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HIGH-STRENGTH CONCRETE FOR PEACEKEEPER FACILITIES(U)
 ARMY ENGINEER WATERWAYS EXPERIMENT STATION VICKSBURG MS
 STRUCTURES LAB K L SAUCIER MAR 84 WES/MP/SL-84-3

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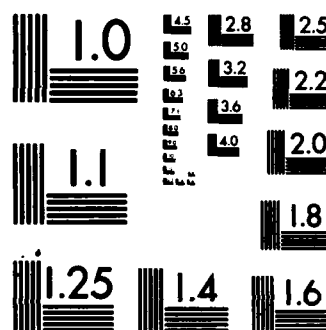
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MISCELLANEOUS PAPER SL-84-3



US Army Corps
of Engineers

HIGH-STRENGTH CONCRETE FOR PEACEKEEPER FACILITIES

by

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U. S. Army Engineer Waterways Experiment Station
P. O. Box 631, Vicksburg, Miss. 39180

AD-A140 510



March 1984

Final Report

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Prepared for U. S. Army Corps of Engineers
Missile Construction Office
Norton AFB, San Bernardino, Calif. 92409

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number) An investigation is described which was conducted to determine the processes and techniques required to produce portland-cement concrete with a compressive strength of 15,000 psi or greater using conventional concreting methods and equipment, and to develop physical property data on the mixtures. It was permitted that special materials and admixtures be used, but a requirement was set that the aggregates and cements be selected from those available in the Cheyenne, Wyoming, area. (Continued)		

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20. ABSTRACT (Continued)

Results indicated that it is feasible to achieve the 15,000-psi compressive strengths but that workability may decrease over a 2-hour period, and this latter development should be studied under job conditions. It is recommended that (a) all materials and procedures to be used on a specific project be tested in the laboratory for basic property information, and (b) selected mixtures be tested in the field under expected environmental conditions prior to actual job use.

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Preface

The investigation described in this report was conducted for the U. S. Army Corps of Engineers Missile Construction Office, Norton AFB, California, by the Concrete Technology Division (CTD) of the Structures Laboratory (SL), U. S. Army Engineer Waterways Experiment Station (WES). Authorization for the investigation was given in DA Form 2544, No. E87 83-7165, dated 21 March 1983.

The investigation was performed under the general supervision of Mr. Bryant Mather, Chief, SL, and Mr. John M. Scanlon, Chief, CTD, and under the direct supervision of Mr. Kenneth L. Saucier, Principal Investigator. Mr. Donald M. Walley, CTD, proportioned the concrete mixtures. This report was prepared by Mr. Saucier.

Funds for publication of this report were provided from those made available for operation of the Concrete Technology Information Analysis Center (CTIAC). This is CTIAC Report No. 70.

Commander and Director of WES during the investigation and the preparation and publication of this report was COL Tilford C. Creel, CE. Technical Director was Mr. F. R. Brown.



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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:

<u>Multiply</u>	<u>By</u>	<u>To Obtain</u>
inches	0.0254	metres
pounds (force) per square inch	6894.757	pascals
pounds (mass)	0.45359237	kilograms
pounds (mass) per cubic yard	0.5932764	kilograms per cubic metre

HIGH-STRENGTH CONCRETE FOR PEACEKEEPER FACILITIES

Background, Purpose, and Scope

Background

1. Previous work has indicated that concrete with a compressive strength of 10,000 psi* is achievable with present-day technology and materials. Quality materials, use of a low water-cement ratio (W/C), and admixtures are required. More recently the use of more effective admixtures, known as high-range water-reducing admixtures (HRWRA), and a very fine silicon-dioxide powder, known as silica fume, have shown promise for increasing the compressive strength of portland-cement concrete above 10,000 psi.

Purpose

2. The purposes of this program were (a) to conduct a study of the processes and techniques required to produce portland-cement concrete with a compressive strength of 15,000 psi or greater using conventional concreting methods and equipment, and (b) to develop physical property data on the mixtures. Special materials and admixtures were permitted, but the aggregates and cements were selected from those available in the Cheyenne, Wyoming, area.

Scope

3. The study consisted of the necessary investigation of materials and methods to produce 15,000-psi concrete. The slump was allowed to vary between 2 and 8 in. Tests included compressive strength at different ages, tensile strength, elastic properties, resistance to freezing and thawing, shrinkage, creep, and loss of slump with time.

Materials, Mixtures, and Tests

Materials

4. One granite coarse aggregate, designated OM 19 G-1, one limestone aggregate, designated OM 19 G-2, and one limestone sand, designated OM 19 S-1, were received for use in the study. Both project coarse aggregates were washed prior to use. The granite was also screened over a 1-in. sieve to remove

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

oversize material. In addition, a laboratory rock was used in a number of mixtures when it became apparent that the large number of trial batches required would exhaust the supply of project aggregate before all the physical property tests could be conducted. A local chert aggregate and a local lightweight aggregate were used in several trial mixtures. Aggregate property data on the project aggregates and the laboratory limestone aggregate are given in Tables 1-4.

5. The portland cement was a Type II from Wyoming. Information on the cement is given in Table 5. Results of tests of a Class F fly ash, a Class C fly ash, and the silica fume used in the study are given in Tables 6A, 6B, and 7, respectively.

6. A naphthalene-based HRWRA and a melamine-based HRWRA were used in the study. An air-entraining admixture was used in selected admixtures. Fibers were incorporated in three mixtures on a trial basis.

Mixtures

7. Seventy-six mixtures were proportioned. Results are given in Table 8. In addition to the mixtures given, many batches were discarded when they were found to be harsh or unworkable. The first five mixtures were based on previous experience applied to project material and using the recommended dosage of admixture. Subsequent mixtures introduced the materials and proportions required to provide a comprehensive study of all reasonable combinations. Pertinent information on the mixtures is given in the remarks column of Table 8. Mixing was done according to ASTM C 192-81.

Tests

8. Tests were conducted according to the following ASTM standards:

- a. Slump - C 143-78.
- b. Compressive strength - C 39-81.
- c. Splitting tensile strength - C 496-79.
- d. Modulus of elasticity and Poisson's ratio - C 469-81.
- e. Resistance to freezing and thawing - C 666-80.
- f. Length change on drying - C 157-80.
- g. Creep - C 512-82.

9. The compressive strength specimens were 3-in.-diameter by 6-in.-long cylinders cured in water until time of test. Due to the very high test strength, compressive specimens were ground to tolerance on a surface grinder rather than being capped. Electrical resistance strain gages were used to record stress-strain data for calculation of modulus of elasticity and Poisson's ratio.

Results

Proportioning

10. The proportioning work, Table 8, indicated that it is indeed possible to achieve workable, low W/C concrete with various combinations of the selected materials. Slumps in the range up to 8 in. were secured with water-cementitious ratios approximating 0.25 and without segregation or harshness in most instances. During the proportioning study, however, it became apparent that a slight reduction in W/C or slight increase in admixture dosage could instantly change the workability of a mixture. A decrease of 0.01 in W/C could make a mixture very sticky or an increase of 0.1 percent in admixture dosage could result in a harsh mixture. Apparently, these changes are the result of working near the critical minimum amount of water ($W/C = 0.25$) and the critical maximum dosage of admixture (1.0 percent of cement). The slump test is not a good indicator of workability under these circumstances. A high-slump mixture may consolidate satisfactorily yet be sticky and hard to move. A high-slump mixture may even "flow" during the slump test, but be very harsh. It is not possible to relate the characteristics of the mixture developed herein directly to a field situation due to variations of materials, the chemistry of the cement and admixtures, and the differences in mixing actions and temperature. These mixtures could, however, be used as a basis for field mixtures to be tried under actual job conditions with job equipment.

11. Slump loss tests were conducted on three mixtures, Nos. 38, 48, and 58, to determine loss of workability with time. An initial slump test was conducted immediately after mixing. The concrete was then allowed to be at rest for 25 min, at which time it was remixed for 5 min. This cycle was repeated until the end of the test. Results are given in Table 9. Indications are that some workability will be lost over a period of 2 hr, but the concrete will remain placeable for 2 hr. Redosing with admixture is a viable option for restoring workability, but redosing tests were not conducted in this study. Again, the importance of these tests is to indicate that extended workability is possible to achieve with these mixtures; field tests should be conducted under actual project conditions.

Compressive strength

12. Compressive strength results are given in Table 10. The tests were conducted on 3- by 6-in. cylinders (3 x 6) unless otherwise noted. Indications are that:

- a. Compressive strengths of approximately 10,000 psi may be attained at 7-days age with the materials used and the slump specified.
- b. Compressive strengths of 12,000 psi may be achieved at 28-days age.
- c. Compressive strengths of 15,000 psi may be attained at 90-days age.
- d. Compressive strengths of 20,000 psi may be attained with selected mixtures at extended ages.
- e. The use of high-range water-reducing admixtures is necessary to achieve the desired strengths at the required slumps.
- f. Fly ash and silica fume enhance the potential for increased compressive strength.
- g. High-strength, air-entrained concrete containing silica fume is feasible.
- h. Fibers may be used in high-strength concrete; however, a significant loss in workability results.
- i. Lightweight high-strength (10,000-psi) concrete could not be attained with the materials and techniques used herein.

13. To facilitate comparison of the two project aggregates, strength results are given in Tables 11 and 12 for limestone and granite coarse aggregates, respectively. A cursory examination of the results reveals that the granite aggregate produced slightly higher strengths for comparable mixtures. However, it is obvious that 15,000-psi concrete may be attained with either of the coarse aggregates and selected cementitious materials and admixtures used in the program.

Splitting tensile strength

14. Splitting tensile strength results are given in Table 13. Tensile strengths of approximately 1200 psi were achieved on several mixtures. Thus, the tensile strength is approximately 9 percent of the comparable compressive strength. This compares to the normally accepted value of 10 percent used for conventional concrete.

Elastic properties

15. Stress-strain curves for 18 specimens tested in compression to failure are given in Figures 1-18. The curves for vertical strain are essentially linear to failure. Some nonlinearity is apparent in the horizontal or

circumferential strain. Young's modulus of elasticity and Poisson's ratio results are given in Table 13. Young's modulus for the representative samples tested approximated 6.0×10^6 psi. This is twice the normally accepted value for conventional concrete. Poisson's ratio varied somewhat depending on the curvature of the horizontal strain curve and at what stress level the ratio was computed. Actual values ranged between 0.20 and 0.25.

Drying shrinkage tests

16. Results of length change tests, conducted on mixtures No. 22 and 35, are given in Tables 14-17. All specimens were cured in water in accordance with ASTM C 157. For the control tests, Tables 14 and 16, cement was substituted for silica fume on a weight basis. Thus, the total amount of water and the W/C remained constant for all four mixtures. On the 1-in. unrestrained bars expansion was noted in all mixtures. However, significantly more expansion was noted on the mixtures without silica fume. Approximately 0.004 percent shrinkage was noted with the 3-in. bars on the mixtures containing silica fume at 100-days age.

Resistance to freezing and thawing

17. Tests for resistance to freezing and thawing were conducted on three mixtures; one air-entrained limestone coarse aggregate mixture, one air-entrained granite aggregate mixture, and one nonair-entrained granite mixture. Results are given in Tables 18, 19, and 20. After 300 cycles of freezing and thawing all mixtures had a relative modulus (E) of at least 80 percent. At approximately 350 cycles both granite mixtures (air- and nonair-entrained) had a modulus of about 85 percent but the air-entrained limestone mixture had dropped to approximately 70 percent. At approximately 400 cycles the granite mixtures still had a modulus of approximately 80 percent, but the limestone mixture had dropped to 50 percent. All testing was terminated when the modulus decreased to 50 percent on each of the three mixtures. Apparently, the combination of a very dense rock (granite) and a very low W/C provided excellent resistance to freezing and thawing. It would appear that the nonair-entrained concrete did not achieve critical saturation with water under the test conditions used.

Creep tests

18. Creep tests were conducted on specimens from mixture No. 22 with and without silica fume in accordance with ASTM C 512-82. The creep load was 2000 psi. Results for total strain, creep strain, and specific creep up to 3-months age are given in Figures 19-24. At 90-days age indications are that (a) creep is essentially equal for mixtures with and without silica fume, (b) total strain approximated 500 millionths, (c) creep strain approximated 200 millionths, and (d) specific creep was approximately 0.1 millionth per psi.

