 1988 (Nov Dec). "Assessing Heated Concrete and Masonry with Thermoluminescence," ACI Materials Journal, Vol 85, No. 6, Detroit, MI.

The assessment of fire-damaged concrete and masonry to determine whether a structure is still structurally sound depends largely on accurately determining the maximum temperature distribution within the

damaged structure. This paper describes a new method that can be used to achieve that.

Thermoluminescence (TL) is the light produced when certain materials are heated. Plotting the light output of a heated concrete or masonry specimen against its temperature in a TL test produces a characteristic glow curve of the specimen. By comparing the glow curves of field samples extracted from various locations and depths of a structure after a fire against standard specimens processed in the laboratory, an estimate can be made of the maximum temperature distribution within the structure.

B-384 Hammersley, G. P. 1988 (Dec). "Alkali-silica Reaction in Dams and Other Major Water Retaining Structures: Diagnosis and Assessment," Proceedings, Institution of Civil Engineers, London, Part 1, Vol 84, pp 1193-1211 London, England.

The problem of a lack of a unified approach to the investigation of alkali-silica reaction (ASR) in concrete structures is stated, and the report of the British Cement Association Working Party on the diagnosis of ASR intended to rectify this situation is introduced. The procedures and methods appropriate to the diagnosis and prognosis of ASR are described, including the planning, desk study, site inspection, sampling, laboratory testing and analysis, and long-term monitoring stages of the investigation. Guidance is given on the evaluation of diagnostic evidence and the assessment of the potential for further expansive ASR. The special technical, environmental, and logistical problems posed by dams and other major water-retaining structures are considered.

B-385 Khanna, J., et al. 1988. "Investigations of Distress in Precast Concrete Piles at Rodney Terminal, Saint John, New Brunswick," Concrete in Marine Environment--Proceedings of the Second International Conference, St. Andrews, NB, SP-109, pp 277-320, American Concrete Institute, Detroit. MI.

The Rodney Terminal is a 610-m-long, 37-m-wide, L-shaped container wharf of concrete construction. It was constructed during 1974-75 and utilized over seventeen hundred 24-in. (600-mm) hollow-core, octagonal, precast piles.

Soon after construction, pile distress began to be noted. Forty piles were repaired in 1978 and seven piles were replaced in 1982. Since the pile deterioration was rapid and progressive, extensive investigations were carried out to determine the causes of the pile deterioration and possible remedial measures. Later, studies were carried out to investigate whether the piles had met the contract specifications.

These investigations revealed that distress was primarily vertical cracks in the outer one-half of the pile walls. Scouring and freezing and thawing spalling, over time, caused loss of the pile wall. The vertical cracks were related to thermal stresses during the winter

months and possibly high thermal gradients during steam curing at the time of manufacture. The rapid freezing and thawing deterioration was due to inadequate air entrainment of the concrete. The pile distress was also caused, in a few cases, by manufacturing defects.

The investigations suggested that the following changes to the original design and specifications may have reduced the problems: (1) higher percentage of circumferential steel; (2) air-void system determinations on samples of the hardened concrete to ensure that the specification intent was being met; and (3) use of solid instead of hollow core piles.

Remedial steps at the Rodney Terminal have included epoxy-grouting (unsuccessful), pile replacement (expensive), fiberglass jacket over reinforced grouted annulus, insulated fiberglass jackets over reinforced grouted annulus, air-entrained and steel fiber-reinforced concrete jackets, and insulated jackets.

B-386 Roper, H., Heiman, J. L., and Baweja, D. 1988. "Site and Laboratory Evaluation of Repairs to Marine Concrete Structures and Maintenance Methodologies--Two Case Studies," Concrete in Marine Environment--Proceedings of the Second International Conference, St. Andrews, NB, SP-109, pp 563-586, American Concrete Institute, Detroit, MI.

In Australia, the major population centers are located on the coast. A significant proportion of the nation's heavy industrial infrastructure and civil engineering work is also coastal. A wide variety of structures have been constructed in aggressive marine environments. Many of these structures have had long histories of durability problems and subsequent repair. Paper reports on field and laboratory studies that have been carried out to evaluate the performance of two-wharf structures and their repair systems. It discusses the usefulness of various methods of detecting corrosion activity and considers the effects of chloride contamination and carbonation on damaged structures. Some aspects of repair materials for use in the marine environment are considered.

