MISCELLANEOUS PAPER NO. 1-825

RECOMMENDED LONG-RANGE RESEARCH PROGRAM FOR BLAST-LOADED STRUCTURES

by

E. F. Smith

D. R. Denton

November 1966

Prepared for

The Office of Civil Defense

In cooperation with the

Office, Chief of Engineers

and

Stanford Research Institute

Conducted by

U. S. Army Engineer Waterways Experiment Station

CORPS OF ENGINEERS

Vicksburg, Mississippi

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ARMY-MRC VICKSBURG, MISS.

FOREWORD

The Office of Civil Defense (OCD), under Work Order No. OCD-05-63-77 "Engineering Advisory Services," and indorsements thereon, requested the U. S. Army Engineer Waterways Experiment Station (WES) in cooperation with the Office, Chief of Engineers (OCE) and the Stanford Research Institute (SRI) to develop a long-range program of needed research on building elements of blast-loaded structures.

Acknowledgement is made to the following personnel who provided valuable guidance and review assistance during the preparation of this report: Messrs. Norbert E. Landdeck and George N. Sisson, OCD; Messrs. Raymond F. Stellar and Martin D. Kirkpatrick, OCE; and Mr. James F. Halsey, SRI.

This report was prepared by Dr. Eugene F. Smith and Mr. Don R. Denton, Chief and Engineer, respectively, Structural Dynamics Section, Protective Structures Branch, Nuclear Weapons Effects Division (NWED). The references listed in Appendix C were compiled by Mr. Gayle E. Albritton, Engineer, Structural Dynamics Section, Protective Structures Branch, NWED.

The recommended program was developed under the general supervision of Mr. Guy L. Arbuthnot, Jr., Chief, NWED, and under the direct supervision of Messrs. W. J. Flathau, Chief, Protective Structures Branch, and

J. V. Dawsey, Jr., Chief, Weapons Data Application Section, Protective Structures Branch.

Director of the WES during the development of this program was Col. John R. Oswalt, Jr., CE. Technical Director was Mr. J. B. Tiffany.

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RECOMMENDED LONG-RANGE RESEARCH PROGRAM FOR BLAST-LOADED STRUCTURES

INTRODUCTION

The Office of Civil Defense (OCD) is responsible for planning and providing fallout shelter spaces. Reinforced-concrete and masonry-type structures are efficient material systems for protection from gamma radiation (fallout) and are utilized extensively as fallout shelters. A need now exists for information with which to evaluate the inherent protection provided by existing fallout shelters against airblast loads in low overpressure regions.

It is known that conventional structures provide some inherent protection against the blast effects of nuclear weapons.[1*] However, little is known concerning the ultimate dynamic strength and behavior of conventional building elements, and even less is known about the ultimate dynamic strength of structural subassemblies and complex structural systems. Structural subassemblies are defined for purposes of this report as three-dimensional building elements and/or two or more integrally connected two-dimensional elements.

In this report, short- and long-range programs of research on building elements of blast-loaded structures are developed and discussed. Recommendations are also included on the nature, conduct, and scope of a research program which is believed to best meet the needs of the OCD for information on the response of building elements to blast loads.

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* Raised numbers refer to similarly numbered items in the References at the end of the main text of this report.

A discussion of the following relevant factors is included in this report: (a) the state-of-the-art of building elements subjected to static and dynamic loads; (b) the objectives of the OCD program of research on building elements; (c) the scope of the research program; (d) a classification of mechanisms by which building elements fail; (e) a description of typical building elements in OCD-approved shelters, so that the specific type of failure of typical building elements can be indicated; (f) the approach taken to implement the research program; (g) the sequence of conducting the test programs; and (h) the test equipment and pertinent facilities required to perform the experimental investigations.

The developmental study[2] by Wiss, Janey, Elstner and Associates for the Protective Structures Development Center (PSDC), the current and the long-range Defense Atomic Support Agency (DASA) research programs,[3] and the draft report, "Research Needs in Structural Engineering for the Decade 1966-1975,"[4] prepared by the American Society of Civil Engineers, were consulted frequently in the development of this program and in the preparation of this report. Additional references pertinent to the long-range program are listed in Reference 2 and in Appendix C.

STATE-OF-THE-ART

The state-of-the-art for the ultimate-strength design and analysis of two-dimensional building elements is, in general, fairly well advanced for structures subjected to static loads. Edge beams and slabs with various edge conditions are notable exceptions. Other exceptions are structural subassemblies such as reinforced-concrete floor and roof systems, connections and joints, and the gross response of subassemblies and structures.

In 1956, the joint ACI-ASCE Committee 421 initiated a program to improve current design procedures for conventional reinforced-concrete floor and roof systems. The test program was initially conducted at the University of Illinois;[5] it was continued by the Portland Cement Association.[6] Results of this program contributed to the improvement of design procedures for working loads[7] and to an understanding of the manner in which typical floor systems, including supporting elements, fail under static loads. The results from these investigations and from another static-load test to failure[8] on a full-scale reinforced-concrete structure indicated that available analytical methods for predicting or estimating the ultimate strength of floor systems under static loads are inadequate. Thus, additional well-planned experimental investigations are needed to determine the performance and ultimate-strength characteristics of complex structures and systems.

Little information is available concerning the ultimate dynamic strength of building elements. For some types of structural components, dynamic-load tests have not been conducted.

OBJECTIVES

The objectives of the research program proposed herein are: (a) to provide information concerning the performance and ultimate or collapse strength of blast-loaded building elements in conventional structures identified in the National Fallout Shelter Survey; (b) to provide criteria to OCD planners responsible for predicting possible casualties and/or damage to shelter occupants located in low-overpressure regions during a nuclear attack (Figure 1); (c) to provide information which would form the basis for improved blast-resistant design of future structures.

SCOPE

This program shall be oriented toward determining the inherent protection afforded by OCD-approved shelters against blast and shock effects upon occupants in relation to the structural integrity and response level of structural systems. In an initial study,[9] accelerations and velocities of slabs lightly damaged by blast loads exceeded tolerable limits for humans as given in Reference 10. Thus, it is believed that biological and physiological factors must be programmed into the research effort to provide a total evaluation of protection offered by sheltered areas from the effects of nuclear weapons.

CLASSIFICATION OF FAILURE MECHANISMS

The mechanisms by which typical building elements, subassemblies, and buildings likely will fail in a blast environment, together with the severity of damage likely to be inflicted upon occupants of shelters, are classified below.

a. Ductile behavior. This type of failure may be characterized by large structural deformations. Injury to occupants is likely to be caused by falling or moving objects and motion of the occupants relative to the motion of the structure.

b. Semiductile behavior. This type of failure may be characterized by large structural deformations followed by abrupt collapse of elements and/or subassemblies. Injury to occupants is likely to be caused by falling or moving objects and collapse of elements and/or subassemblies. Fatalities for this type of failure could be high.

c. Catastrophic failure. This type of failure may be characterized by collapse of the structure or subassemblies. Injury is likely to be severe or fatal. Thus, fatalities for this type of failure could be extremely high.

DESCRIPTION OF TYPICAL BUILDING ELEMENTS

Typical building elements can be classified in three groups: (a) floor (and roof) systems; (b) floor-system supporting elements; and (c) wall or wall-panel systems.

In general, floor systems receive their loads from their own weight, including finish and surfacing material (dead loads), and from the weight of occupants, furniture, and any interior partitions (live loads). The loads imposed on floor systems are, in general, approximately 40 to 70 pounds per square foot (psf) for light loads, 70 to 110 psf for moderate loads, and 110 to 150 psf for heavy loads. Blast loads likely to be imposed on such floor systems in low-overpressure areas may be from five to twenty times these design live loads.

Various types of floor systems are used to resist the dead and live loads, for example: (a) reinforced-concrete one-way slab, one-way joist, two-way slab, flat-plate, flat-slab, waffle-slab, and lift-slab; (b) composite steel deck with topping; and (c) structural clay tile with topping. Of these floor systems, the two-way slab (Figure 2), the flat plate (Figure 3), and the flat slab (Figure 4) have been used extensively in the construction of major existing buildings. In a recent issue of

Engineering-News Record, it was reported that "more concrete is cast in flat-plate floor and roof construction than in any other structural elements of reinforced concrete buildings in the U. S."[11] It is believed that flat plates, flat slabs, and two-way slabs will fail in either a catastrophic or a semiductile manner under severe overloads in a blast environment as indicated from the results of previous investigations.[12,13,14]

The loads from floor systems are transferred to the building frames and to the elements supporting the floor system, such as: (a) beams, girders, and columns (Figure 5); (b) beams and columns (Figure 5), but without girders; (c) columns without and with capitals (Figures 3 and 4, respectively); and (d) monolithic reinforced-concrete walls. Under dynamic overloads, beams and girders are likely to fail in either a ductile or a semiductile manner, while columns and walls are likely to fail in a catastrophic manner. The joints and connections in a frame are likely to fail in a semiductile or a catastrophic manner under severe overloads. In this connection, it was stated in Reference 2: "We believe that most of our conventional structural systems will fail at some connection between the vertical supporting systems and the flexural members. The reinforcement will tear out of the supporting column or walls and the concrete having already sheared through will cause the slab to drop almost in one piece. This form of failure is, of course, undesirable but is likely in many of the systems that exist today."