Conclusions

19. The results of this investigation indicate the following:

- a. It is feasible to achieve 15,000-psi compressive strength concrete with selected cementitious materials and aggregates from the Wyoming area.
- b. Some workability may be lost over a time period of 2 hr; thus, this phenomenon should be investigated under job conditions.
- c. Tensile strengths approximating 1200 psi were achieved. Modulus of elasticity was approximately 6.0×10^6 psi and Poisson's ratio was approximately 0.20.
- d. Shrinkage of typical high-strength concrete containing silica fume was indicated to be on the order of 0.004 percent at 100 days in water.
- e. Freeze-thaw-resistant concrete was achieved with both project aggregates in an air-entrained mixture. In addition, a nonair-entrained mixture with the granite aggregate developed significant freeze-thaw resistance.
- f. Creep was essentially equal for mixtures with and without silica fume, approximating 200 millionths of strain at 3-months age under 2000 psi of stress.

Recommendations

20. It is recommended that (a) all materials and procedures to be used on a specific project be tested in the laboratory for basic property information, and (b) selected mixtures be tested in the field under expected environmental conditions prior to actual job use.

Table 1

STATE		INDEX NO.		AGGREGATE DATA SHEET		TESTED BY: TGR	
LAT.		LONG.				DATE: 29 April 1983	
LAB SYMBOL NO.: OM19 G-1				TYPE OF MATERIAL: Granite No. 4 to 1 in.			
LOCATION: Granite Canyon, Wyoming Omaha District							
PRODUCER:							
SAMPLED BY: Omaha District							
TESTED FOR:							
USED AT:							
PROCESSING BEFORE TESTING:							
GEOLOGICAL FORMATION AND AGE:							
GRADING (CRD-C 103) (CUM. % PASSING):						TEST RESULTS	
SIEVE	3-6"	1 1/2"-3"	3/4"-1 1/2"	#4-1"	FINE AGG.	3-6"	1 1/2"-3"
6 IN.							
5 IN.							
4 IN.							
3 IN.							
2 1/2 IN.							
2 IN.							
1 1/2 IN.							
1 IN.							
3/4 IN.							
1/2 IN.							
3/8 IN.							
NO. 4							
NO. 8							
NO. 16							
NO. 30							
NO. 50							
NO. 100							
NO. 200							
-200 (a)							
F.M. (b)							
(a) CRD-C 105 (b) CRD-C 104						MORTAR:	
MORTAR-BAR EXPANSION AT 100F, % (CRD-C 123):						FINE AGGREGATE	
LOW-ALK. CEMENT: % N ₂ O EQUIVALENT:						COARSE AGGREGATE	
HIGH-ALK. CEMENT: % N ₂ O EQUIVALENT:						F&T HW-CD HD-CW	
SOUNDNESS IN CONCRETE (CRD-C 40, 114):						DFE 300	
FINE AGG. COARSE AGG:						DFE 300	
PETROGRAPHIC DATA (CRD-C 127):							
REMARKS:							

Table 2

STATE		INDEX NO.		AGGREGATE DATA SHEET		TESTED BY: TGR	
LAT.		LONG.		DATE: 29 April 1983			
LAB SYMBOL NO.: OM19 G-2				TYPE OF MATERIAL: Limestone No. 4 to 1 in.			
LOCATION: Granite Canyon, Wyoming							
Omaha District							
PRODUCER: G. W. Sugar; Harriman, Wyoming							
SAMPLED BY: Omaha District							
TESTED FOR:							
USED AT:							
PROCESSING BEFORE TESTING:							
GEOLOGICAL FORMATION AND AGE:							
GRADING (CRD-C 103) (CUM. % PASSING):						TEST RESULTS	
SIEVE	3-6"	1 1/2-3"	3/4-1 1/2"	#4-1"	FINE AGG.	3-6"	1 1/2-3"
6 IN.							
5 IN.							
4 IN.							
3 IN.							
2 1/2 IN.							
2 IN.							
1 1/2 IN.				100			
1 IN.				99			
3/4 IN.				64			
1/2 IN.				27			
3/8 IN.				14			
NO. 4				1			
NO. 8				0			
NO. 16							
NO. 30							
NO. 50							
NO. 100							
NO. 200							
-200 (a)							
F.M. (b)							
(a) CRD-C 105 (b) CRD-C 104						MORTAR:	
MORTAR-BAR EXPANSION AT 100F, % (CRD-C 123):						FINE AGGREGATE	
						COARSE AGGREGATE	
LOW-ALK. CEMENT: % N ₂ O EQUIVALENT:						2 MO. 6 MO. 9 MO. 12 MO. 3 MO. 6 MO. 9 MO. 12 MO.	
HIGH-ALK. CEMENT: % N ₂ O EQUIVALENT:							
SOUNDNESS IN CONCRETE (CRD-C 40, 114):						F&T HW-CD HD-CW	
FINE AGG. COARSE AGG:						DFE ₃₀₀	
FINE AGG. COARSE AGG:						DFE ₃₀₀	
PETROGRAPHIC DATA (CRD-C 127):							
REMARKS:							

Table 3

STATE	INDEX NO.	AGGREGATE DATA SHEET		TESTED BY TGR	
LAT.	LONG.			DATE: 29 April 1983	
LAB SYMBOL NO.: OM19 S-1		TYPE OF MATERIAL: Limestone Sand			
LOCATION: Granite Canyon, Wyoming					
Omaha District					
PRODUCER:					
SAMPLED BY: Omaha District					
TESTED FOR:					
USED AT:					
PROCESSING BEFORE TESTING:					
GEOLOGICAL FORMATION AND AGE:					
GRADING (CRD-C 103) (CUM. % PASSING):					
SIEVE	3-6"	1 1/2-3"	3/4-1 1/2"	#4-3/8"	FINE AGG.
6 IN.					2.62
5 IN.					0.71
4 IN.					
3 IN.					
2 1/2 IN.					
2 IN.					
1 1/2 IN.					
1 IN.					
3/4 IN.					
1/2 IN.					
3/8 IN.					
NO. 4					100
NO. 8					83
NO. 16					63
NO. 30					42
NO. 50					16
NO. 100					5
NO. 200					
-200 (a)					
F.M. (b)					2.92
TEST RESULTS					
BULK SP. GR., S.S.D. (CRD-C 107, 108)					
ABSORPTION, % (CRD-C 107, 108)					
ORGANIC IMPURITIES, FIG. NO. (CRD-C 121)					
SOFT PARTICLES, % (CRD-C 130)					
% LIGHTER THAN SP. GR. (CRD-C 122)					
% FLAT AND ELONGATED (CRD-C 119, 120)					
WT. AV. LOSS, 5 CYC. H ₂ SO ₄ (CRD-C 115)					
L.A. ABRASION LOSS, % (CRD-C 117, 145) GRADING					
UNIT WT., LB./CU. FT. (CRD-C 106)					
FRIABLE PARTICLES, % (CRD-C 142)					
SPEC. HEAT, BTU/LB./DEG. F. (CRD-C 124)					
REACTIVITY WITH NaOH					
SC, MM/L:					
RC, MM/L:					
(CRD-C 128)					
MORTAR-MAKING PROPERTIES (CRD-C 116)					
TYPE CEMENT, RATIO: DAYS, %, DAYS, %					
LINEAR THERMAL EXPANSION, MILLIONTHS/DEG. F. (CRD-C 125, 126):					
ROCK TYPE		PARALLEL	ACROSS	ON	AVERAGE
(a) CRD-C 105 (b) CRD-C 104					
MORTAR:					
MORTAR-BAR EXPANSION AT 100F., % (CRD-C 123):					
		FINE AGGREGATE		COARSE AGGREGATE	
		2 MO.	6 MO.	9 MO.	12 MO.
LOW-ALK. CEMENT: % Na ₂ O EQUIVALENT:					
HIGH-ALK. CEMENT: % Na ₂ O EQUIVALENT:					
SOUNDNESS IN CONCRETE (CRD-C 40, 114):					
FINE AGG.		COARSE AGG.		DFE ₃₀₀	
FINE AGG.		COARSE AGG.		DFE ₃₀₀	
PETROGRAPHIC DATA (CRD-C 127):					
REMARKS:					

Table 4

STATE Ala.	INDEX NO. 6 (Suppl 7)	AGGREGATE DATA SHEET	TESTED BY: USAEWES
LAT 33 N	LONG 86 W		DATE 3 Feb 1975
LAB SYMBOL NO. CL-2 G-1, Ms-1		TYPE OF MATERIAL Limestone	
LOCATION: Sec. 8, T 22 S, R 2 W, 1-1/2 miles NW of Calera, Ala. (Calera Quarry)			
PRODUCER: Vulcan Materials Co., Birmingham, Ala.			
SAMPLED BY USAEWES			
TESTED FOR Laboratory Stock			
USED AT: USAEWES			
PROCESSING BEFORE TESTING			
GEOLOGICAL FORMATION AND AGE			
GRADING (CRD-C 103) (CUM. % PASSING):		TEST RESULTS	
SIEVE	3-6"	1 1/2-3	3/4-1 1/2"
6 IN.			
5 IN.			
4 IN.			
3 IN.			
2 1/2 IN.			
2 IN.			
1 1/2 IN.			
1 IN.			
3/4 IN.			
1/2 IN.			
3/8 IN.			
NO. 4			
NO. 8			
NO. 16			
NO. 30			
NO. 50			
NO. 100			
NO. 200			
-200 (a)			
F.M. (b)			
(a) CRD-C 105 (b) CRD-C 104		MORTAR:	
MORTAR-BAR EXPANSION AT 100F, % (CRD-C 123):		FINE AGGREGATE	
LOW-ALK. CEMENT: % Na_2O EQUIVALENT:		COARSE AGGREGATE	
HIGH-ALK. CEMENT: % Na_2O EQUIVALENT:			
SOUNDNESS IN CONCRETE (CRD-C 40, 114):		F&T	
FINE AGG. COARSE AGG. DFE 300		HW-CD	
FINE AGG. COARSE AGG. DFE 300		HD-CW	
PETROGRAPHIC DATA (CRD-C 127):			
REMARKS:			

Table 5

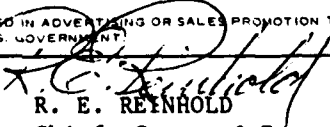
TO: Structures Laboratory Waterways Exp Station ATTN: Ken Saucier P. O. Box 631 Vicksburg, MS 39180		REPORT OF TESTS OF PORTLAND CEMENT RC 894		FROM: CORPS OF ENGINEERS U. S. ARMY Structures Laboratory Waterways Exp Station ATTN: Cem & Pozz Unit P. O. Box 631 Vicksburg, MS 39180	
TEST REPORT NO. WES-171-83	BIN NO.	CWT REPRESENTED.	DATE: 2 May 83		
SPECIFICATION: ASTM C 150, II, High Strength		DATE SAMPLED: 21 April 1983			
COMPANY: Monolith	LOCATION: Laramie, WY	BRAND:			
THIS CEMENT DOES X MEET SPECIFICATION REQUIREMENTS					
SAMPLE NO.	1				
S.O.	20.6				
A ₂ O ₃	4.3				
F ₂ O ₃	3.2				
M ₂ O	0.9				
SO ₃	2.8				
LOSS ON IGNITION	2.3				
ALKALIES-TOTAL AS Na ₂ O	0.35				
Na ₂ O, %	0.12				
K ₂ O, %	0.35				
INSOLUBLE RESIDUE	0.52				
ClO ₂	64.5				
C ₂ S	65				
C ₃ A	6				
C ₄ S	10				
C ₃ A + C ₄ S	71				
C ₃ AF	10				
C ₄ AF + 2C ₃ A	22				
HEAT OF HYDRATION, 70, CAL/G					
HEAT OF HYDRATION, 280, CAL/G					
SURFACE AREA, SQ CM/G (A.P.)	4030				
AIR CONTENT	8				
COMP. STRENGTH, 3 D, PSI	3600				
COMP. STRENGTH, 7 D, PSI	4770				
COMP. STRENGTH, 28 D, PSI *	6090				
FALSE SET - PEN. F.I.					
SAMPLE NO.	1				
AUTOCLAVE EXP.	0.02				
INITIAL SET, HR/MIN	2:45				
FINAL SET, HR/MIN	4:25				
SAMPLE NO.					
AUTOCLAVE EXP.					
INITIAL SET, HR/MIN					
FINAL SET, HR/MIN					
REMARKS: High Strength Concrete Program - Ken Saucier cc: Don Walley					
THE INFORMATION GIVEN IN THIS REPORT SHALL NOT BE USED IN ADVERTISING OR SALES PROMOTION TO INDICATE EITHER EXPLICITLY OR IMPLICITLY ENDORSEMENT OF THIS PRODUCT BY THE U.S. GOVERNMENT.  R. E. REINHOLD Chief, Cement & Pozzolan Unit					