B-387 Sharp, J. V., Figg, J. W., and Leeming, M. B. 1988. "Assessment of Corrosion of the Reinforcement in Marine Concrete by Electrochemical and Other Methods," Concrete in Marine Environment--Proceedings of the Second International Conference, St. Andrews, NB, SP-109, pp 105-126, American Concrete Institute, Detroit, MI.

Several projects in the "Concrete in the Oceans" program have measured electrical potentials and resistivities on reinforced concrete specimens exposed to a marine environment. A state-of-the-art survey was also undertaken on corrosion monitoring techniques which led to experimental work to improve the use of these techniques, particularly on marine structures. The main conclusions from this test program are discussed. Two independent sets of electropotential and resistivity measurements taken on beam specimens exposed to a splash zone environment for periods up to 5 years have been compared with the actual

corrosion found after the reinforcement was broken out of the specimens. The comparison of these two sets of data and the ability of these monitoring techniques to predict likely corrosion are discussed and related to the various parameters such as the disposition of the cracks, the depth of cover, and the type of concrete. Based on the work described in this paper, the limitations of corrosion monitoring methods are also highlighted.

B-388 Alexander, M. G. 1988. "Use of Ultrasonic Pulse Velocity for Fracture Testing of Cemented Materials," Cement, Concrete, and Aggregates, Vol 10, No. 1, pp 9-14, Philadelphia, PA.

This article describes the use of the ultrasonic pulse velocity technique to measure two important features of fracture in notched concrete beams: the extent of the microcracking zone that develops ahead of the notch or crack, and the depth of the main (or stress-free) crack. Beams of 100 mm in width and ranging from 100 to 500 mm in depth were tested, and ultrasonic pulses were transmitted longitudinally through the beams at various elevations. Ultrasonic readings taken at elevations above or below the visible crack tip were sensitive to the development of the microcracked zone or to main crack growth, respectively. Based on pulse transit time measurements, the average depth of the microcracked zone was about 44 percent of the residual beam depth, taking all the beam sizes together. Crack depths estimated from pulse transit times were found to agree with visible crack depths to less than 10 percent on average.

B-389 (Deleted)

B-390 Taylor, M. A. 1988. "Evaluation of Concrete Constituents Using Photon Radiation," Nondestructive Testing, SP-112, pp 41-62, American Concrete Institute, Detroit, MI.

Gamma-ray absorption techniques were used to determine the amounts of each component in a system of mixtures (such as concrete). The technique uses photons of several energies in contrast to previous applications where only one energy was employed. The use of multiple energies provides more information than the single-beam system, and thus more properties can be determined.

Several possible models for cementitious materials are discussed and compared. The paper presents the experimental determination of the initial data set needed prior to prediction experiments. One predictive technique is evaluated by comparison with blind tests.

B-391 "Standard Practice for Microscopical Determination of Air-Void Content and Parameters of the Air-Void System in Hardened Concrete." 1988. Designation C 457-82a, 1988 Annual Book of ASTM Standards, Vol 04.02, American Society for Testing Materials, Philadelphia, PA.

This practice describes microscopical determinations of air-void content, specific surface, spacing factor, and air-paste ratio of the

air-void system in hardened concrete. Two methods are described as follows: the linear traverse (Rosiwal) method and the modified point-count method.

These methods are based upon measurement of the air-void system in hardened concrete by prescribed microscopical procedures on sawed and ground sections intersecting portions of the interior of samples or specimens of concrete from the field or laboratory.

B-392 "Standard Practice for Examination and Sampling of Hardened Concrete in Constructions." 1988. Designation C 823-83 (Reapproved 1988), 1988 Annual Book of ASTM Standards, Vol 04.02, American Society for Testing Materials, Philadelphia, PA.

This practice outlines procedures for visual examination and sampling of hardened concrete in constructions. Reference is made to the examination and sampling of concrete in prefabricated building units, precast products, and laboratory specimens.