To enclose a building and to transfer wind loads on the structure to the floor-system supporting elements, various wall or wall-panel systems are used. Some typical examples, in addition to monolithic reinforced-concrete walls, are: (a) masonry (concrete block) walls (Figure 6);

(b) brick and structural clay tile walls; and (c) prefabricated (concrete, aluminum, or steel) panels (Figure 7). Under severe dynamic overloads masonry, brick, and structural clay tile walls are likely to fail in a catastrophic manner. The monolithic reinforced-concrete walls and prefabricated panels are likely to fail in either a semiductile or catastrophic manner. In addition, under blast-loading conditions, these walls or wall-panel systems are likely to create missile, fragmentation, and impactive problems.

APPROACH

The recommended long-range research program is divided into four phases (Figure 8), which are comprised of both theoretical and experimental investigations (Figures 9 through 13). The investigations listed in each phase are intended to be carried out only so far as additional study is required to meet established goals. The following is a general description of the studies in each phase.

Phase 1 - Structural Elements (Figure 10).

These studies are primarily experimental in nature and are designed to develop a basic understanding of the ultimate dynamic strength of primary building elements. Where possible, the experimental tests will be complemented by analytical studies to improve methods of dynamic analysis and design.

The response of building elements and structural subassemblies will be studied simultaneously, where possible.

A recommended program for the next research effort is included in Appendix A. An analysis of previous tests and studies on wall panels together with a recommended program of study is given in Appendix B.

Phase 2 - Structural Subassemblies (Figure 11).

These studies are designed to provide insight into the performance of full-scale structures subjected to blast loading. The ultimate dynamic strength studies on floor and roof systems should be the dominant study in this phase. Two-way slabs, flat plates, and flat slabs should be investigated. The results obtained from the nine-panel model floor systems tested by the University of Illinois[5] and the Portland Cement Association[6] should influence the experimental portion of these programs. Theoretical studies should be undertaken and correlated with the results of experimental investigations.

Phase 3 - Simple Structures (Figure 12).

The studies in this phase are intended to provide basic information required to determine the ultimate dynamic strength in terms of injury to occupants of OCD-approved shelters found in conventional low-rise buildings. The results of this phase and previous phases, together with results of model tests on one-story structures, should permit improved blast-resistant design procedures for conventional structures to be developed.

Phase 4 - Complex Structural Components (Figure 13).

Protection afforded by major structural systems housing OCD shelters, such as wings in building complexes and high-rise structures, will be investigated in this phase. Analytical studies, model studies, and, if possible, field tests will be undertaken.

SEQUENCE OF CONDUCTING TEST PROGRAMS

It is recommended that the program as well as the sequence in which particular studies (units of work) are to be investigated should be determined with guidance furnished by joint discussions with personnel from OCD, Stanford Research Institute, and other organizations associated with the research program on a yearly basis. The sequence of conducting the investigations would reflect current priorities, pertinent data from other sources, and the availability of funds and personnel.

FACILITIES AND EQUIPMENT REQUIRED TO PERFORM INVESTIGATIONS

The facilities and equipment required to perform this research are, in general, available at the Waterways Experiment Station (WES). Such facilities as the Large and Small Blast Load Generators, the 500-kip loader, the 200-kip dynamic loader, and approximately 90 channels of recording instrumentation with peripheral data reduction equipment are available. The WES Big Black Test Site is also available for conducting airblast field tests using high explosives (HE).

When appropriate, consideration will be given to performing tests in other facilities,[15] such as the shock tubes of the Air Force Weapons Laboratory (AFWL), the conical-shock tube of the Naval Ordnance Laboratory (NOL), the blast simulation devices of the Naval Civil Engineering Laboratory (NCEL), and others.

APPLICATION OF TEST RESULTS

The completion of the studies listed in Phase 1 and a portion of Phase 2 should provide information for assessing the approximate protection level of OCD shelters located in basements and first floors of low-rise buildings. This would encompass about one-third of the designated shelter areas with respect to that portion of the civilian population using OCD shelters. The completion of the studies in Phase 3 would possibly permit an evaluation of approximately two-thirds of the OCD-approved shelter areas. Information concerning the percentage of the OCD fallout shelters that are located in basements, low-rise buildings, upper stories of multi-story buildings, etc., will continue to be updated and reflected in future planning.

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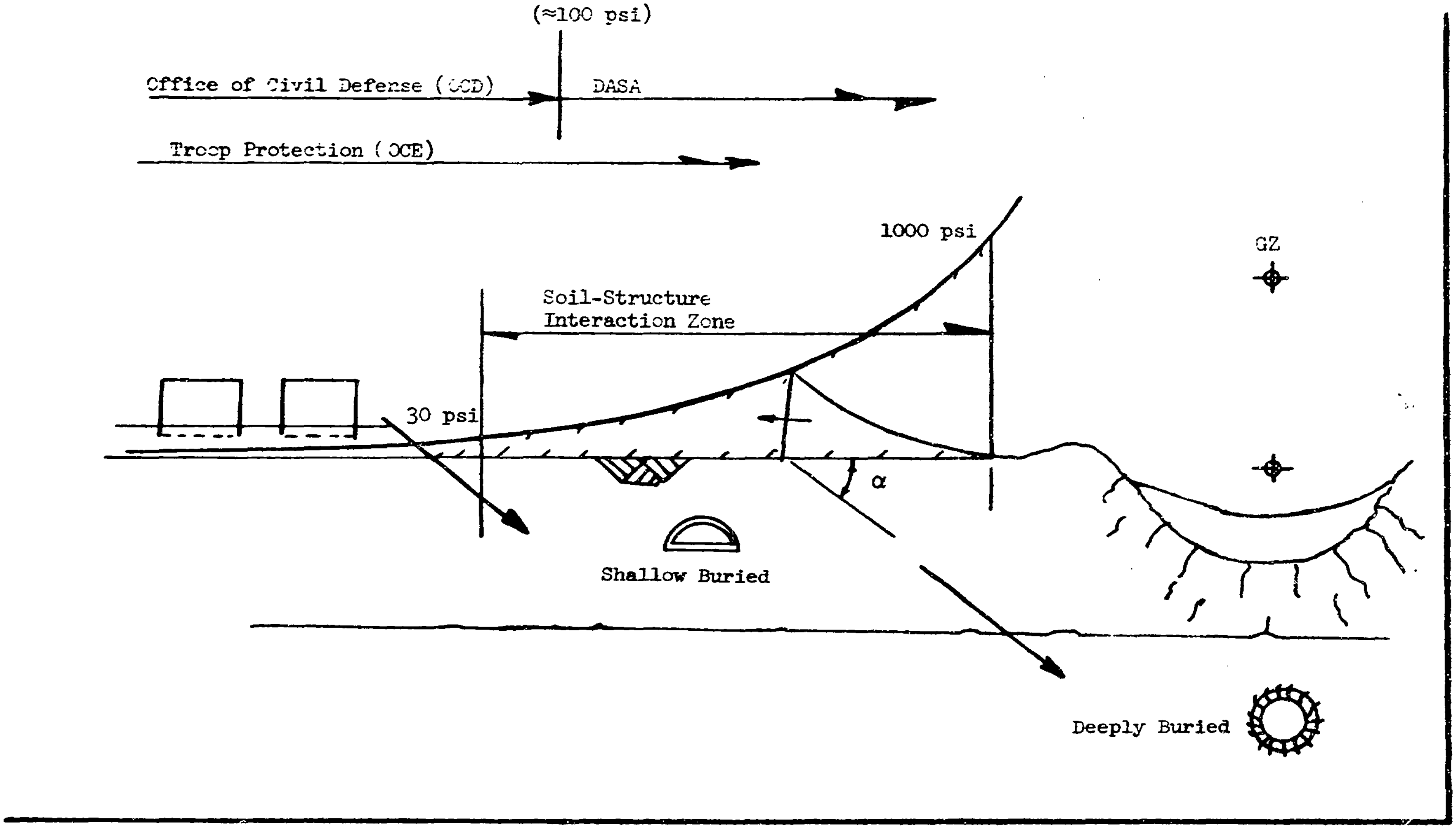


(≈100 psi)
Office of Civil Defense (OCD)
DASA
Troop Protection (OCE)
1000 psi
GZ
Soil-Structure
Interaction Zone
30 psi
α
Shallow Buried
Deeply Buried