Table 6A

LABORATORY: Structures Laboratory USAE Waterways Exp St ATTN: Cem & Pozz Test Br P.O. Box 631 Vicksburg, MS 39180		REPORT OF TESTS ON POZZOLAN SS-C-1960/5 AD-590		REPORT NO.: WES-319F-79				
				SHEET 1 OF 1				
				DATE: 16 July 79 6 August 79				
CLASS (F) N		KIND OF POZZOLAN: Fly Ash						
SOURCE: Williams Bros., Atlanta, GA				BRAND:				
TEST RESULTS OF THIS SAMPLE LOT ☒ COMPLY ☐ DO NOT COMPLY WITH SPECIFICATION LIMITS (SEE REMARKS)								
FOR USE AT:								
CONTRACT NO.:								
DISTRICT(S):								
SAMPLED BY: Structures Branch				DATE SAMPLED: 2 July 79				
CAR NO.:		BIN NO.:						
FIELD SAMPLE NO.:			LAB SAMPLE NO.:					
DATE RECEIVED: 2 July 79			LAB JOB NO.:					
TESTED BY: Cem & Pozz Testing Branch			CHECKED BY:					
TESTS ON COMPOSITE OF THE 100-TON SAMPLES LISTED BELOW								
SiO₂ + Al₂O₃ + Fe₂O₃ %	MgO %	SO₃ %	AVAILABLE ALKALIES %	POZZOLAN STRENGTH % CONTROL	INCREASE IN SHRINKAGE % (d)	AUTOCCLAVE EXPANSION %	REDUCTION IN EXPANSION % (d)	
REQUIREMENTS								
MIN 70.0	MAX 5.0	MAX 4.0	MAX 1.5	MIN 75	MAX 0.03	MAX 0.50	MIN 75	
TEST RESULTS								
88.5	1.3	0.7	* 0.65	* 91			0.03	
TESTS ON SAMPLES REPRESENTING 100 TONS OR LESS								
SAMPLE NO.	MOISTURE CONTENT %	LOSS ON IGNITION %	Fineness 325 Mesh Sieve % Retained	% pts var from avg prev 10	LIME POZZOLAN STRENGTH PSI 2" cubes	WATER REQUIREMENT % of Control	SPECIFIC GRAVITY	SP GR VARIATION FROM AVERAGE OF PRECEDING 10. %
REQUIREMENTS								
—	MAX 3.0	MAX 10.0 (N) 6.0 (P)	MAX 34	MAX 5	MIN 900	MAX 105	———	MAX 5
TEST RESULTS								
1	0.5	2.0	21	1120		97	2.43	
AVERAGE								

(M) APPLICABLE ONLY TO CLASS M LABORATORY CEMENT USED Alpha, Birmingham, AL, WES-216-79
(M) OPTIONAL REQUIREMENT LABORATORY LIME USED Chemstone

REMARKS: Meets / day specification requirements. *28 day test report

(Signature)
W. G. MILLER
Chemist
Chief, Cement & Pozzolan Test Branch

NOTE: THE INFORMATION GIVEN IN THIS REPORT SHALL NOT BE USED IN ADVERTISING OR SALES PROMOTION TO INDICATE EITHER EXPLICITLY OR IMPLICITLY ENDORSEMENT OF THIS PRODUCT BY THE U. S. GOVERNMENT.

Table 6B

LABORATORY Structures Laboratory Waterways Exp Station ATTN: Cem & Pozz Unit P. O. Box 631 Vicksburg, MS 39180		REPORT OF TESTS ON POZZOLAN AD 712		REPORT NO. WES-42C-83			
				SHEET 1 OF 1			
				DATE 23 February 1983 23 March 1983			
CLASS F (C) IN		KIND OF POZZOLAN					
SOURCE: Bayou Ash, New Roads, LA		BRAND					
TEST RESULTS OF THIS SAMPLE LOT ☒ COMPLY ☐ DO NOT COMPLY WITH SPECIFICATION LIMITS (SEE REMARKS)							
FOR USE AT: Old River Auxiliary Structure							
CONTRACT NO.:							
DISTRICT(S):							
SAMPLED BY:				DATE SAMPLED: 8 Feb 83			
CAR NO.:		BIN NO.:					
FIELD SAMPLE NO.:			LAB SAMPLE NO.:				
DATE RECEIVED: 11 Feb 83			LAB JOB NO.:				
TESTED BY: Cem & Pozz Unit			CHECKED BY:				
TESTS ON COMPOSITE OF THE 100-TON SAMPLES LISTED BELOW							
SiO ₂ + Al ₂ O ₃ + Fe ₂ O ₃	MgO	SO ₃	AVAILABLE ALKALIES	POZZOLAN STRENGTH % CONTROL	INCREASE IN SHRINKAGE % (a)	AUTOCCLAVE EXPANSION	REDUCTION IN EXPANSION % (b)
REQUIREMENTS							
MIN 70.0	MAX 5.0	MAX 5.0	MAX 1.50	MIN 75	MAX 0.03	MAX 0.8	MIN 75
TEST RESULTS							
59.0	5.5	3.2		* 105		-0.01	
TESTS ON SAMPLES REPRESENTING 100 TONS OR LESS							
SAMPLE NO.	MOISTURE CONTENT	LOSS ON IGNITION	Fineness % pts 325 Mesh var from Sieve % avg prev Retained 10	LIME POZZOLAN STRENGTH PSI	WATER REQUIREMENT % of Control	SPECIFIC GRAVITY	SP GR VARIATION FROM AVERAGE OF PRECEDING 10, %
REQUIREMENTS							
—	MAX 3.0	MAX 10.0 (N) 5.0 (F)	MAX 34	MAX 5	MIN 900	MAX 105	MAX 5
TEST RESULTS							
1	0.1	0.2	12	2	1830	98	2.75
CaO %: 25.0							
AVERAGE							
(a) APPLICABLE ONLY TO CLASS N				LABORATORY CEMENT USED Arkansas, Foreman, ARK			
(b) OPTIONAL REQUIREMENT				LABORATORY LIME USED Chemstone			
REMARKS: Meets 7 day specification requirements, *28 day test results							
R. E. REINHOLD Chief, Cement & Pozzolan Unit							
NOTE: THE INFORMATION GIVEN IN THIS REPORT SHALL NOT BE USED IN ADVERTISING OR SALES PROMOTION TO INDICATE EITHER EXPLICITLY OR IMPLICITLY ENDORSEMENT OF THIS PRODUCT BY THE U. S. GOVERNMENT.							

Table 7
CORRECTED 12 APRIL 1983

LABORATORY Structures Laboratory Waterways Exp Station ATTN: Cem & Pozz Unit P. O. Box 631 Vicksburg, MS 39180		REPORT OF TESTS ON POZZOLAN AD 536(5)		REPORT NO.: WES-43S-83				
				SHEET 1 OF 2				
				DATE: 23 February 1983 28 March 1983				
CLASS 2 N		KIND OF POZZOLAN Silica Fume						
SOURCE Reynolds Metals, Sheffield, Ala		BRAND:						
TEST RESULTS OF THIS SAMPLE LOT ☐ COMPLY ☒ DO NOT COMPLY WITH SPECIFICATION LIMITS (SEE REMARKS)								
Fineness (AP) m^2/kg : 2584, $e=0.727$								
" " " " : 3806, $e=0.700$								
" " " " : 4783, $e=0.678$								
Extrapolated m^2/kg : 12780, $e=0.500$, Correlation Coefficient: -1								
Date Sampled: 10 Feb 83								
FIELD SAMPLE NO.:			LAB SAMPLE NO.:					
DATE RECEIVED: 11 Feb 83			LAB JOB NO.:					
TESTED BY: Cem & Pozz Unit			CHECKED BY:					
TESTS ON COMPOSITE OF THE 100-TON SAMPLES LISTED BELOW								
$SiO_2 + Al_2O_3$ + Fe_2O_3	MgO	SO_3	AVAILABLE ALKALIES	POZZOLAN STRENGTH CONTROL	INCREASE IN SHRINKAGE % (b)	AUTOCCLAVE EXPANSION % (b)	REDUCTION IN EXPANSION % (b)	
REQUIREMENTS								
MIN 70.0	MAX 5.0	MAX 5.0	MAX 1.50	MIN 75	MAX 0.03	MAX 0.8	MIN 75	
TEST RESULTS								
				* 109	-0.14			
TESTS ON SAMPLES REPRESENTING 100 TONS OR LESS								
SAMPLE NO.	MOISTURE CONTENT	LOSS ON IGNITION	Fineness 325 Mesh Sieve % Retained	% pts var from avg prev 10	LIME POZZOLAN STRENGTH PSI	WATER REQUIREMENT % of Control	SPECIFIC GRAVITY	SP GR VARIATION FROM AVERAGE OF PRECEDING 10, %
REQUIREMENTS								
MAX 3.0	MAX 10.0 (N) 5.0 (F)	MAX 34	MAX 5	MIN 900	MAX 105		MAX 5	
TEST RESULTS								
1		1	-	2140	* 120	2.25	-	
Heat of Hydration								
Portland Cement, RC 883(4)						W/C: 0.27	W/C: 0.40	
					7 days:	56	75 cal/gm	
					28 days:	62	83	"
RC883(4), 85g + AD536(5), 15g + Hi range WRA, 4g :								
					7 days:	50	53	"
					28 days:	48	61	"
AVERAGE								
(a) APPLICABLE ONLY TO CLASS N								
(b) OPTIONAL REQUIREMENT								
LABORATORY CEMENT USED					United, Artesia, MS			
LABORATORY LIME USED					Chemstone			
REMARKS *Fails water requirement.								
 R. E. REINHOLD Chief, Cement & Pozzolan Unit								
NOTE: THE INFORMATION GIVEN IN THIS REPORT SHALL NOT BE USED IN ADVERTISING OR SALES PROMOTION TO INDICATE EITHER EXPLICITLY OR IMPLICITLY ENDORSEMENT OF THIS PRODUCT BY THE U. S. GOVERNMENT.								

TABLE 8 HIGH-STRENGTH MIXTURES

Mix- ture No.	Rock Type	Cement/ Sil. Fume/ Fly Ash/ lb/cu yd		W/C By wt cmt mtl's		% HRWR per 100 # cmt mtl's		Slump in.	S/A %	Remarks
1	LS	940	0.27	0.5	1/2	38	Slump too low; used D-19 HRWR admixture.			
2	LS	940	0.28	0.5	2-3/4	38	Upped the W/C for more slump.			
3	LS	940	0.30	0.5	2	38	Upped the W/C again.			
4	LS	940	0.32	0.5	5-1/2	38	Upped the W/C again. Increased slump.			
5	LS	940	0.32	0.5	6-1/2	40	Upped the S/A. Got the slump.			
6	WES	940	0.28	0.5	1	38	Concerned about high W/C and strength. Lowered S/A. Used WES rock.			
7	LS	799/141	0.30	0.5-0.8	1 to 6	38	First fume mix (15%). Increase to 0.8 HRWR makes big slump diff.			
8	WES	799/141	0.30	0.5	1-1/4	38	Repeat of last mix using WES rock and 0.5 HRWR.			
9	WES	799/141	0.28	0.7-0.8	1-1/2 to 6-1/2	38	Repeat of last mix lowering W/C, upping HRWR using WES rock.			
10	WES	799/141	0.26	0.8	1-1/2	38	Repeat of last mix lowering W/C even more and upping HRWR to 0.8.			
11	WES	799/141	0.30	0.8	6-3/4	40	Repeat of No. 8 increasing HRWR to 0.8 and S/A to 40% for workability.			
12	LS	799/141	0.28	0.8	1	38	Modification of No. 7 decreasing the W/C and using 0.8 HRWR. Too stiff.			
13	LS	799/141	0.28	0.8	2	38	Repeat of last one using 0.28 W/C at the beginning. Acceptable.			
14	LS	799/141	0.30	0.8	6	38	Upped W/C; still concerned that W/C of 0.30 too high.			
15	WES	859/139	0.24	1.86	9-1/2	40	Upped HRWR, upped S/A, lowered W/C; error increased CMT and decreased fume.			
16	WES	859/139	0.24	1.16	8	40	Lowered HRWR and slump just fell inside criteria.			
17	WES	859/139	0.24	0.93	2-1/2	40	Brought HRWR down some more, slump came down with it. O.K.			
18	WES	799/141	0.24	1.25	3-1/4	40	Just to see what No. 15 would look like using right CMT & fume. O.K.			
19	WES	799/141	0.26	1.0-1.25	3 to 9	40	Upped the W/C to See if 1.0 HRWR would compare to 1.25 at 0.24 W/C. It did.			
20	WES	658/141/ 141	0.24	1.0	40	40	First fume-fly ash mixture (15% each by weight). Looked good.			
21	LS	799/141	0.24	1.0	3	40	Slightly harsh; vibrated O.K.			
22	LS	959/169	0.24	1.0	7-3/4	40	Better looking than 21; less harsh; vibrated well.			
23	LS	959/169	0.22	1.0	3-1/2	40	Lowered W/C; same as 22; looked good.			
24	G	940	0.24	1.0	8	40	Sticky; vibrated, but hard to work with.			
25	G	940	0.22	1.0	3	40	Very sticky; balled up; added 0.2% HRWR to make placeable.			
26	G	799/141	0.24	1.0	3-1/2	40	Not sticky, but harsh; appearance of being wet.			