B-393 "Standard Practice for Petrographic Examination of Hardened Concrete." 1988. Designation C 856-83 (Reapproved 1988), 1988 Annual Book of ASTM Standards, Vol 04.02, American Society for Testing Materials, Philadelphia, PA.

This practice outlines procedures for the petrographic examination of samples of hardened concrete. The samples examined may be taken from concrete constructions, they may be concrete products or portions thereof, or they may be concrete or mortar specimens that have been exposed in natural environments to simulated service conditions, or subjected to laboratory tests. The phrase "concrete constructions" is intended to include all sorts of objects, units, or structures that have been built of hydraulic cement concrete.

The petrographic procedures outlined herein are applicable to the examination of samples of all types of hardened hydraulic-cement mixtures, including concrete, mortar, grout, plaster, stucco, terrazzo, and the like. In this practice, the material for examination is designated as "concrete," even though the commentary may be applicable to the other mixtures, unless the reference is specifically to media other than concrete.

B-394 "Standard Test Method for Obtaining and Testing Drilled Cores and Sawed Beams of Concrete." 1988. Designation C 42-87, 1988 Annual Book of ASTM Standards, Vol 04.02, American Society for Testing Materials, Philadelphia, PA.

This test method covers obtaining, preparing, and testing (1) cores drilled from concrete for length or compressive or splitting tensile strength determinations and (2) beams sawed from concrete for flexural strength determinations.

B-395 "Standard Test Method for Pulse Velocity through Concrete." 1988. Designation C 597-83, 1988 Annual Book of ASTM Standards, Vol 04.02, American Society for Testing Materials, Philadelphia, PA.

Pulses of compressional waves are generated by an electro-acoustical transducer that is held in contact with one surface of the concrete under test. After transversing through the concrete, the pulses are received and converted into electrical energy by a second transducer located a distance L from the transmitting transducer. The transit time T is measured electronically. The pulse velocity V is calculated by dividing L by T.

B-396 "Standard Test Method for Resistance of Concrete to Rapid Freezing and Thawing." 1988. Designation C 666-84, 1988 Annual Book of ASTM Standards, Vol 04.02, American Society for Testing Materials, Philadelphia, PA.

This test method covers the determination of the resistance of concrete specimens to rapidly repeated cycles of freezing and thawing in the laboratory by two different procedures: Procedure A, Rapid Freezing and Thawing in Water, and Procedure B, Rapid Freezing in Air and Thawing in Water. Both procedures are intended for use in determining the effects of variations in the properties of concrete on the resistance of the concrete to the freezing-and-thawing cycles specified in the particular procedure. Neither procedure is intended to provide a quantitative measure of the length of service that may be expected from a specific type of concrete.

B-397 "Standard Test Method for Scaling Resistance of Concrete Surfaces Exposed to Deicing Chemicals." 1988. Designation C 672-84, 1988 Annual Book of ASTM Standards, Vol 04.02, American Society for Testing Materials, Philadelphia, PA.

This test method covers determination of the resistance to scaling of a horizontal concrete surface exposed to freezing-and-thawing cycles in the presence of deicing chemicals. It is intended for use in evaluating this surface resistance qualitatively by visual examination.

B-398 "Standard Test Method for Rebound Number of Hardened Concrete." 1988. Designation C 805-85, 1988 Annual Book of ASTM Standards, Vol 04.02, American Society for Testing Materials, Philadelphia, PA.

This test method covers the determination of a rebound number of hardened concrete using a spring-driven steel hammer. The rebound number determined by this method may be used to assess the uniformity of concrete in situ, to delineate zones or regions (areas) of poor quality or deteriorated concrete in structures, and to indicate changes with time in characteristics of concrete.

B-399 "Standard Test Method for Half-Cell Potentials of Uncoated Reinforcing Steel in Concrete." 1988. Designation C 876-87, 1988 Annual Book of ASTM Standards, Vol 04.02, American Society for Testing Materials, Philadelphia, PA.

This test method covers the estimation of the electrical half-cell potential of uncoated reinforcing steel in field and laboratory concrete for the purpose of determining the corrosion activity of the reinforcing steel. This test method is limited by electrical circuitry. A concrete surface that has dried to the extent that it is a dielectric and surfaces that are coated with a dielectric material will not provide an acceptable electrical circuit.