Figure 1

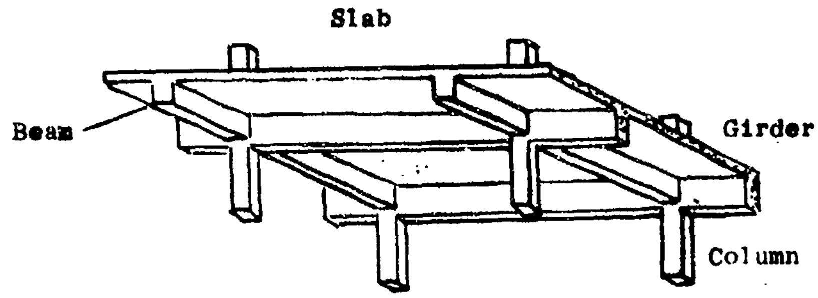


Figure 2. Two-way slab system

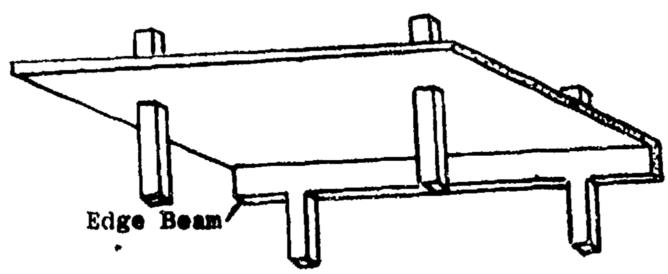


Figure 3. Flat-plate system

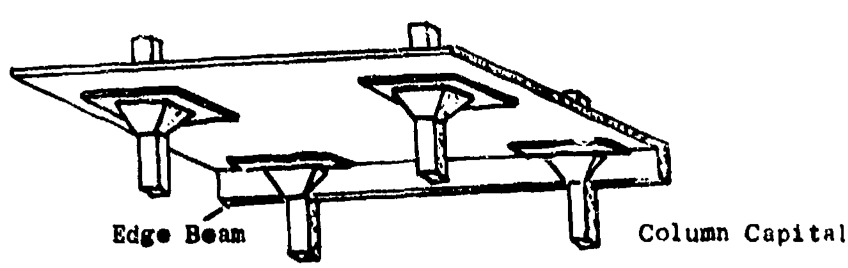


Figure 4. Flat-slab system

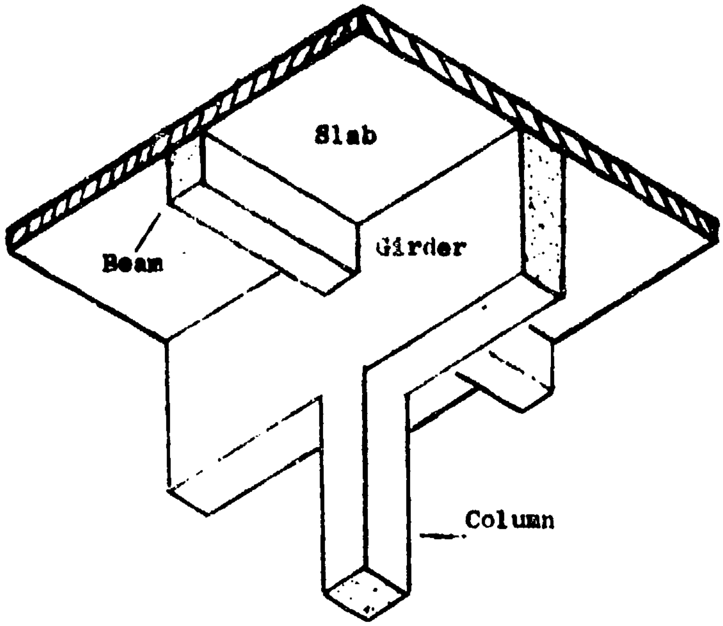


Figure 5. Elements supporting a floor

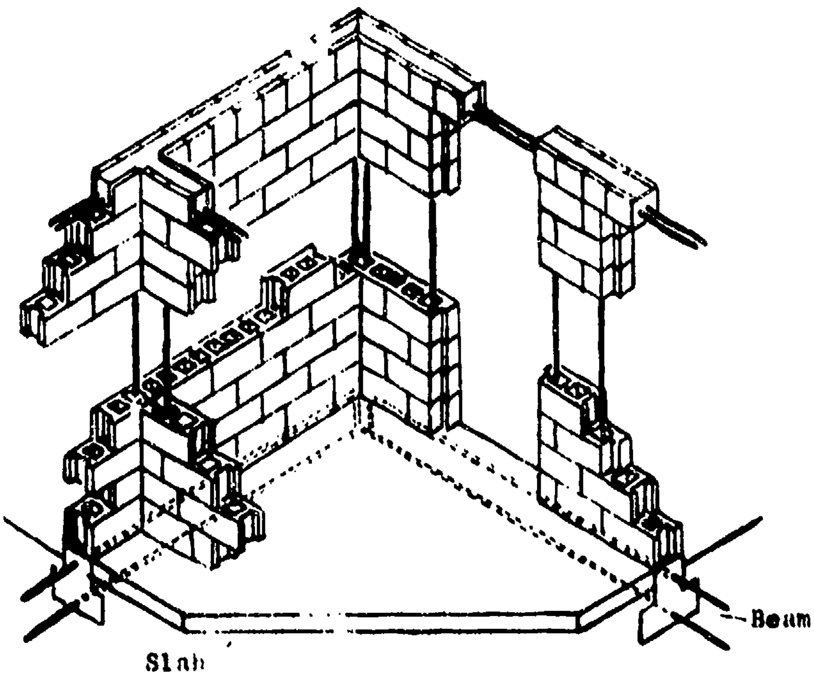


Figure 6. Wall panels

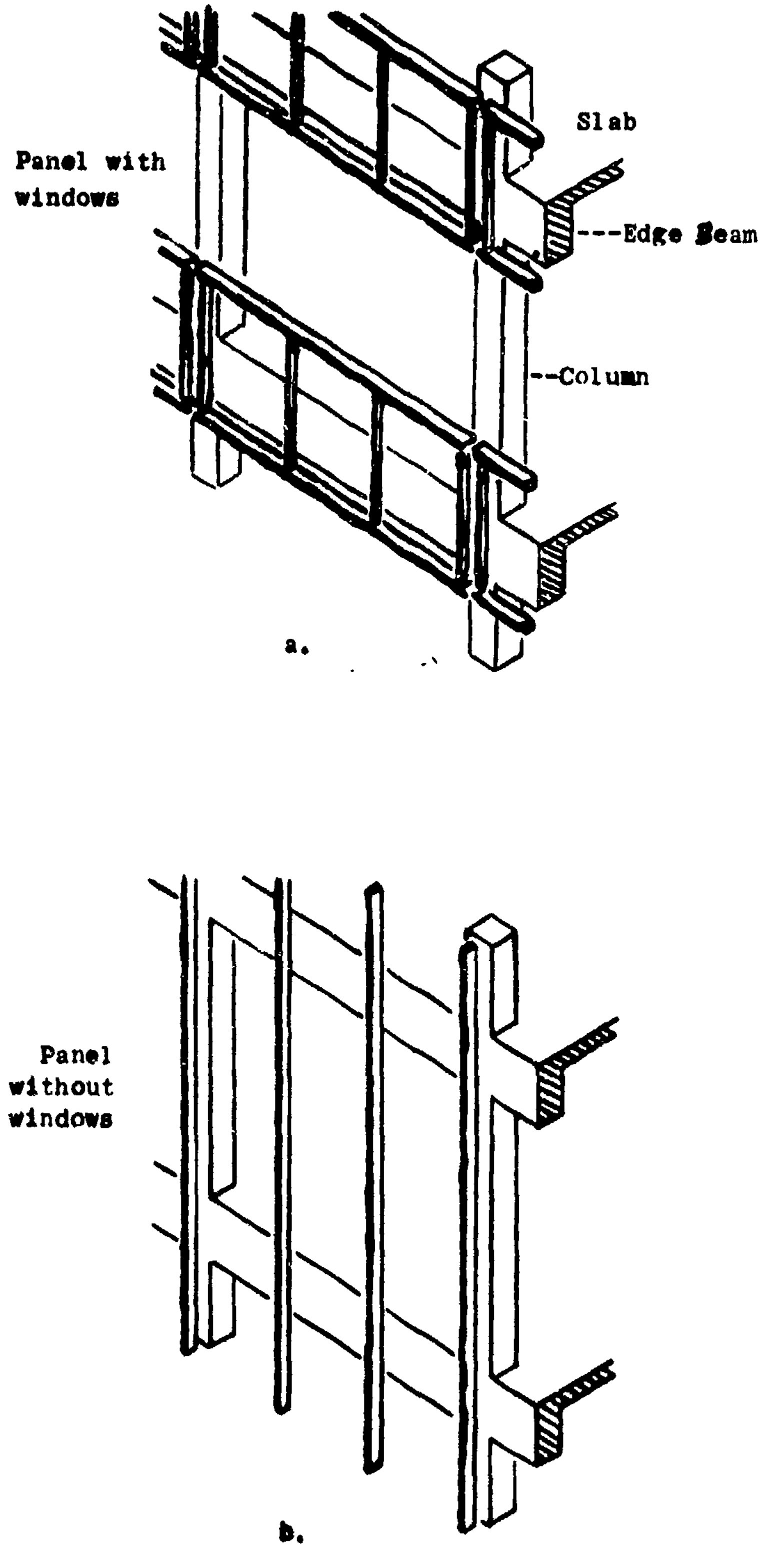