TABLE 8 (CONTINUED)

Mix- ture No.	Rock Type	Cement/ Sil. Fume/ Fly Ash/ lb/cu yd		W/C By wt cmt mtl	% HRWR per 100 # cmt mtl	Slump in.	S/A %	Remarks
		lb/cu yd	W/C By wt cmt mtl					
27	G	799/141	0.26	0.26	1.0	7	40	Looked better than No. 26; vibrated well.
28	LS	799/141	0.24	0.24	1.0	3	45	Made to compare to No. 21. Worked good; sand helped.
29	G	799/0/141	0.24	0.24	1.0	3	40	Very sticky; vibrated well; slump cone flowed; 2 min. extra mixing.
30	LS	799/0/141	0.24	0.24	1.0	2-1/2	40	Very sticky; vibrated well; slump cone flowed; 2 min. extra mixing.
31	G	902/226	0.20	0.20	1.0	2-3/4	40	Not at all sticky; vibrated very well.
32	LS	658/141/0	0.24	0.24	1.0	7	40	Left out the fly ash by error.
33	LS	658/141/141	0.24	0.24	1.0	3-1/2	40	Got it right this time. Very good mix; not sticky; vibrated easily.
34	G	658/141/141	0.24	0.24	1.0	3-1/2	40	#20 with project granite. Handled as good as No. 33.
35	G	959/169	0.24	0.24	1.0	8	40	No. 22 mix with project granite. Almost too wet. Not at all sticky.
36	G	799/141	0.26	0.26	1.0	4	40	This is mix No. 27 over again using project granite; unscreened, uncruised, unwashed.
37	LS	658/141/141	0.24	0.24	1.0	6-1/2	40	This is mix No. 33 over again using project rock, unscreened, unwashed.
38	WES	799/141	0.30	0.30	30 oz.	9	40	First mixture using Rheobuild 561 HRWR; not at all sticky; good vibrating.
39	WES	799/141	0.28	0.28	0.8	6-3/4	40	Air trial mixture; used D-19 HRWR. It took 4 oz. to entrain 5.3% air.
40	WES	799/141	0.30	0.30	40 oz.	8	40	First Melment (33%) mixture; not sticky; 7.4% air; finished good.
41	WES	799/141	0.26	0.26	40 oz.	4	40	Melment again; 3.5% entrained air; good mix in all respects.
42	WES	799/141	0.24	0.24	25.5 oz.	1-3/4	40	
43	WES	898/100	0.24	0.24	1.16	9	40	Mix 16 using 10% silica fume replacement of cement.
44	WES	799/141	0.24	0.24	1.00	3-1/2	40	Rheobuild 561 HRWR; 1% solids.
45	WES	798/200	0.24	0.24	1.16	5	40	Mix 16 with 20% silica fume replacement of cement.
46	WES	799/141	0.30	0.30	8 oz.	8-3/4	40	4.5% air entrained.
47	WES	859/139	0.24	0.24	2.00	10	40	Accidentally doubled HRWR; got 10-in. slump for 3 hr.
48	WES	859/139	0.24	0.24	1.00	3-1/4	40	Maintained 3-1/4-in. slump for 2 hr.
49	WES	859/139	0.24	0.24	1.16	1/4	40	Mix No. 16 with 200 cu yd steel fibers (0.010 x 0.022 x 1.00 in.).
50	WES	799/141	0.24	0.24	1.00	8	40	Substitute Class C fly ash for silica fume on weight basis.

TABLE 8 (CONCLUDED)

Mix- ture No.	Cement		W/C By wt cmt mtl's	% HRWR per 100 # cmt mtl's	Slump in.	S/A %	Remarks
	Rock Type	Sill. Fume/ Fly Ash/ lb/cu yd					
51	WES	752/188	0.24	1.00	9-1/4	40	20% by weight cementitious materials substituted with Class C fly ash.
52	WES	658/282	0.24	1.00	8-1/4	40	30% by weight cementitious materials substituted with Class C fly ash.
53	WES	798/200	0.42	1.16	10	40	Mix with special cement; unsuccessful.
54	Chert	799/141	0.29	1.00	5-1/2	40	Good mix; vibrated well.
55	WES	658/141/ 141	0.24	1.16	8	40	
56	Chert	780/160/0	0.24	2.00		40	Control for mix 57; used Melgran.
57	Chert	780/160/0	0.24			40	2% calcium chloride used; very stiff; no slump test.
58	WES	799/141/0	0.24	1.25	8-1/2	40	
59	WES	859/139/0	0.24	1.16	1/4	40	Repeat of mix 16 using 1-in. fiberglass fibers = 14.8#/cu yd.
60	WES	859/139/0	0.24	1.16	1/2	40	Repeat of mix 16 using fiberglass fibers = 24.3#/cu yd.
61	WES	859/139/0	0.24	1.16	1/2	40	Repeat of mix 16 using polypropylene fibers = 14.8#/cu yd.
62	WES	799/141	0.24	1.25		40	Attempt to entrain air; batch discarded.
63							Not cast.
64	WES	799/141	0.24	1.25	8-1/2	40	Air entrained for freeze/thaw beams (4.6%).
65	WES	799/141	0.24	1.25	9-1/4	40	Non-air-entrained; control for mix 64.
66	LS	799/141	0/24	1/25	8-1/2	40	Air entrained for freeze/thaw beams (4.0%).
67	G	799/141/0	0.24	1.24	8-1/2	40	Air entrained at 2.5%; added AEA to get 5.8%.
68	G	799/141/0	0.24	1.25	9	40	Control for mix 67.
69	LS	846/94/0	0.24	1.25	7	40	
70	LTW	799/141/0	0.24	1.25	2	39.5	3/8-in. expanded clay lightweight coarse aggregate (119.7#/cu ft).
71	LTW	879/155/0	0.24	1.25	10-1/2	45	3/8-in. expanded clay lightweight coarse aggregate (116.9#/cu ft).
72	LTW	959/169/0	0.22	1.25	11	45	Lightweight aggregate. Wet unit weight = 121.2#/cu ft; 4.0% air.
73	LS	959/169/0	0.24	1.0	7	40	Repeat of mix 22; cast creep and shrinkage specimens.
74	LS	1143/0/0	0.24	1.0	7	40	Repeat of mix 22 without silica fume. Cast shrinkage specimens.
75	G	959/169/0	0.24	1.0	8	40	Repeat of mix 35. Cast creep and shrinkage specimens.
76	G	1128/0/0	0.24	1.0	8	40	Repeat of mix 35 without silica fume. Cast shrinkage specimens.

NOTE: Aggregates: LS - Project Limestone

WES - Laboratory Limestone

G - Project Granite

LTW - Lightweight

Table 9
Slump Loss Tests

Mixture No. 38

W/C material: 0.30
S/A percent volume: 40
Cement/silica fume content, lb/yd³: 799/141
WES 3/4 limestone aggregate
Rheobuild 561 HRWR at 30 fl oz./cwt materials.

<u>Time, hours</u>	<u>Slump, in.</u>
0	9
0.5	7-3/4
1.0	7-3/4
1.5	7-3/4
2.0	7-1/2
2.5	5-1/2

Mixture No. 48

W/C material: 0.24
S/A percent volume: 40
Cement/silica fume content lb/yd³ each: 859/139
WES 3/4 limestone aggregate
W. R. Grace D-19 HRWR 1.0% by wt. cement materials.

<u>Time, hours</u>	<u>Slump, in.</u>
0	3-1/4
1	6
2	4

Mixture No. 58

W/C material: 0.24
S/A percent volume: 40
Cement/silica fume content, lb/yd³ each: 799/141
WES 3/4 limestone coarse aggregate
W. R. Grace D-19 HRWR 1-1/4% by wt cement materials.

<u>Time, hours</u>	<u>Slump, in.</u>
0	8-1/2
1	8
2	4

Table 10

Compressive Strength Test Results

Mix- ture No.	W/C Ratio	Cement/Silica Fume/Fly Ash, lb/yd ³ each	Slump, in.	Compressive Strength, psi				Notes
				7 days	14 days	28 days	90 days	
1	0.27	940/0/0	1/2	6,350	7,350 (19 days)		8,820	
2	0.28	940/0/0	2-3/4	5,590	7,340 (19 days)	9,830	10,560	
3	0.30	940/0/0	2	7,670	6,780 (19 days)			
4	0.32	940/0/0	5-1/2	5,350		6,440 (19 days)	10,630	
5	0.32	940/0/0	6-1/2	4,890		6,270	6,170	
6	0.28	940/0/0	1	7,780		8,190 (18 days)	9,790	
7	0.30	799/141/0	6	6,300	9,527 (18 days)	11,650	12,790	
8	0.30	799/141/0	1-1/4	5,640		7,780 (18 days)	7,030	
9	0.28	799/141/0	6-1/2	7,670				8,840 (175 days)
10	0.26	799/141/0	1-1/2	8,040				11,950 (175 days)
11	0.30	799/141/0	6-3/4	8,560				12,590 (175 days)
12	0.28	799/141/0	1					12,170 (175 days)
13	0.28	799/141/0	2	8,830		12,410		8,030 (174 days)
14	0.30	799/141/0	6	6,470	6,960			15,420 (167 days)
15	0.24	859/139/0	9-1/2	10,840				

(Continued)

Table 10 (Continued)

Mix- ture No.	W/C Ratio	Cement/Silica Fume/Fly Ash, lb/yd ³ each	Slump, in.	Compressive Strength, psi			Notes
				7 days	14 days	28 days	90 days
16	0.24	859/139/0	8	10,470		16,830	16,900 (167 days)
17	0.24	859/139/0	2-1/2	11,600		16,660	18,100 (167 days)
18	0.24	799/141/0	3-1/4	11,100		17,750	19,100 (167 days)
19	0.26	799/141/0	9	12,940	13,470 (11 days)	15,910	18,670 (165 days)
20	0.24	658/141/141	3-1/2	11,810	13,480 (11 days)	15,210	18,460 (165 days)
21	0.24	799/141/0	3	11,650		14,820	15,700
22	0.24	959/169/0	4-3/4	12,110		14,640	17,080
23	0.22	959/169/0	3-1/2	12,025		13,970	17,580
24	0.24	940/0/0	8	10,195		12,490	14,290
25	0.22	940/0/0	3	11,795		11,920	14,470
26	0.26	799/141/0	7	12,490		14,680	18,780 (153 days)
27	0.24	799/141/0	3	10,315		14,460	17,440 (153 days)
28	0.24	799/141/0	3	11,255		12,800	15,630 (152 days)
29	0.24	799/0/141	3	10,110		12,990	15,810 Used Class "F" fly ash
30	0.24	799/0/141	2-1/2	9,760		11,180	13,580 Used Class "F" fly ash
31	0.24	902/226/0	2-3/4	10,930		14,290	17,330 (148 days)
32	0.24	658/141/0	7	8,470		13,510	16,200 (148 days)
33	0.24	658/141/141	3-1/2	9,740		14,290	16,370 Mix with silica fume and (148 days) "F" fly ash
34	0.24	658/141/141	3-1/2	9,650		14,000	17,470 Mix with silica fume and (148 days) "F" fly ash