B-400 "Standard Test Methods for Density of Unhardened and Hardened Concrete in Place By Nuclear Methods." 1988. Designation C 1040-85, 1988 Annual Book of ASTM Standards, Vol 04.02, American Society for Testing Materials, Philadelphia. PA.

These test methods cover the determination of the in-place density of unhardened and hardened concrete by gamma radiation. Two methods, direct transmission and backscatter, are described. These test methods are useful as rapid, nondestructive techniques for the in-place determination of the density of unhardened concrete. The backscatter method is also useful for the same purpose on hardened concrete. The fundamental assumptions inherent in the test methods are that Compton scattering is the dominant interaction and that the material under test is homogeneous.

B-401 ACI Committee 201. 1988. "Guide for Making a Condition Survey of Concrete in Service," ACI 201.1R-68 (Revised 1984), ACI Manual of Concrete Practice, Part 1, American Concrete Institute, Detroit, MI.

This guide provides a system for reporting on the condition of concrete in service. It includes a check list of the many details to be considered in making a report and provides standard definitions of 40 terms associated with the durability of concrete. Its purpose is to establish a uniform system for evaluating the condition of concrete.

B-402 ACI Committee 201. 1988. "Guide for Making a Condition Survey of Concrete Pavements," ACI 201.3R-86, ACI Manual of Concrete Practice, Part 1, American Concrete Institute, Detroit, MI.

This guide presents a method for making a condition survey of such concrete pavements as highways, airfields, parking lots, and traffic areas in warehouses. The condition survey consists of (i) an examination of the exposed concrete to identify and define areas of distress, and (ii) a determination of the pavement's riding quality. Condition checklists and descriptions of various distress manifestations are included.

B-403 ACI Committee 207. 1988. "Practice for Evaluation of Concrete in Existing Massive Structures for Service Conditions," ACI 207.3R-79,

(Revised 1985), ACI Manual of Concrete Practice, Part 1, American Concrete Institute, Detroit, MI.

Current methods available for evaluating physical properties of concrete in existing structures to determine its capability of performing satisfactorily under service conditions are identified and discussed. Although general knowledge of the structural design criteria used for the principal structures of a project is essential to determine satisfactory procedures and locations for evaluation of the concrete physical properties, analysis for the purpose of determining structural capability is not within the scope of this report. The report recommends that project design, operation and maintenance records, and inservice inspection data be reviewed. Existing methods of making condition surveys and nondestructive tests are reviewed; destructive phenomena are identified; methods for evaluation of test and survey data are presented; and finally, preparation of the final report is discussed.

B-404 ACI Committee 216. 1988. "Guide for Determining the Fire Endurance of Concrete Elements," ACI 216R-81, ACI Manual of Concrete Practice, Part 3, American Concrete Institute, Detroit, MI.

This Guide for determining the fire resistance of concrete elements is a summary of practical information intended for use by architects, engineers, and building officials who must design concrete structures for particular fire resistances or evaluate structures as designed. The Guide contains information for determining the fire endurance of simply supported slabs and beams; continuous beams and slabs; floors and roofs in which restraint to thermal expansion occurs; walls; and reinforced concrete columns. Information is also given for determining the fire endurance of certain concrete members based on heat transmission criteria.

Also included is information on the properties of steel and concrete at high temperatures and temperature distributions within concrete members exposed to fire.

B-405 ACI Committee 437. 1988. "Strength Evaluation of Existing Concrete Buildings," ACI 437R-67 (Revised 1982), ACI Manual of Concrete Practice, Part 3, American Concrete Institute, Detroit, MI.

Strength of existing concrete buildings may be evaluated either analytically or by static load tests. These recommendations indicate when such an evaluation may be needed, establish criteria for selecting the evaluation method, and indicate the data and conditions necessary for conducting either type of evaluation. Methods of determining concrete and steel properties used in the analytical investigation are described. It is recommended that theoretical analysis follow principles of strength design outlined in ACI 318 and that a structure be considered satisfactory if load factors and deflections satisfy requirements of ACI 318. Procedures for conducting static load tests

are prescribed, and criteria are established for deflection and recovery of the structure being evaluated.