Figure 7. Prefabricated wall panels

OFFICE OF CIVIL DEFENSE

Proposed Long Range Research Program

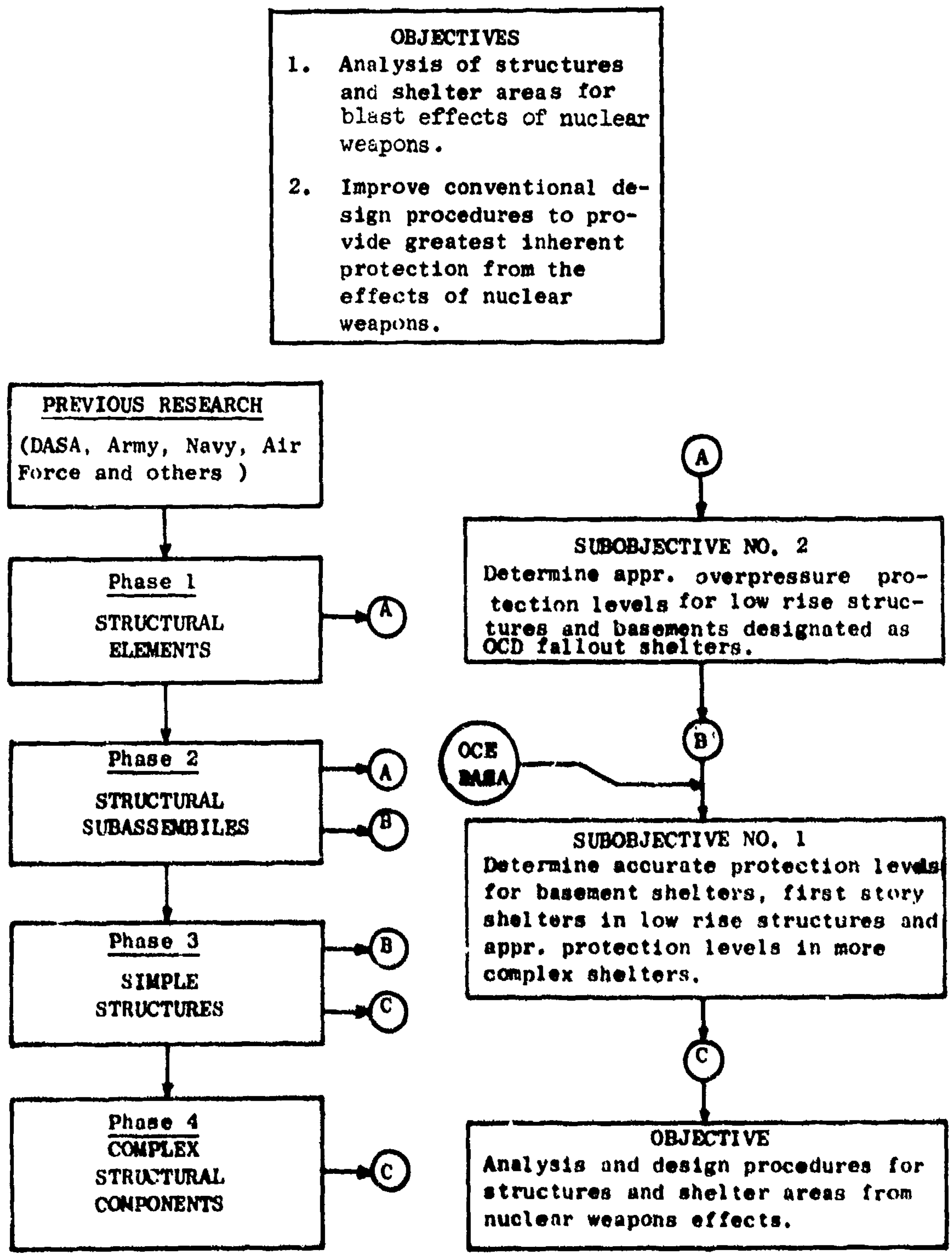


Figure 8

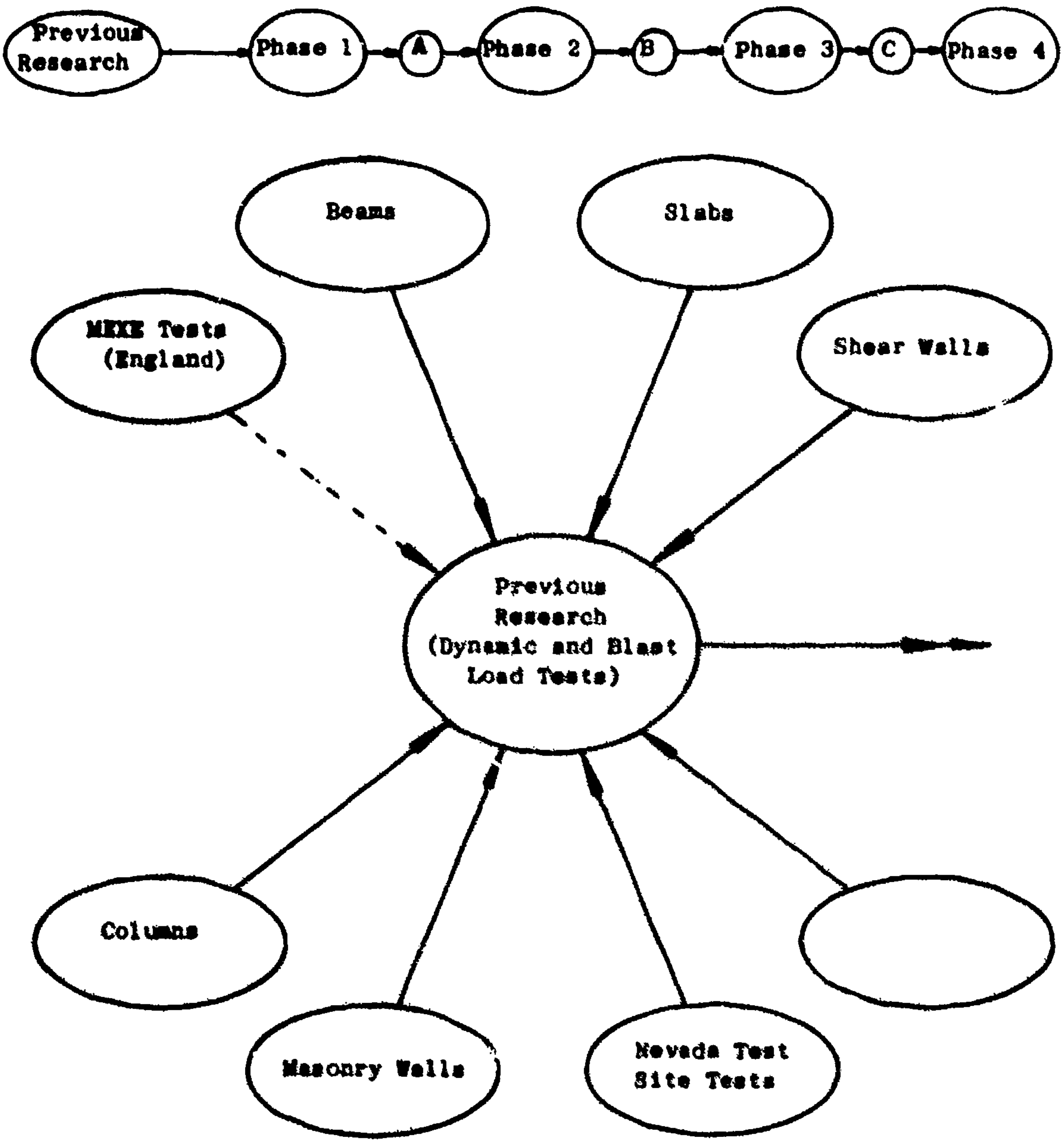

Previous Research
Phase 1
A
Phase 2
B
Phase 3
C
Phase 4
Beams
Slabs
MEXE Tests (England)
Shear Walls
Previous Research (Dynamic and Blast Load Tests)
Columns
Masonry Walls
Nevada Test Site Tests