(Continued)

Table 10 (Continued)

Mix- ture No.	W/C Ratio	Cement/Silica Fume/Fly Ash, lb/yd ³ each	Slump, in.	Compressive Strength, psi			Notes
				7 days	14 days	28 days	90 days
35	0.24	959/169/0	8	10,120		16,300	
36	0.26	799/141/0	4	10,910		13,010	13,745 Harsh mix; 4 by 8 cylinders
37	0.24	658/141/141	6-1/2	11,050		13,390	16,130 (138 days)
38	0.28	799/141/0	9	9,920		13,860	16,300 (116 days)
39	0.28	799/141/0	6-3/4	9,600		12,450	14,400 5.3 percent air (119 days)
40	0.30	799/141/0	8	8,550		11,560	12,200 7.4 percent air (118 days)
41	0.26	799/141/0	4	9,480		12,910	12,660 @ 175 days 13,780 3.5 percent air (118 days)
42	0.24	799/141/0	1-3/4	11,410		16,175	13,370 @ 175 days (118 days)
43	0.24	898/100/0	9	11,730		16,500	17,620 @ 152 days (92 days)
44	0.24	799/141/0	3-1/2	9,370			18,000 @ 152 days (95 days)
45	0.24	798/200/0	5	10,150			17,760 17,270 @ 151 days (94 days)
46	0.30	799/141/0	8-3/4	7,450			16,550 17,330 @ 151 days (94 days)
47	0.24	859/139/0	10	11,365			10,720 4-1/2 percent air 16,300 10,510 @ 147 days (139 days) 2 percent high-range water reducer plus conventional water-reducing admixture
48	0.24	859/139/0	3-1/4	12,200			17,820
49	0.24	859/139/0	1/4	12,695		16,270 (54 days)	18,000 Steel fibers at 200 lb/yd ³
50	0.24	799/0/141	8		9,900 (11 days)	13,830 (134 days)	15,990 Class "C" fly ash (134 days)

(Continued)

Table 10 (Continued)

Mix- ture No.	W/C Ratio	Cement/Silica Fume/Fly Ash, lb/yd ³ each	Slump, in.	Compressive Strength, psi			Notes	
				7 days	14 days	28 days		
51	0.24	752/0/188	9-1/4		10,650 (10 days)	14,610	15,420 (133 days)	Class "C" fly ash; too wet, segregated
52	0.24	658/0/282	8-1/4		10,700 (10 days)	14,460	16,910 (133 days)	Class "C" fly ash
53	0.42	798/200/0	10		2,350 (10 days)	3,490	4,530 (133 days)	
54	0.24	799/141/0	5-1/2		9,950 (10 days)	12,480	12,560 (114 days)	Chert gravel aggregate
55	0.24	658/141/141	8	11,600 (8 days)		16,400	18,420 (113 days)	
56	0.24	780/160/0		8,550		10,050	--	Mix with CaCl ₂ ; see 24-hr test curve
57	0.24	780/160/0		7,500		8,220	--	Mix with CaCl ₂ ; see 24-hr test curve
58	0.24	799/141/0	8-1/2			17,890 (42 days)	19,380 (108 days)	20,760 psi at 164 days, on a 4 by 8 cylinder
59	0.24	859/139/0	1/4	10,400			16,200 (107 days)	Repeat of mix 16 with fiber- glass reinforcement
60	0.24	859/139/0	1/2	10,900			17,050 (107 days)	Repeat of mix 16 with fiber- glass reinforcement
61	0.24	859/139/0	1/2	9,100			13,760 (106 days)	Repeat of mix 16 with poly- propylene fibers
62								Not cast

(Continued)

Table 10 (Concluded)

Mix- ture No.	W/C Ratio	Cement/Silica Fume/Fly Ash lb/yd ³ each	Slump, in.	Compressive Strength, psi			Notes
				7 days	14 days	28 days	
63							Not cast
64	0.24	799/141/0	8-1/2	10,400		14,260 (35 days)	16,020 (105 days) Air = 4.6 percent; cast three freeze-thaw beams
65	0.24	799/141/0	9-1/4	11,600		16,440 (35 days)	18,960 (158 days) Air = 1.0 percent; cast three freeze-thaw beams
66	0.24	799/141/0	8-1/2			14,220 (32 days)	14,710 (155 days) Air = 4.0 percent; cast three freeze-thaw beams
67	0.24	799/141/0	8-1/2			13,350 (31 days)	16,840 (154 days) Air = 5.8 percent; cast three freeze-thaw beams
68	0.24	799/141/0	9			16,590 (31 days)	18,390 (154 days) Air = 0.8 percent; cast three freeze-thaw beams
69	0.24	846/94/0				16,270 (34 days)	15,100 (100 days)
70	0.24	799/141/0	2			5,530 (20 days)	8,420 (82 days) Lightweight aggregate mixture; very harsh
71	0.24	879/155/0	10-1/2			7,590 (19 days)	7,790 (83 days) Lightweight mix; worked better than No. 71; density 116.9 lb/ft ³
72	0.22	959/169/0	11			7,120 (18 days)	8,300 (84 days) Density 121.2 lb/ft ³
73	0.24	959/169/0				14,060 (17 days)	15,400 (102 days) Repeat of mix 22
74	0.24	959/01169				10,540 (17 days)	12,930 (102 days) Repeat of mix 22 without silica fume
75	0.24	959/169/0					14,140 (102 days) Repeat of mix 35
76	0.24	959/01169					11,920 (102 days) Repeat of mix 35 without silica fume

Note: Strength data for mixes 73-76 are from 4 by 8 cylinders.

Table 11

Mixtures with Project Limestone Coarse Aggregate

No. Batch	W/C	Cement/ Silica Fume/ Fly Ash, lb/yd ³	HRWR % of Cmt Mtls	Slump, in.	Compressive Strength, psi, at Days			
					6-7	14	28	90+
1	0.27	940/0/0	0.5	1/2	6,350	7350		8,820
2	0.28	940/0/0	0.5	2-3/4	5,590	7340	9,830	10,560
3	0.30	940/0/0	0.5	2	7,670	6780		
4	0.32	940/0/0	0.5	5-1/2	5,350	6440		10,630
5	0.32	940/0/0	0.5	6-1/2	4,890		6,270	6,170
7	0.30	799/141/0	0.8	6	6,300	9527	11,650	12,790
12	0.28	799/141/0	0.8	1				12,590
13	0.28	799/141/0	0.8	2	8,830		12,410	12,170
14	0.30	799/141/0	0.8	6	6,470	6960		8,030
21	0.24	799/141/0	1.0	3	11,650		14,820	15,700
22	0.24	959/169/0	1.0	7-3/4	12,110		14,640	17,080
23	0.22	959/169/0	1.0	3-1/2	12,025		13,970	17,580
28	0.24	799/141/0	1.0	3	11,255		12,800	15,630
30	0.24	799/0/141	1.0	2-1/2	9,760		11,180	13,580
32	0.24	658/141/0	1.0	7	8,470		13,510	16,200
33	0.24	658/141/141	1.0	3-1/2	9,740		14,290	16,130
37	0.24	658/141/141	1.0	6-1/2	11,050		13,390	16,130
66	0.24	799/141/0	1.25	8-1/2			14,220	14,710
69	0.24	846/94/0	1.25				16,270	15,100
73	0.24	959/169/0	1.0			14060		15,400
74	0.24	1143/0/0	1.0			10540		12,930

Table 12

Mixtures with Project Granite Coarse Aggregate

No. Batch	W/C	Cement/ Silica Fume/ Fly Ash, lb/yd ³	HRWR % of Cmt Mtls	Slump, in.	Compressive Strength, psi, at Days			
					6-7	14	28	90+
24	0.24	940/0/0	1.00	8	10,195		12,490	14,290
25	0.22	940/0/0	1.00	3	11,795		11,920	14,470
26	0.24	799/141/0	1.00	3-1/2	12,490		14,680	18,780
27	0.26	799/141/0	1.00	7	10,315		14,460	17,440
29	0.24	799/0/141	1.00	3	10,110		12,990	15,810
31	0.20	902/226/0	1.00	2-3/4	10,930		14,290	17,330
34	0.24	658/141/141	1.00	3-1/2	9,650		14,000	17,470
35	0.24	959/169/0	1.00	8	10,120		16,300	16,090
36	0.26	799/141/0	1.00	7	10,910		13,010	13,745
67	0.24	799/141/0	1.25	8-1/2			13,350	16,840
68	0.24	799/141/0	1.25	9			16,590	18,390
75	0.24	959/169/0	1.00	8				14,140
76	0.24	1128/0/0	1.00	8				

Table 13

ELASTIC PROPERTY RESULTS

Mixture No.	Young's Modulus psi x 10 ⁶	Poisson's Ratio ν	Compressive Strength 28 Days psi	Split Tensile Strength psi %
38	6.40	-	13,860	-
39	6.49	-	12,450	-
40	6.36	-	11,560	-
41	6.15	-	12,910	-
64	6.64	0.242	14,260 (35 days)	1140 (31 days)
65	6.68	0.256	16,440 (35 days)	1260 (31 days)
66	6.78	0.230	14,220 (32 days)	1180 (29 days)
67	5.91	0.208	13,350 (31 days)	1220 (28 days)
68	6.25	0.216	16,590 (31 days)	1440 (28 days)
72	3.70	0.210	7,120 (18 days)	

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Table 14

EXPANSION DATA SHEET				Lab <u>XX</u> Field <u> </u>	Page <u> </u> of <u> </u> Pages
PROJECT: <u>HIGH STRENGTH CONCRETE</u>			DATE CAST: <u>30 SEP 83</u>		
MIX DESIGN: <u>NO. 22 WITHOUT SILICA FUME</u>			DATE DEMOLDED: <u>1 OCT 83</u> at <u>24</u> HRS Age		
Source Of Data: <u>LABORATORY</u>			Remarks: <u>CONTROL MIXTURE</u>		
ASTM C 490 & ASTM C 157			TYPE II CEMENT <u>1128.0 LBS/YD³</u>		
MATERIAL FOR 1-IN. PRISMS PASSED THE NO. 4 SIEVE.			WATER <u>270.0 LBS/YD³</u>		
			W/C <u>0.24</u>		

1-IN. UN RESTRAINED						3-IN. UNRESTRAINED					
DATE	AGE (DAYS)	BAR 1	% EXP	BAR 2	AVERAGE	BAR 1	% EXP	BAR 2	% EXP	AVERAGE	
Oct 1	INITIAL	0.2643	----	0.2068	----	0.1295	----	0.1161	----	----	
	2										
	3										
	4										
	5										
	6										
	7										
	8										
	9										
	10										
	11										
	12										
	13										
Oct 14	14	0.2654	0.011	0.2079	0.011	0.1297	0.002	0.1161	0.000	0.001	
	21										
Oct 28	28	0.2656	0.013	0.2081	0.013	0.1294	-0.001	0.1159	-0.002	-0.002	
Jan 10	101	0.2670	0.027	0.2094	0.027	0.1304	0.009	0.1171	0.010	0.010	

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Table 15

EXPANSION DATA SHEET				Lab <u>xx</u> Field <u> </u>		Page <u> </u> of <u> </u> Pages	
PROJECT: <u>HIGH STRENGTH CONCRETE</u>				DATE CAST: <u>30 SEP 83</u>			
MIX DESIGN: <u>NO. 22 WITH SILICA FUME</u>				DATE DEMOLDED: <u>1 OCT 83</u> at <u>24 HRS</u> Age			
Source Of Data: <u>LABORATORY</u>				Remarks: <u>TEST MIXTURE</u>			
<u>ASTM C 490 & ASTM C 157</u>				<u>TYPE II CEMENT 958.8 LBS/YD³</u>			
<u>MATERIAL FOR 1-IN. PRISMS PASSED THE NO. 4 SIEVE.</u>				<u>SILICA FUME 169.2 LBS/YD³</u>			
				<u>WATER 270.7 LBS/YD³</u>			
				<u>W/C 0.24</u>			