B-406 Alexander, A. M., and Thornton, H. T., Jr. 1988. "Developments in Ultrasonic Pitch-Catch and Pulse-Echo for Measurements in Concrete," Nondestructive Testing, SP-112, American Concrete Institute, Detroit, MI.

A new improved prototype ultrasonic pitch-catch (two-transducer) and pulse-echo (one-transducer) system has been developed for concrete. Signal generation and detection is done with piezoelectric crystals. A literature search revealed that no piezoelectric pulse-echo system had been developed for the ultrasonic range (>20 kHz) and that pitch-catch measurements needed further development. No commercial system could be found on the market for making pitch-catch measurements. Only about 10 references that deal directly with ultrasonic pitch-catch measurements in concrete were located. There are none that deal with ultrasonic pulse-echo.

Although investigators have made progress in understanding the problems associated with the development of pulse echo for concrete, the heterogeneous nature of concrete and the state of the art of ultrasonic materials and techniques prior to the present have prevented the development of a practical system like that used for homogeneous materials. The literature revealed that resolution was poor due to long pulse lengths (high Q value) for the transducers. Investigators had problems with interfering Rayleigh waves at low frequencies. Signal-to-noise ratios (SNR) ranged from only about 2 to 6. The latest state-of-the-art transmitter (Ohio State University) had a diameter of 18 in. (457 mm) and a mass of 40 lb (18 kg). Measurements showed extraneous signals other than the desired longitudinal mode due to mode conversion in the transducers. Also these transducers lacked the proper focal length, directivity, and sensitivity.

Research by the US Army Engineer Waterways Experiment Station (WES) has resulted in the development of a 200-kHz pitch-catch system with a SNR of 18 and a pulse-echo system with a SNR of 8. The mass and dimensions of the improved system have been significantly reduced from the prior state-of-the-art system. The WES system has the lowest Q (shortest ringing time and widest bandwidth) and therefore the shortest pulse length on record. This system works well for making thickness measurements of portland-cement concrete pavement and can indicate the presence of voids.

B-407 (Deleted)

B-408 Ohtsu, M. 1988. "Diagnostics of Cracks in Concrete Based on Acoustic Emission," Nondestructive Testing, SP-112, American Concrete Institute, Detroit, MI.

On the basis of the acoustic emission (AE) measuring technique, a diagnostic method for nondestructive evaluation of cracks in concrete is

proposed. The diagnostics consist of a mechanical criterion of crack initiation, a quantitative waveform analysis of AE, the evaluation of deterioration by a test of core specimen, and the ultrasonic spectroscopic investigation of cracked members. Results of basic studies on these methods are summarized.

The stress intensity factor K_{Ic} of linear elastic fracture mechanics is considered as the mechanical criterion of crack initiation. The critical value was determined from AE observation and numerical solutions by the boundary element method. A quantitative waveform analysis is developed for source characterization of AE. A new procedure for determining crack locations, crack types, and orientations is proposed. The deterioration of a concrete structure is examined by the test of core specimens under uniaxial loading. Existing cracks are evaluated nondestructively by ultrasonic spectroscopy. Results of basic studies confirm the feasibility and the usefulness of the proposed method as diagnostics of cracks in concrete structures.

B-409 Maji, A. K., and Shah, S. P. 1988. "Application of Acoustic Emission and Laser Holography to Study Microfracture in Concrete," Nondestructive Testing, SP-112, American Concrete Institute, Detroit, MI.

The fracture process of a composite material involves crushing or slippage of adjacent particles, microcracking, etc. resulting in changes in the load versus displacement behavior. A study of the fracture process is necessary to develop a rational material model.

Laser holographic interferometry was applied to study the whole field deformation pattern in real time. Cracks could be detected as discontinuities in the fringe pattern corresponding to discontinuities in the displacement field. Sensitivity of about 0.3 microns was obtainable. Speckle photography was used to quantitatively measure displacement discontinuities at bond cracks at various stages of loading.

Acoustic Emission (AE) techniques were applied to monitor microseismic activities resulting from the various fracture phenomena. The rate of microfracture was measured from the AE event rates. A source location algorithm was used to calculate the locations of the AE events.