Figure 9

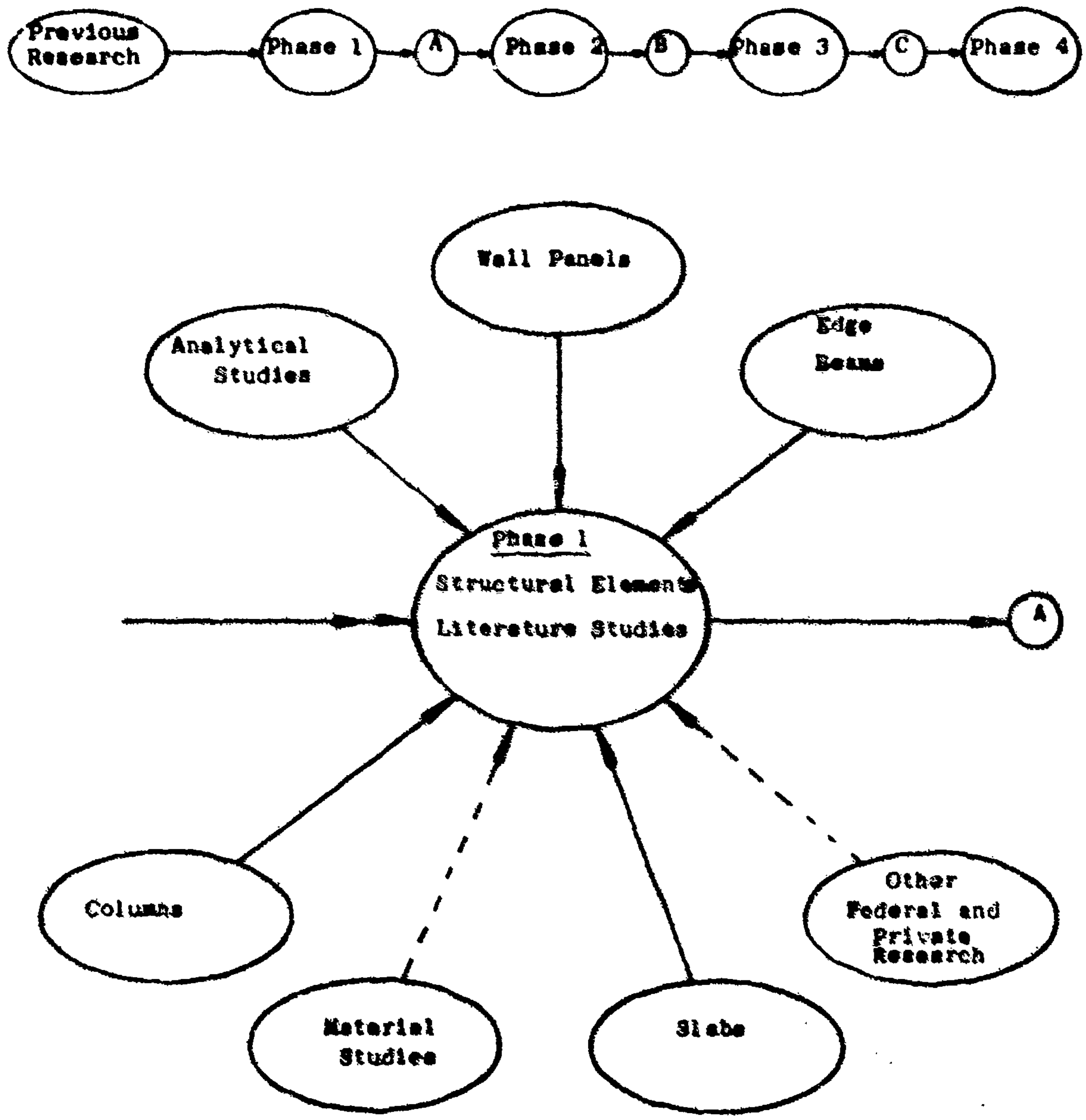

Previous Research
Phase 1
A
Phase 2
B
Phase 3
C
Phase 4
Wall Panels
Analytical Studies
Edge Beams
Phase 1
Structural Elements
Literature Studies
A
Columns
Material Studies
Slabs
Other Federal and Private Research

Figure 10


Previous Research
Phase 1
A
Phase 2
B
Phase 3
C
Phase 4

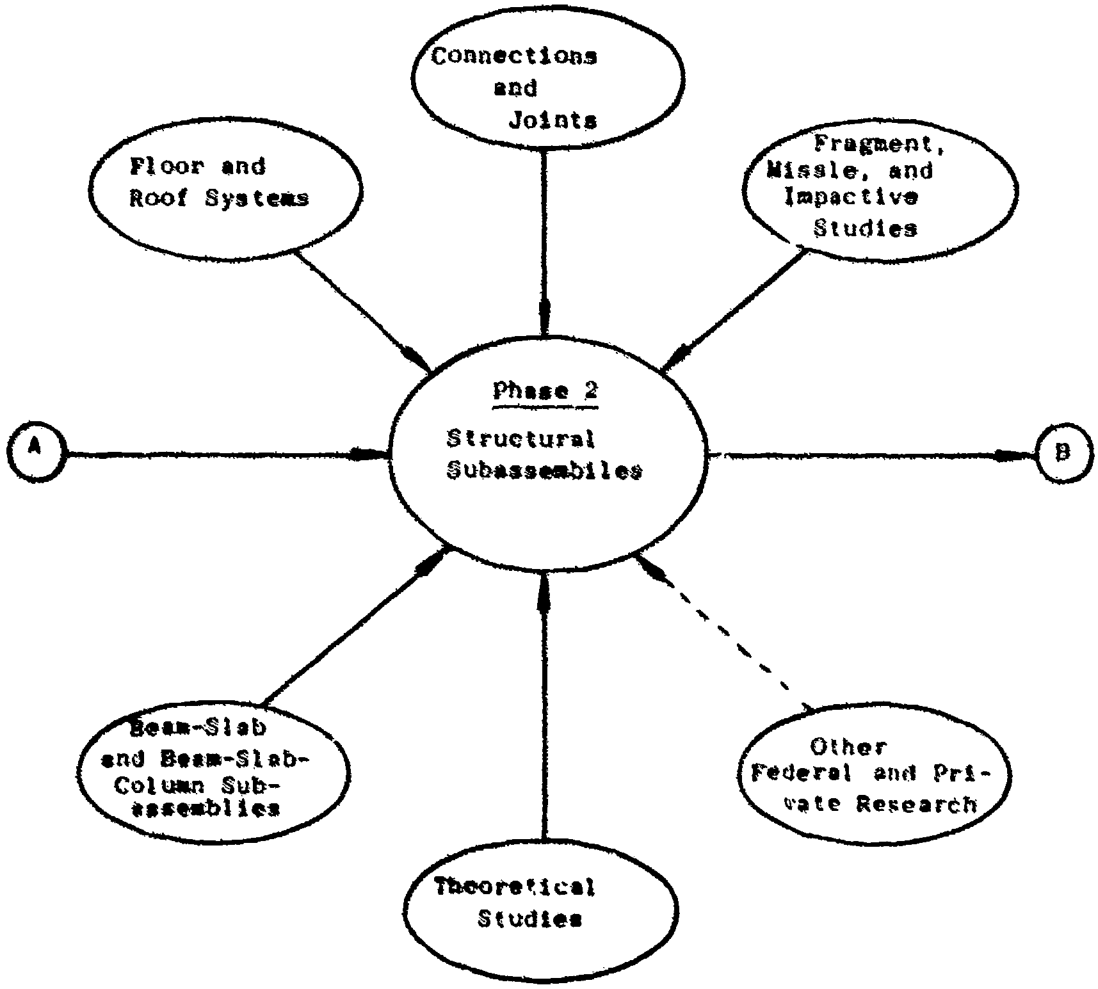

Connections and Joints
Floor and Roof Systems
Fragment, Missle, and Impactive Studies
Phase 2
Structural Subassembiles
A
B
Beam-Slab and Beam-Slab-Column Sub-assemblies
Other Federal and Pri-vate Research
Theoretical Studies