1-IN. UNRESTRAINED						3-IN. UNRESTRAINED					
DATE	AGE (DAYS)	BAR 1	% EXP	BAR 2	% EXP	AVERAGE	BAR 1	% EXP	BAR 2	% EXP	AVERAGE
Oct 1	INITIAL	0.2574	----	0.2408	----	----	0.1304	----	0.1323	----	----
	2										
	3										
	4										
	5										
	6										
	7										
	8										
	9										
	10										
	11										
	12										
	13										
Oct 14	14	0.2574	0.000	0.2408	0.000	0.000	0.1297	-0.007	0.1315	-0.008	-0.008
	21										
Oct 28	28	0.2573	-0.001	0.2407	-0.001	-0.001	0.1293	-0.011	0.1311	-0.012	-0.012
Jan 10	101	0.2580	0.006	0.2414	0.006	0.006	0.1301	-0.003	0.1317	-0.006	-0.005

Table 16

EXPANSION DATA SHEET				Lab <u>XX</u> Field <u> </u>	Page <u> </u> of <u> </u> Pages
PROJECT: <u>HIGH STRENGTH CONCRETE</u>			DATE CAST: <u>30 SEP 83</u>		
MIX DESIGN: <u>NO. 35 WITHOUT SILICA FUME</u>			DATE DEMOLDED: <u>1 OCT 83</u> at <u>24</u> HRS Age		
Source Of Data: <u>LABORATORY</u>			Remarks: <u>CONTROL MIXTURE</u>		
<u>ASTM C 490 & ASTM C 157</u>			<u>TYPE II CEMENT 1128.0 LBS/YD³</u>		
<u>MATERIAL FOR 1-IN. PRISMS PASSED THE NO. 4 SIEVE.</u>			<u>WATER 270.7 LBS/YD³</u>		
			<u>W/C 0.24</u>		

1-IN. UNRESTRAINED										3-IN. UNRESTRAINED									
DATE	AGE (DAYS)	BAR 1	% EXP	BAR 2	% EXP	AVERAGE	BAR 1	% EXP	BAR 2	% EXP	AVERAGE								
Oct 1	INITIAL	0.1420	----	0.1253	----	----	0.1381	----	0.1344	----	----								
	2																		
	3																		
	4																		
	5																		
	6																		
	7																		
	8																		
	9																		
	10																		
	11																		
	12																		
	13																		
Oct 14	14	0.1431	0.011	0.1263	0.010	0.011	0.1380	-0.001	0.1344	0.000	-0.001								
	21																		
Oct 28	28	0.1431	0.011	0.1266	0.013	0.012	0.1377	-0.004	0.1341	-0.003	-0.004								
Jan 10	101	0.1444	0.024	0.1279	0.026	0.025	0.1389	0.008	0.1352	0.008	0.008								

EXPANSION DATA SHEET				Lab <u>XX</u> Field <u> </u>		Page <u> </u> of <u> </u> Pages	
PROJECT: HIGH STRENGTH CONCRETE				DATE CAST: 30 SEP 83			
MIX DESIGN: NO. 35 WITH SILICA FUME				DATE DEMOLDED: 1 OCT 83 at 24 HRS Age			
Source Of Data: LABORATORY				Remarks: TEST MIXTURE			
ASTM C 490 & ASTM C 157				TYPE II CEMENT 958.8 LBS/YD ³			
MATERIAL FOR 1-IN. PRISMS PASSED THE NO. 4 SIEVE				SILICA FUME 169.2 LBS/YD ³			
				WATER 270.0 LBS/YD			
				W/C 0.24			

1-IN. UNRESTRAINED										3-IN. UNRESTRAINED									
DATE	AGE (DAYS)	BAR 1	% EXP	BAR 2	% EXP	AVERAGE	BAR 1	% EXP	BAR 2	% EXP	AVERAGE								
Oct 1	INITIAL	0.2658	----	0.3052	----	----	0.1318	----	0.1300	----	----								
	2																		
	3																		
	4																		
	5																		
	6																		
	7																		
	8																		
	9																		
	10																		
	11																		
	12																		
	13																		
Oct 14	14	0.2658	0.000	0.3049	-0.003	-0.002	0.1312	-0.006	0.1293	-0.007	-0.007								
	21																		
Oct 28	28	0.2657	-0.001	0.3047	-0.005	-0.003	0.1309	-0.009	0.1290	-0.010	-0.010								
Jan 10	101	0.2664	0.006	0.3055	0.003	0.005	0.1316	-0.002	0.1297	-0.003	-0.003								

Table 18

DATA SHEET FOR HARDENED CONCRETE SPECIMENS (CRD-C 13, 25, 40, 47, 114, 38, 36, 37, 35, 124)									
SYMBOL:		JOB NO: 441-S591		MEMO NO.		DATE: 8-5-83		INITIALS: DMW	
PROJECT: HIGH STR.		SPECIMEN TYPE: 3-1/2 X 9-1/2 X 16 in.		FIELD: 0.		LAB: 0.			
DATE PLACED: 8/8/83		DATE CURED:		CURING: TYPE: Inundated Pot Room		DURATION: 28 D			
FINE AGG: Limestone OM 19 S-1		COARSE AGG: Limestone OM 19 G-2		MAX. 1 in.					
CEMENT RC (894(1))		TH. C.F. B/CY:		ACT. C.F. B/CY: 940 cmt+silfume S/A 1 VOL: 40					
AIR 1 TOTAL: 4.0		IN-1 1/2:		W/C GPB: 0.24		SLUMP IN. (-1 1/2): 8-1/2			
TH. U.W. LB/CU. FT:		ACT. U.W. (PLASTIC):		ADMIX:					
TESTS:	F & T BEAMS C 114 ☐ C 13 ☐	F & T 10" CORES C 47 ☐	SPEC. HEAT C 35, 124 ☐	HWCD C 40 ☐	HDCW C 40 ☐	SHRINKAGE C 25 ☐	HEAT RISE C 38 ☐	DIFFUSIV. C 36, 7 ☐	OTHER ☐ SEE REMARKS
BEGIN DATE:									
SPEC. NO.	97-81								
	97-82								
	97-83								

TEST RESULTS									
(A) (B)	100 100	90 80	80 60	70 40	60 20	50 0	0	50	40
NO. OF CYCLES (A) (B): TIME HR (C)									
RELATIVE E, %									
TEMP. RISE, DEG. F (C)									
DENSITY (HARDENED) LB/CU. FT:									
INITIALS:									

SPEC. NO.	SYMBOL	DFE	NO. CYCLES		INIT. FREQ.	REM. ARKS
			E-90	TOTAL		

SPEC. NO.	HEAT RISE, F		DIFF. FT ² /HR	SPEC. HEAT	REMARKS
	7 D	14 D			

(A) FOR 3 1/2 X 4 1/2 X 16-IN BEAMS
(B) FOR CORE SPECIMENS
(C) FOR TEMPERATURE RISE

LAB TRIAL MIXT NO. 66 (TEST MIXT: NO CONTROL)

SPEC. NO.	RELATIVE E AT NO. OF CYCLES SHOWN								DATE TEST COMPLETED:
	Cycles	0	47	93	152	210	256	294	
9781	100	96	95	96	95	93	86	71	
9782	100	96	96	96	95	93	77	74	
9783	100	97	96	97	94	91	93	60	

INITIALS:

REPORT OF EXAMINATION AFTER TEST

Relative E at No. of Cycles Shown		
Cycles	380	430
9781	64	45
9782	43	49
9783	48	--

DATE: INITIALS:

REMARKS:

W. R. Grace HRWR DAXAD 19 (dry) 1-1/4% by wt cmt mtlis (cmt+fume)
AEA AMEX 210 6 fl oz per cwt cmt mtlis (cmt+fume)

Table 19

DATA SHEET FOR HARDENED CONCRETE SPECIMENS (CRD-C 13, 25, 40, 47, 114, 38, 36, 37, 35, 124)									
SYMBOL:		JOB NO: 441-S592		MEMO NO:		DATE: 8-9-83		INITIALS: DMW	
PROJECT: HIGH STR. CONC		SPECIMEN TYPE: 3-1/2 x 4-1/2 x 16 in.		CURING TYPE: Inundated Fog Room		DURATION: 28 D		FIELD: B.	
DATE PLACED: 8/9/83		DATE CURED:		FINE AGG: Limestone OM 19 S-1		COARSE AGG: Granite OM 19 G-1		MAX. 1-1/2 in.	
CEMENT RC 894 (2)		TH. C.F. B/CY:		ACT. C.F. B/CY: 940 cmt+silfume		S/A % VOL: 40			
AIR % TOTAL: 5.8		IN-11/2:		W/C GPB: 0.24		SLUMP IN. (-11/2): 8-1/2			
TH. U.W. LB/CU. FT:		ACT. U.W. (PLASTIC):		ADMIX:					
TESTS:	F & T BEAMS C 114 □ C 13 □	F & T 10" CORES C 47 □	SPEC. HEAT C 35, 124 □	HWCD C 40 □	HDCW C 40 □	SHRINKAGE C 25 □	HEAT RISE C 38 □	DIFFUSIV. C 36, 7 □	OTHER □ SEE REMARKS
BEGIN DATE:									
SPEC. NO.	97-84 87-85 87-86								

TEST RESULTS

(A) FOR 3 1/2 X 4 1/2 X 16-IN BEAMS
(B) FOR CORE SPECIMENS
(C) FOR TEMPERATURE RISE

SPEC. NO.	SYMBOL	DFE	NO. CYCLES		INIT. FREQ.	REMARKS
			E-50	TOTAL		

SPEC. NO.	HEAT RISE, F		DIFF. FT ² /HR	SPEC. HEAT	REMARKS
	7 D	14 D			

DENSITY (HARDENED) LB/CU. FT: _____
INITIALS: _____

LAB TRIAL MIXT NO. 67 (TEST MIXT)

SPEC. NO.	RELATIVE E AT NO. OF CYCLES SHOWN							
Cycles	0	58	119	165	200	246	307	346
9784	100	99	97	97	96	96	88	81
9785	100	97	97	97	97	96	90	82
9786	100	97	96	96	96	95	95	94

DATE TEST COMPLETED: _____
INITIALS: _____

REPORT OF EXAMINATION AFTER TEST

Relative E at No. of Cycles Shown

Cycles	395	437
9784	77	31
9785	79	29
9786	93	27

DATE: _____ INITIALS: _____

REMARKS:

W. R. Grace HRWR DAX49-19(dry) 1-1/4% by wt cmt mtl (cmt+fume)
AEA AMEX 210 8 fl oz per cwt cmt mtl (cmt+sil fume)

Table 20

DATA SHEET FOR HARDENED CONCRETE SPECIMENS (CRD-C 13, 25, 40, 47, 114, 38, 36, 37, 35, 124)											
SYMBOL:		JOB NO: 441-S592		MEMO NO:		DATE: 8-9-83		INITIALS: DMW			
PROJECT: HIGH STR CONC				SPECIMEN TYPE: 3-1/2 x 4-1/2 x 16 in				FIELD: 0			
DATE PLACED: 8/9/83		DATE CURED:		CURING TYPE: Inundated Fog Room				DURATION: 28 D			
FINE AGG: Limestone		OM 19 S-1		COARSE AGG: Granite 19 G-1				MAX. 1-1/2 in			
CEMENT RC 894(2)		TH. C.F. B/CY:		ACT. C.F. B/CY: 940 cmt+sulfume				S/A ± VOL: 40			
AIR ± TOTAL: 0.8		IN-11/2:		W/C GPB: 0.24		SLUMP IN. (-11/2): 9					
TH. U.W. LB/CU. FT:				ACT. U.W. (PLASTIC):				ADMIX:			
TESTS:		F & T BEAMS C 114 □ C 13 □		F & T 10" CORES C 47 □		SPEC. HEAT C 35, 124 □		HWCD C 40 □		HDCW C 40 □	
SHRINKAGE C 25 □		HEAT RISE C 38 □		DIFFUSIV. C 36, 7 □		OTHER □ SEE REMARKS					
BEGIN DATE:											
SPEC. NO. 97-87 97-88 97-89											