Model concrete specimens with cylindrical limestone aggregates were used to simulate concrete and ease efforts of analysis. Rectangular blocks were tested in uniaxial compression in a closed-loop testing machine under the control of axial deformations to allow stable crack propagation in the post peak region. Specimens were made with different aggregate and void sizes to study their effect on crack patterns and load-displacement behaviors.

B-410 Yun, C. H., Choi, K. R., Kim, S. Y., and Song. Y. C. 1988. "Comparative Evaluation of Nondestructive Test Methods for In-Place Strength

Determination," Nondestructive Testing, SP-112, American Concrete Institute, Detroit, MI.

This paper presents an investigation to determine the within-test variability of various nondestructive test (NDT) methods and the correlation between NDT test results and the corresponding compressive strength of cores. The size effects of coarse aggregate on the variability and correlation were also evaluated. The NDT test methods evaluated in the test series include: rebound hammer; pulse velocity; probe penetration; pullout; and CAPO (Cut and Pullout). Companion tests of field-cured standard cylinders and cores were also made at the ages when the NDT tests were made. The tests were performed on plain concrete slabs, 1,000 mm × 1,000 mm × 300 mm, at the ages of 1, 3, 7, 14, 28, and 90 days. The test variables included the size of coarse aggregate (sand only, 25 mm, and 40 mm) and the compressive strength of concrete (210, 280, and 350 kg/sq cm).

The test results show that the within-test variability of the in situ tests reported herein with the exception of the pulse velocity test, is 2 to 5 times higher than that of the corresponding standard compression test, and is affected significantly by the amount of coarse aggregate and its size. There is a good relationship between the results of in situ tests and the compressive strength. In general, the highest degree of correlation is for the pullout test followed in order by the CAPO (cut and pullout) test, rebound test, probe penetration test, and pulse velocity test.

B-411 Teodoru, G. V. 1988. "The Use of Simultaneous Nondestructive Tests to Predict The Compressive Strength of Concrete," Nondestructive Testing, SP-112, American Concrete Institute, Detroit, MI.

The aim of the present work is to analyze the correlations between several nondestructive measured values (ultrasonic velocity and attenuation, rebound number) and the compressive strength of concrete. A computational program performs a step-by-step analysis in the following way. First, isolated linear correlations are established for each one of the three nondestructive tests, as usual. Then the results are compared, both pair by pair and all data together in the sense of a general multiple correlation of the values. Since the results obtained from the nondestructive tests are unequally scattered, the program determines interactively, in a second step, the multiple coefficients of correlation and restarts the analysis several times by tentatively disregarding the presumably bad experimental results. Since the measured values also comprise a large spectrum of magnitude (ultrasonic pulse velocity from 2.5 km/s to 4.8 km/s, ultrasonic damping from 70 dB to 25 dB, rebound indices from 12 to 65 and concrete strength in compression from 4 N/mm^2 to 80 N/mm^2) limits of validity of the assumed correlations are investigated concomitantly with the process of analysis. A last step is performed with the aim of identifying a tendency of deviation of the single and multiple correlations from the basic linear ones. The utility of this concept of multiple correlation for concrete quality control, especially for a plant for precast elements,

is evident both directly by means of the transformation of nondestructive testing values into the compression strength of concrete, as well as for the utilization of this transformation for statistical quality analysis.

B-412 Sansalone, M., and Carino, N. J. 1988. "Laboratory and Field Studies of the Impact-Echo Method for Flaw Detection in Concrete," Nondestructive Testing, SP-112, American Concrete Institute, Detroit, MI.

A nondestructive test method has been developed for locating defects in concrete. The technique is referred to as the impact-echo method and is based on monitoring surface displacements resulting from the interactions of transient stress waves with internal discontinuities. This paper describes the technique and presents results of laboratory studies designed to evaluate the capabilities of the method. These laboratory studies were carried out on 500-mm thick slabs which contained a variety of artificial flaws embedded at known locations. Frequency analysis of recorded time-domain waveforms is explained and shown to be a quick and simple signal processing technique. Finally, results are presented from a field study in which the impact-echo method was used to investigate a 150-mm thick slab believed to contain voids.

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