Figure 11

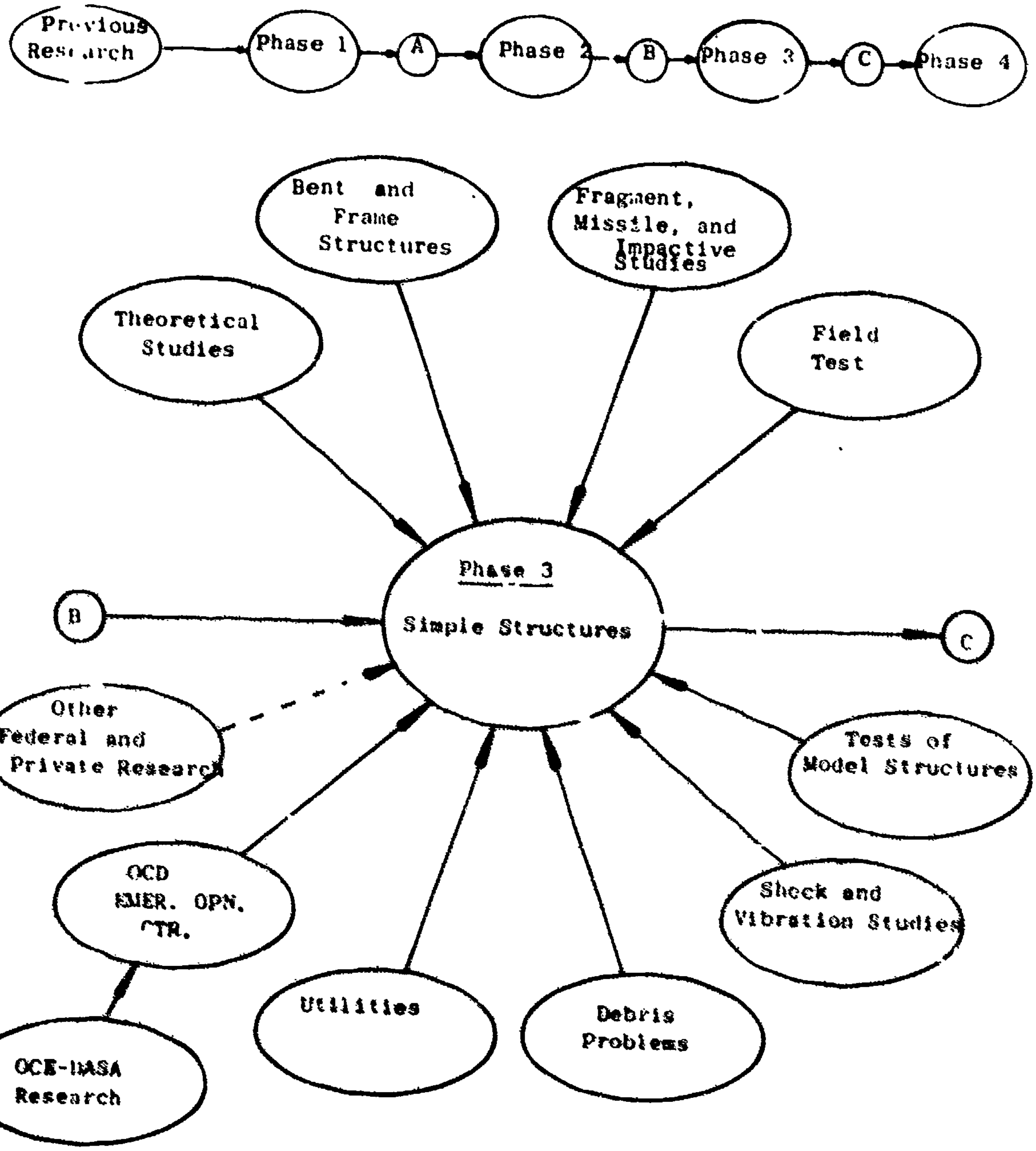
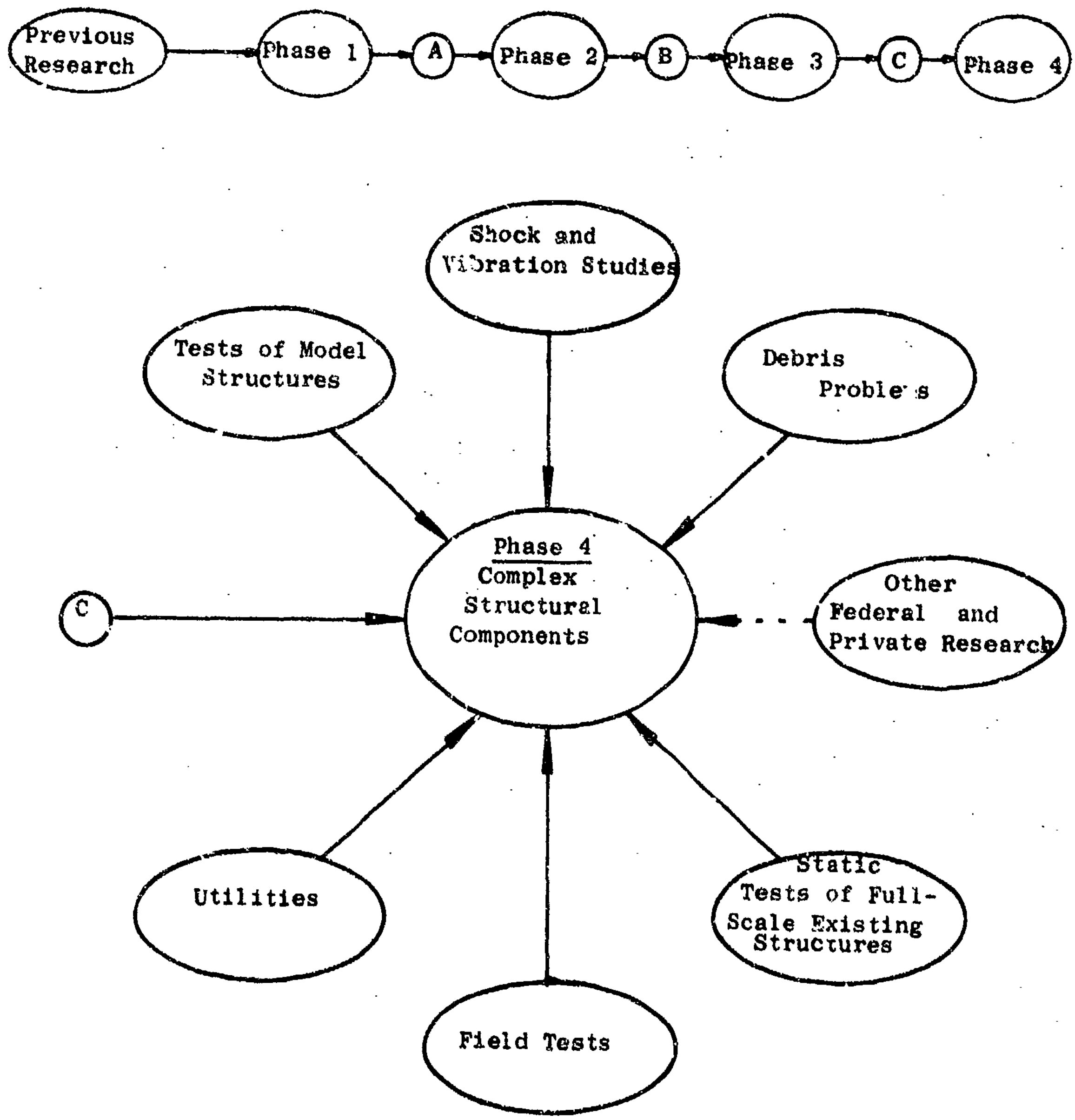

Previous Research
Phase 1
A
Phase 2
B
Phase 3
C
Phase 4
Bent and Frame Structures
Fragment, Missile, and Impactive Studies
Theoretical Studies
Field Test
Phase 3
Simple Structures
B
C
Other Federal and Private Research
Tests of Model Structures
OCD EMER. OPN. CTR.
Shock and Vibration Studies
Utilities
Debris Problems
OCE-DASA Research

Figure 1.



Previous Research
Phase 1
A
Phase 2
B
Phase 3
C
Phase 4
Shock and Vibration Studies
Tests of Model Structures
Debris Problems
Phase 4
Complex Structural Components
C
Other Federal and Private Research
Utilities
Static Tests of Full-Scale Existing Structures
Field Tests

Figure 13

APPENDIX A

RECOMMENDED PROGRAM OF RESEARCH: PHASE 1 AND CALENDAR YEARS 1966-1968

Background

The floor system above the protected area is most apt to influence survival in a basement-type fallout shelter subjected to low-overpressure blast loads, while the roof and wall systems are most likely to influence survival in low- and high-rise building shelters.

Two-way and flat slabs are probably the most extensively used floor systems in older low-rise and multistory structures. In the past decade, however, flat plates, with more usable enclosed volume and attendant savings in construction costs, replaced two-way and flat-slab systems as the most widely used floor system in major building construction. Thus, floor systems in OCD-approved shelter areas in low-rise and multistory buildings which were constructed in urban areas prior to World War II are likely to be either flat slabs or two-way slabs, while the floor systems in such buildings constructed in recent years are likely to be flat plates. In semiurban areas, two-way slabs are still likely to be widely used.