TEST RESULTS

(A) FOR 3 1/2 X 4 1/2 X 16-IN BEAMS
(B) FOR CORE SPECIMENS
(C) FOR TEMPERATURE RISE

SPEC. NO.	SYMBOL	DFE	NO. CYCLES		INIT. FREQ.	REM. ARKS
			E-50	TOTAL		

SPEC. NO.	HEAT RISE, F		DIFF. FT ² /HR	SPEC. HEAT	REMARKS
	7 D	14 D			

DENSITY (HARDENED) LB/CU. FT: _____
INITIALS: _____

LAB MIXT NO. 68 (CONTROL MIXT FOR NO. 67)

SPEC. NO.	RELATIVE E AT NO. OF CYCLES SHOWN							
Cycles	0	58	119	165	200	246	307	346
9887	100	99	99	99	98	97	96	93
9888	100	96	98	98	98	97	96	95
9889	100	97	96	96	96	96	91	80

DATE TEST COMPLETED: _____
INITIALS: _____

REPORT OF EXAMINATION AFTER TEST

Relative E at No. of Cycles Shown

Cycles	395	437
9887	83	31
9888	85	30
9889	72	26

REMARKS:

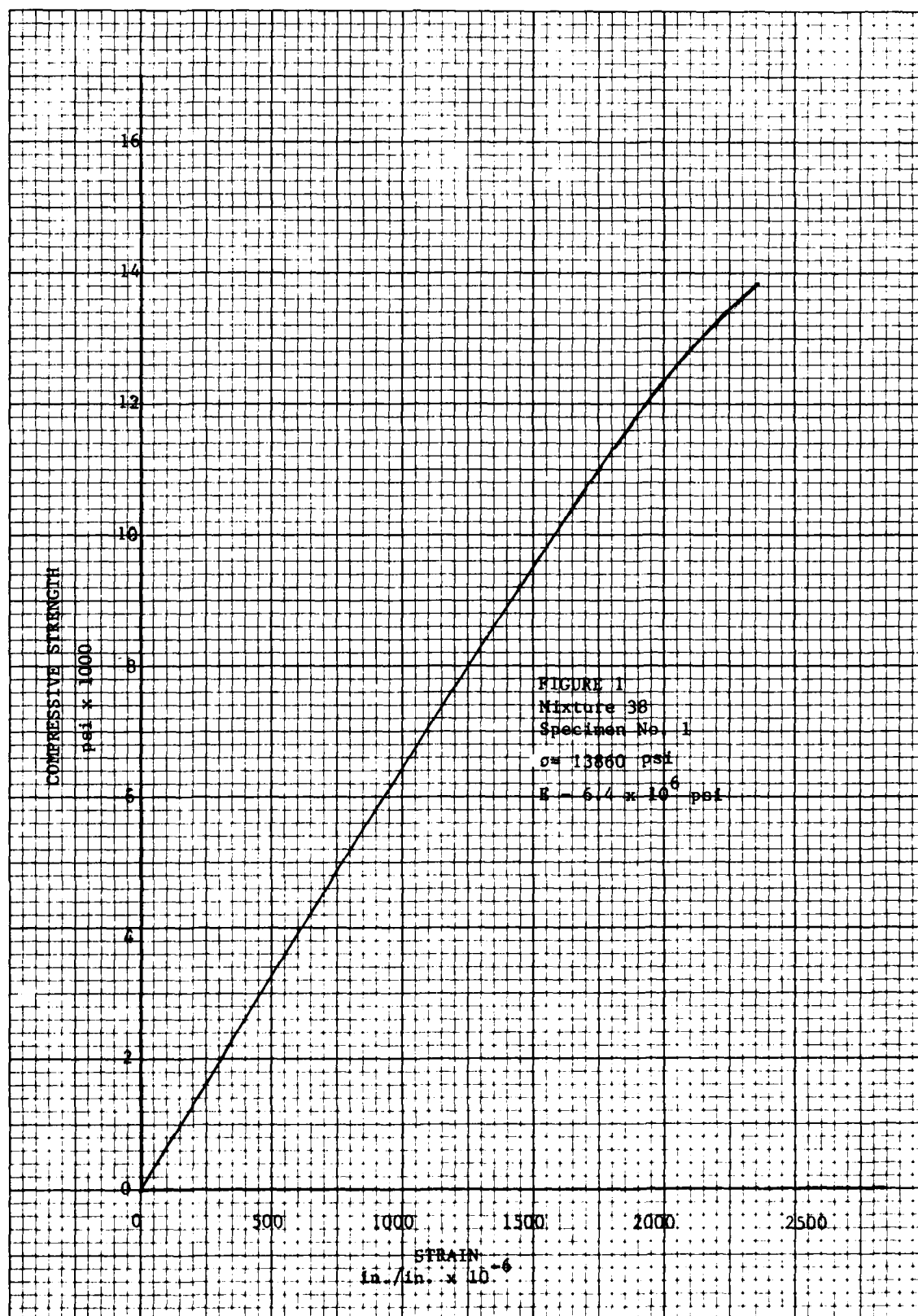
W. R. Grace HRWR DAXAD-19 (dry) 1-1/4% by wt cmt mtl's (cmt + fume)
Control Mixture - No AEA used - the 0.8% is entrapped air.

DATE: _____

INITIALS: _____

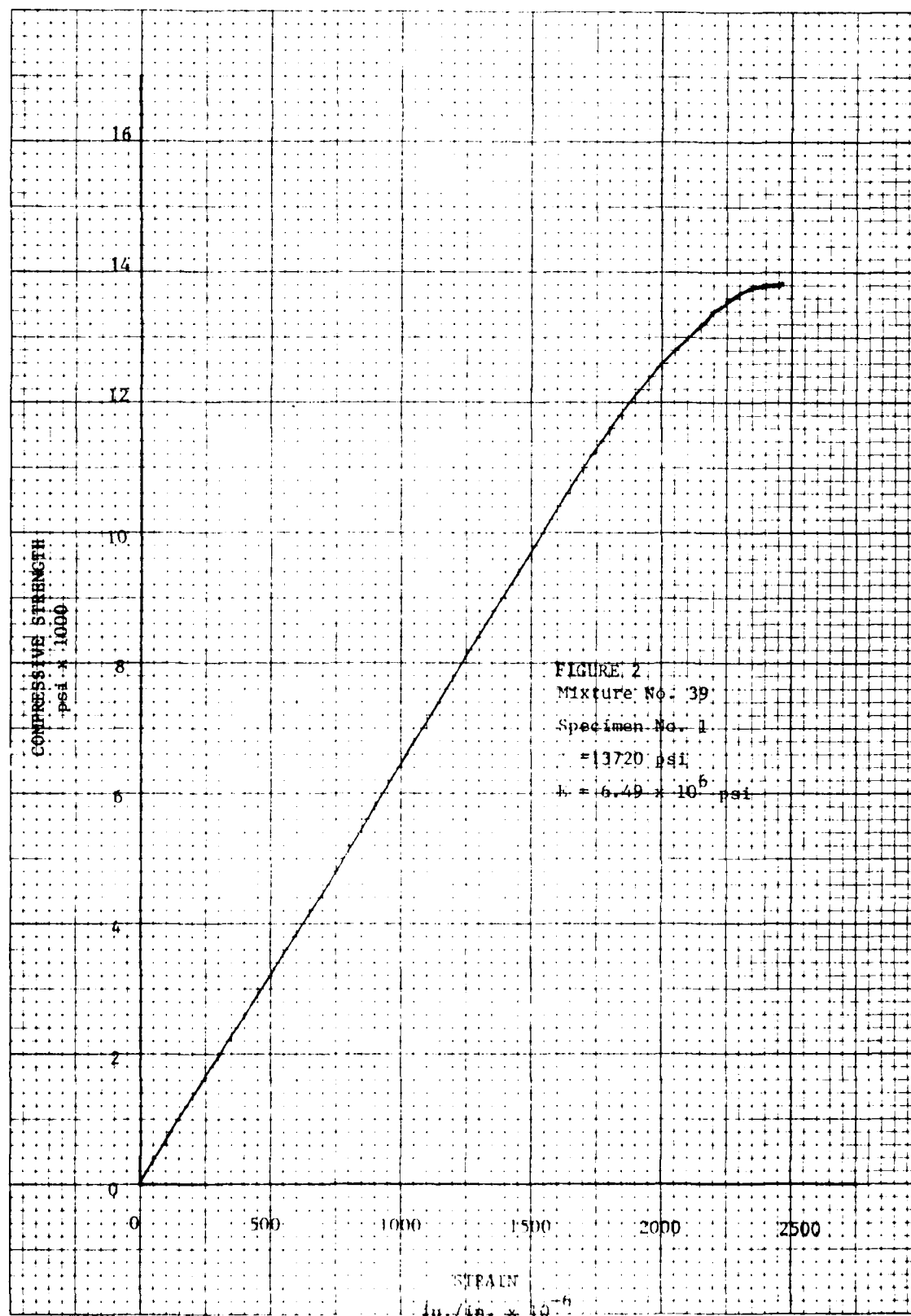
EUBENE DIETZGEN CO.
MADE IN U. S. A.

NO. 340-10, DIETZGEN GRAPH PAPER
10 X 10 PER INCH



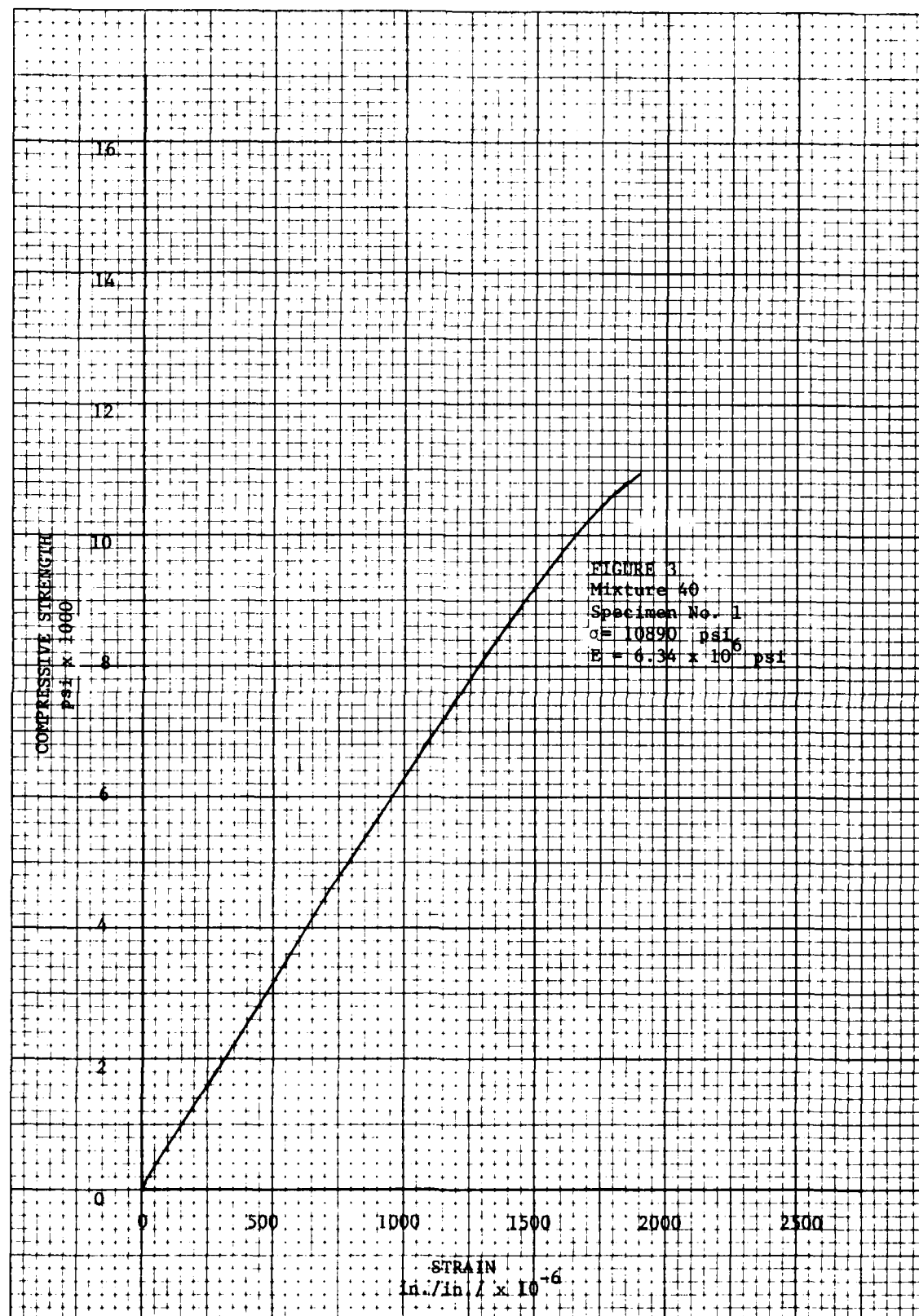
EUGENE DIETZGEN CO.
MADE IN U. S. A.