Two-way slab systems are likely to fail in a semiductile manner (because of premature torsional failure of the edge beams[14*]) in an air-blast environment, while flat-plate floor systems designed by code provisions (ACI 318-56 and -63) are likely to fail catastrophically (by columns punching through the slab[6,12]).

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* Raised numbers refer to similarly numbered items in the References at the end of the main text.

For the reasons given in the previous paragraphs, the next research efforts should be investigations of a two-way slab system, a flat-plate system, and wall-panel systems so that procedures and methods can be developed to evaluate and improve the ultimate dynamic or collapse strength of such systems.

A program of research on two-way slab and flat-plate systems is described and developed in this appendix.

Experimental Program

Two investigations and one support study are recommended to be undertaken during the calendar years 1966-1968: two-way slab and flat-plate and a support study of edge (L-shaped) beams.

Continuous floor systems generally have three types of panels (Figure A.1): interior, edge, and corner panels. The results of previous investigations[12,14] indicate that edge beams of two-way slab and flat-plate systems may fail due to torsional distress, and flat plates may fail by columns punching through the slab, under severe static overloads prior to the flexural failure of the slab itself. Therefore, it is not desirable at this time to test a complete continuous floor system. It is desirable, however, to simulate the action and stiffness of adjacent panels in two-way slabs while primarily testing a single panel with or without beams (rigidly supported), as appropriate. Initially, it is desirable to investigate only the critical sections of flat-plate systems, namely, column-slab joints and edge (L) beams.

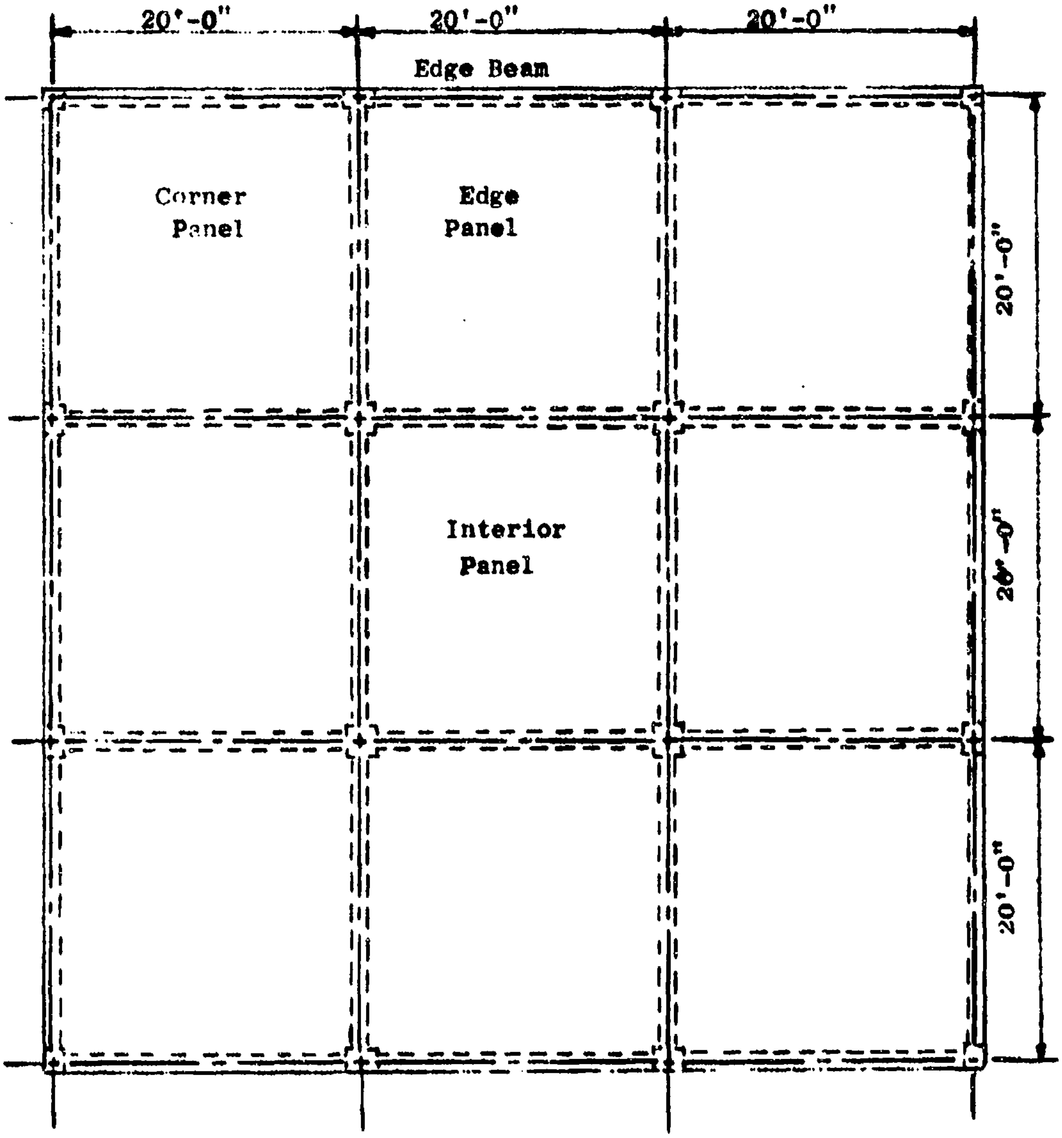
Two-way slab investigations. Interior, corner, and edge panels of a nine-panel prototype two-way slab system (Figure A.1) will be tested to failure statically and dynamically. The effect of adjacent panels will be simulated (Figures A.2, A.3, and A.4). Static test results will be compared with results of a previous model investigation[14] of the prototype system, and will provide guidance for the design of the dynamic tests in the Large Blast Load Generator.

Flat-plate investigation. Column-slab joints such as exist in flat-plate systems will be tested under concentric and eccentric static and dynamic (airblast) loads to study the problem of columns punching through slabs. Means to effectively and economically improve the column-punching resistance should be developed from the tests.

Wall-panel investigations. Various types and configurations of wall panels, which will include on-job constructed and prefabricated panels, will be tested dynamically. A general test program for wall panels is presented in Appendix B.

Recommended limited support studies. Recommended limited studies in support of the floor-system investigations and completion of Phase 1 are: (a) edge beams subjected to dynamic torsional moments, to study the problem of premature failure of edge beams in two-way slab, flat-plate, and flat-slab floor systems; (b) columns subjected to concentrically and eccentrically applied dynamic overloads, to study the problem of column behavior (and possible collapse) under such dynamic overloads; and (c) beam-column joints (fixed-end beams), to study the effect of distressed joints (plastic hinges) on the dynamic shear strength of such connections.

Other limited support studies will be recommended after research investigations in calendar years 1966-1968 have been initiated.



Plan

(Two-way slab system shown)

Figure A.1. Prototype floor system dimensions

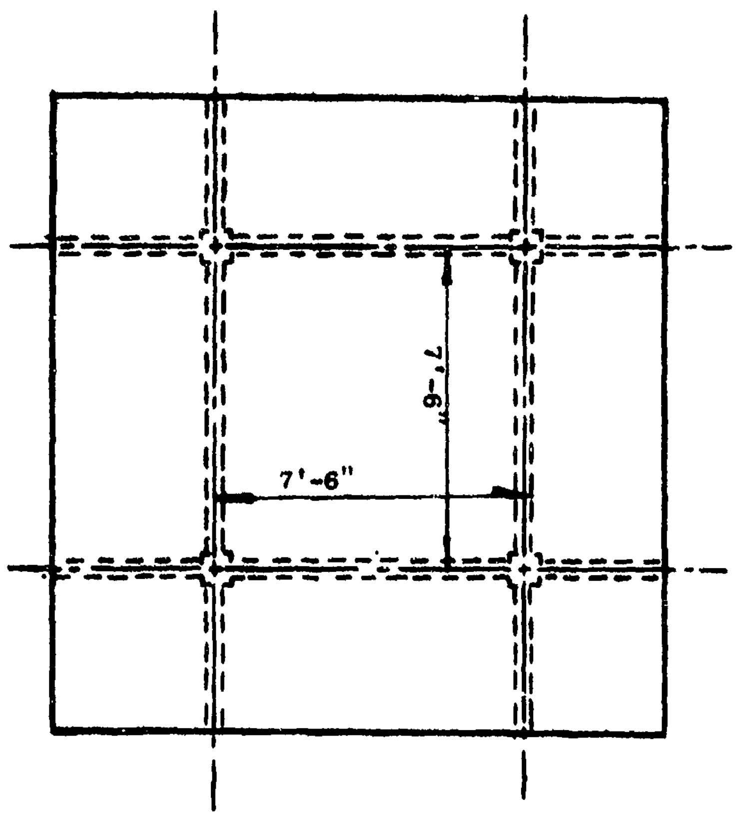


Figure A.2. Interior panel test configuration

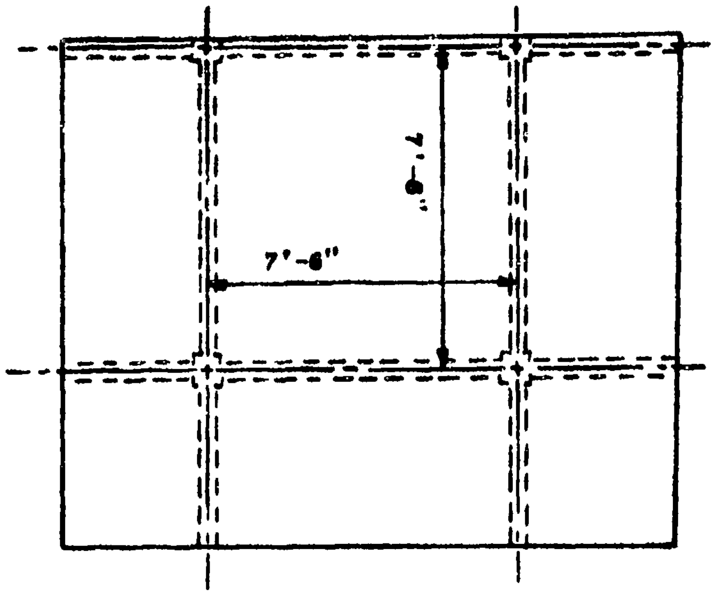


Figure A.3. Edge panel test configuration

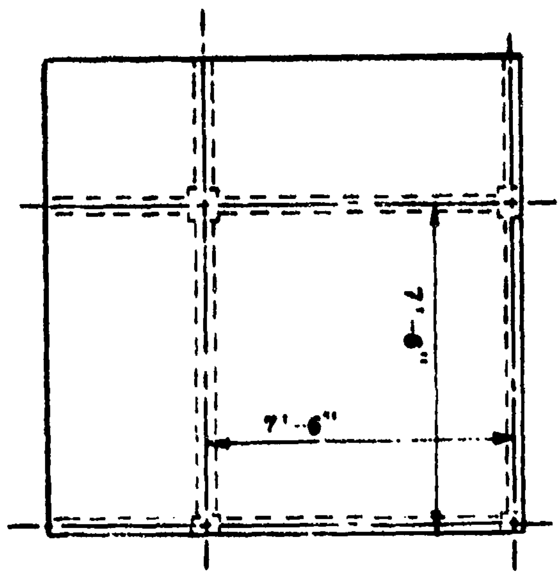


Figure A.4. Corner panel test configuration

APPENDIX B

WALL PANELS

Background

Walls are likely to influence survival of occupants housed in OCD-approved fallout shelters located in above-ground floors in buildings. Exterior walls are more apt to influence survival than interior walls; interior load-bearing walls are more likely to influence survival than nonload-bearing walls. Walls and wall construction vary widely with the type and purpose of the building and the geographic locality; in addition, several types of walls may be used in a building. No material is used exclusively in wall construction in the building industry. Wall panels, curtain walls, and interior partitions are termed herein simply walls.

The state-of-the-art for the analysis of wall panels subjected to lateral airblast loads is not generally well advanced. A limited number of experimental studies[17,18,19]* to determine the resistance of walls to lateral uniform static loads and lateral airblast loads have been conducted. The most extensive investigations were conducted in a Nevada field test under Operation UPSHOT - KNOTHOLE.[18,19] In the Nevada test, 72 simulated full-scale walls constructed of various types of materials and construction were tested. Eighteen panels with openings and eighteen without openings were tested at two overpressure levels. The walls, considered typical of conventional construction, included 8- and 12-in. solid brick and cinder block, tile and brick veneers, corrugated-steel

* Raised numbers refer to similarly numbered items in the References at the end of the main text.

sections, and precast reinforced-concrete channels. Dynamic-deflection and pressure measurements, pretest and posttest visual surveys were made.

It was found from these tests that (a) the resistance of walls to dynamic pressures is significantly affected by as much as 15 percent openings (aperture) compared to a similar wall without an opening, (b) interior partitions behind exterior walls with a 15 percent opening may be expected to collapse before collapse of the exterior wall occurs, and (c) missiles and fragments from exterior walls are blown with considerable velocity against the interior partitions. The results of the Nevada tests further indicate that wall panels constructed of brick and block are, in general, brittle, and their resistance to blast loads is significantly affected by edge conditions. Unfortunately, pressure records were not obtained for 36 of the 72 wall panels.

Classification of Walls

Several types of walls likely to be used in areas designated as OCD fallout shelters are listed in Table B1. The wall types are categorized according to their usage and their probable relative influence upon survival of occupants and things from the effects of the dynamic reflected pressures (not to be confused with overpressure) from a nuclear explosion.

Prefabricated Walls. In the post-World War II period, high-rise buildings, prefabricated exterior walls and wall sections were commonly used. In modern commercial, office, and residential buildings, glass, and prefabricated panels such as shown in Figure 7 of the main text are common. Corrugated-steel panels are occasionally used in warehouses and storage buildings, while reinforced-concrete structural sections (T-beams, channel sections) are frequently used in low-rise and smaller commercial buildings such as shopping centers and professional centers.

The blast resistance of some types of simple prefabricated walls such as corrugated-steel sections can be predicted reasonably accurately; however, additional tests on other types of prefabricated panels are desirable.

In-Place Constructed Walls. The majority of wall areas in existing buildings in the United States are probably the in-place constructed type. The most common types of in-place constructed walls are brick, concrete block, and cinder block. Concrete and cinder blocks with brick exterior facing (veneer) are commonly used as exterior walls of low-rise, small (urban) buildings and in some high-rise structures, particularly in older structures. Exterior and interior walls of concrete and cinder block (see Figure 6) are widely used in various types of commercial and public buildings.

In buildings utilizing in-place-constructed walls the exterior walls are likely to be constructed of 6- and 8-in. concrete and cinder blocks. The interior, nonload-bearing walls are likely to be constructed of 4- and 6-in. blocks. Concrete and cinder blocks, brick, and brick veneers may be either reinforced or unreinforced. Reinforced-concrete, tile, and tile-brick veneers are not as widely used as brick or block construction.

It is believed that the primary effort for the wall-panel study should be addressed to experimental investigations to determine the blast resistance of and protection provided by walls constructed of bricks, blocks, and block-brick veneers. Reinforced and unreinforced panels with and without openings should be investigated. Concurrent with the investigations to determine the blast-resistant strength of the brick and block walls, the potential hazard to people and equipment created by missiles and fragments from failed wall sections should be studied.

Recommended Experimental Program

It is recommended that experimental tests be conducted to determine the collapse strength of the more common in-place constructed walls (brick, cinder and concrete blocks) subjected to static and lateral airblast loads. In order to take advantage of the quantity of data available from the Nevada tests, it is recommended that the initial experimental tests in the laboratory be conducted on in-place constructed panels similar to those previously tested in Operation UPSHOT - KNOTHOLE.[18,19] In addition to the blast resistance of individual wall panels of different materials and construction, the following areas require systematic study in order that the resistance of OCD-approved shelters located above ground can be evaluated adequately:

a. The pressure-time distribution on solid walls and on both sides of walls with different percentages of openings subjected to incident pressure.

b. The blast resistance of in-place constructed walls partially restrained from lateral movement.

c. The blast resistance of exterior and interior walls partially supported by adjoining interior partitions and space dividers.

d. The resistance of walls to lateral in-place loading, i.e. lateral loads on the ends of the walls that act parallel and in line with the wall.

Table B1

Exterior and Interior Wall Types

Exterior	
Prefabricated	**In-Place Constructed**
Corrugated steel	Brick
Reinforced-concrete sections (T-beams, channels, etc.)	Concrete and cinder block (4- and 6-in. common)
Asbestos-cement	Clay tile
Aluminum siding	Concrete, cinder block, and brick veneers
Glass panels	Tile and brick veneers
Architectural shapes	Reinforced concrete
	Other

Interior	
Load Bearing	**Nonload Bearing**
Concrete and cinder block (6- and 8-in. common)	Concrete and cinder block
Reinforced concrete (shear walls)	Tile
	Wood, wood construction
	Prefabricated sections
	Space dividers

APPENDIX C

REFERENCES OF FULL SCALE AND LABORATORY DYNAMIC TESTS OF STRUCTURES AND STRUCTURAL ELEMENTS

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