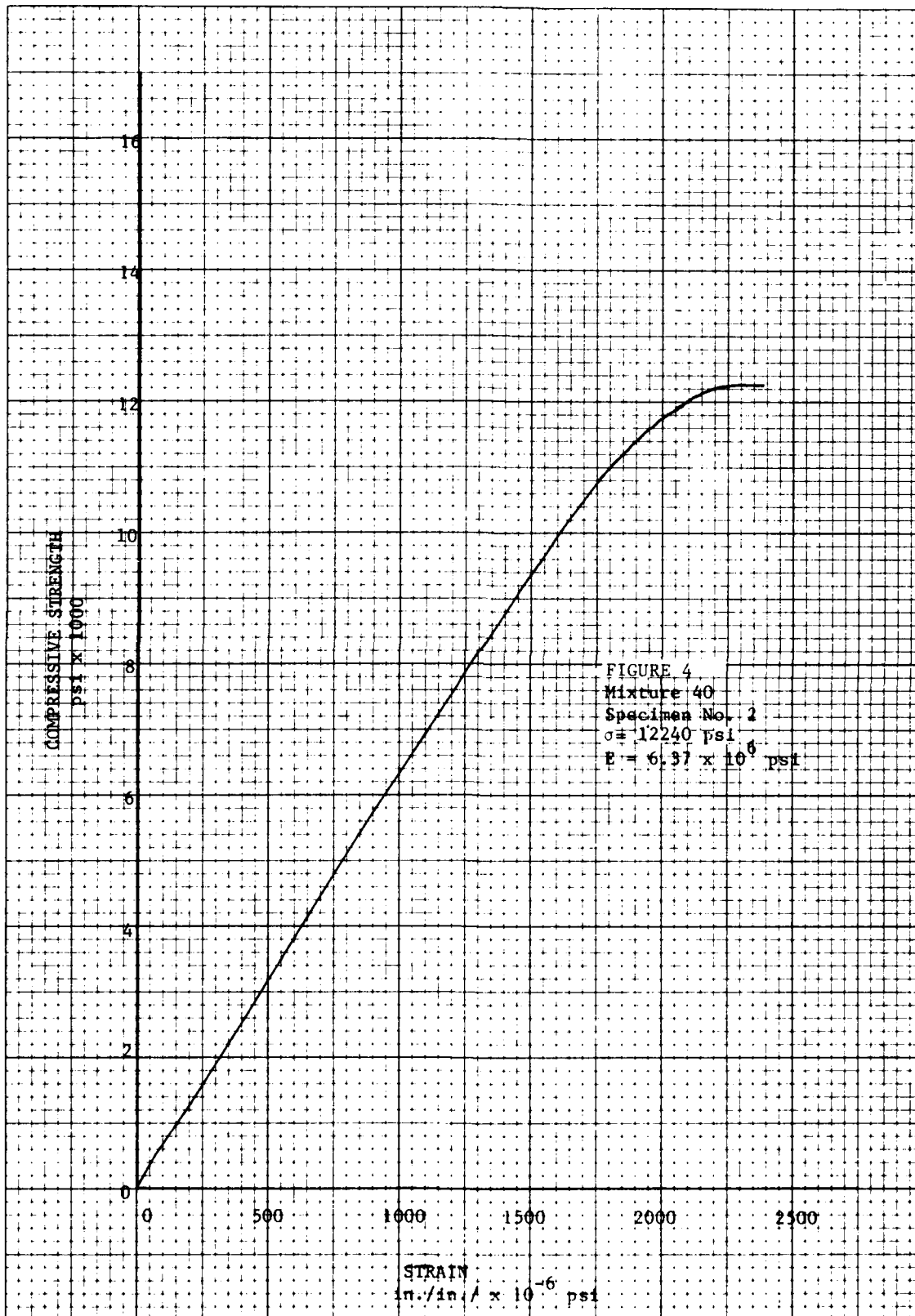
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10 X 10 PER INCH



EUGENE DIETZGEN CO.
MADE IN U. S. A.

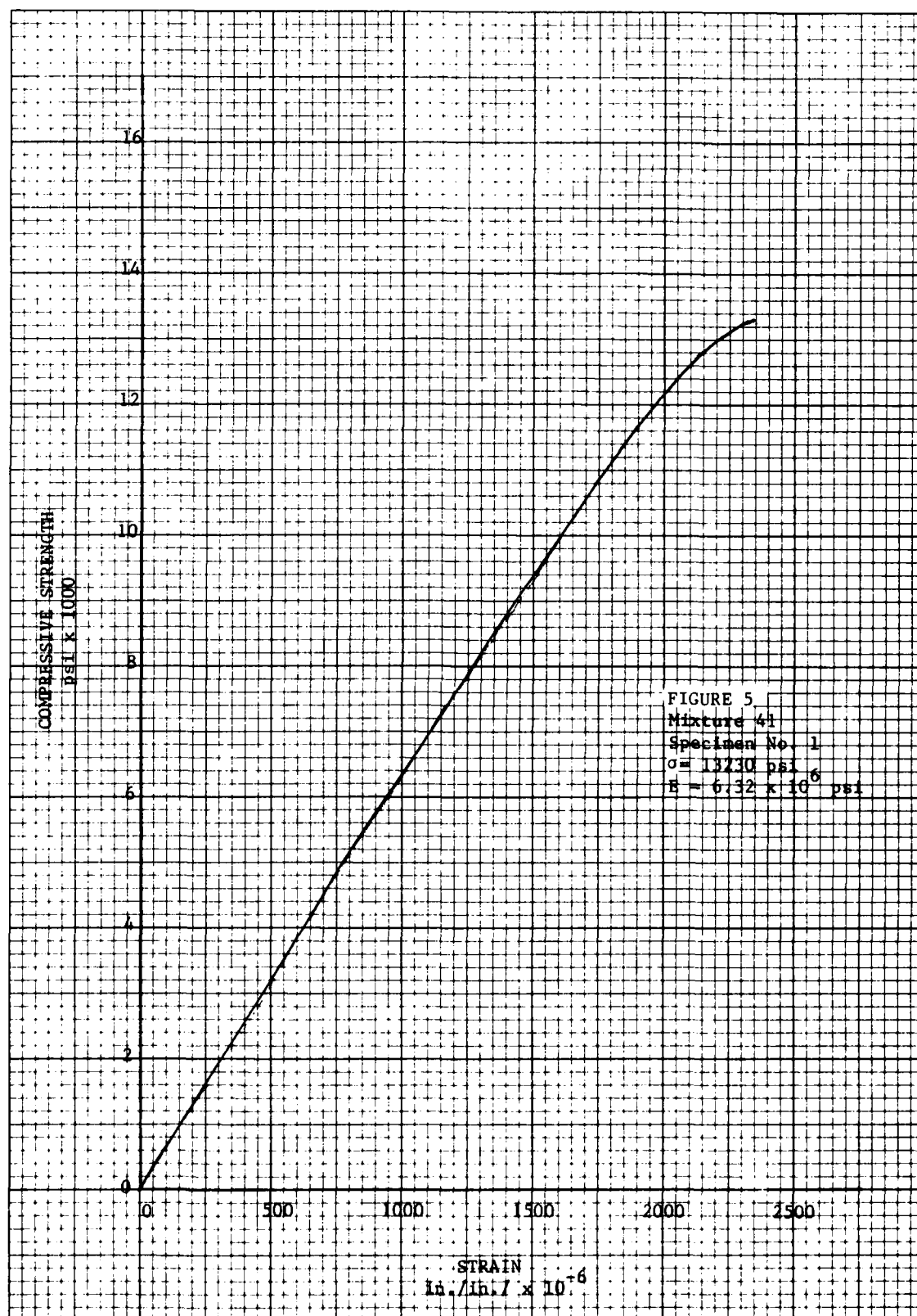
NO. 340-10 DIETZGEN GRAPH PAPER
10 X 10 PER INCH





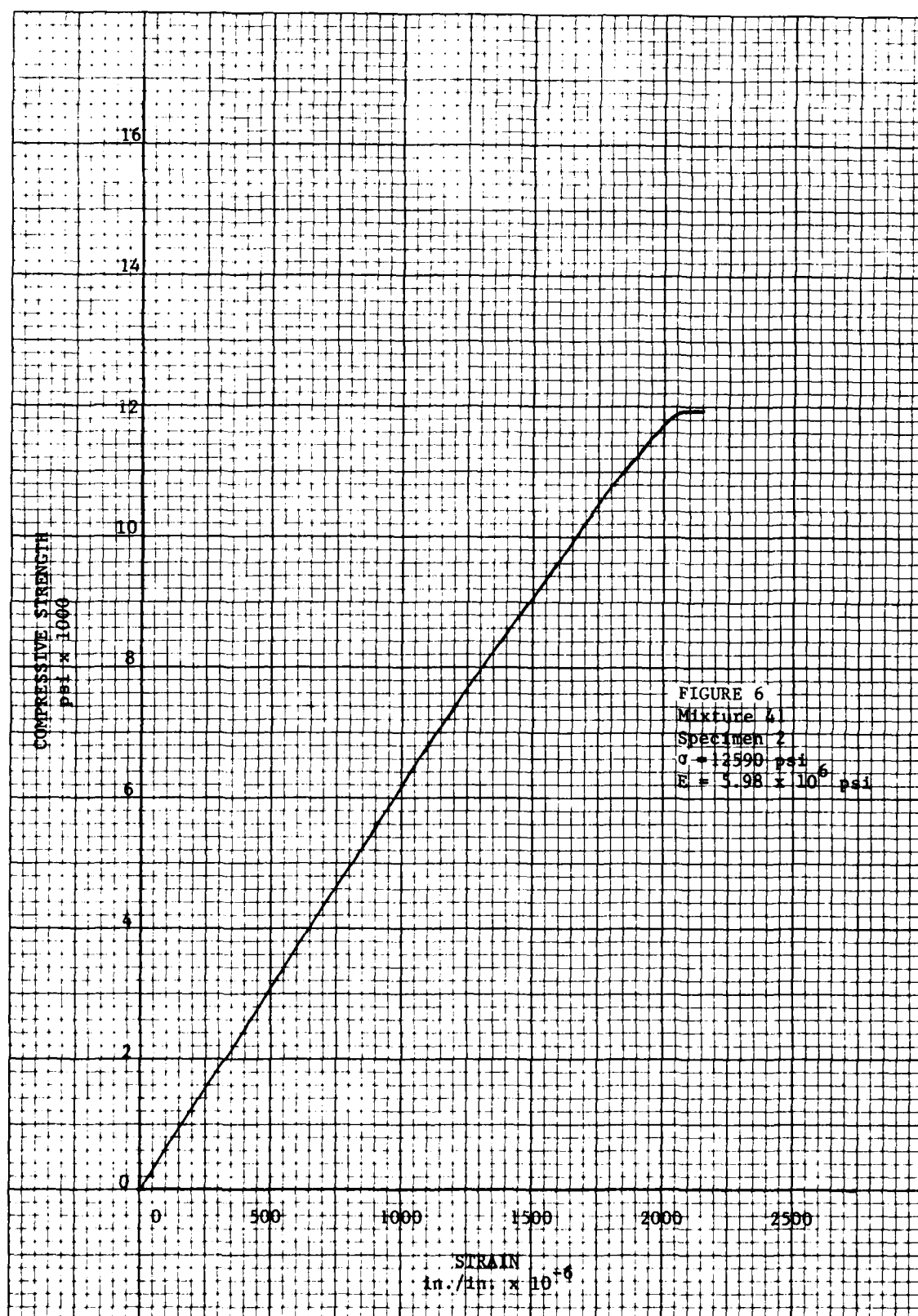
EUGENE DIETZGEN CO.
MADE IN U. S. A.

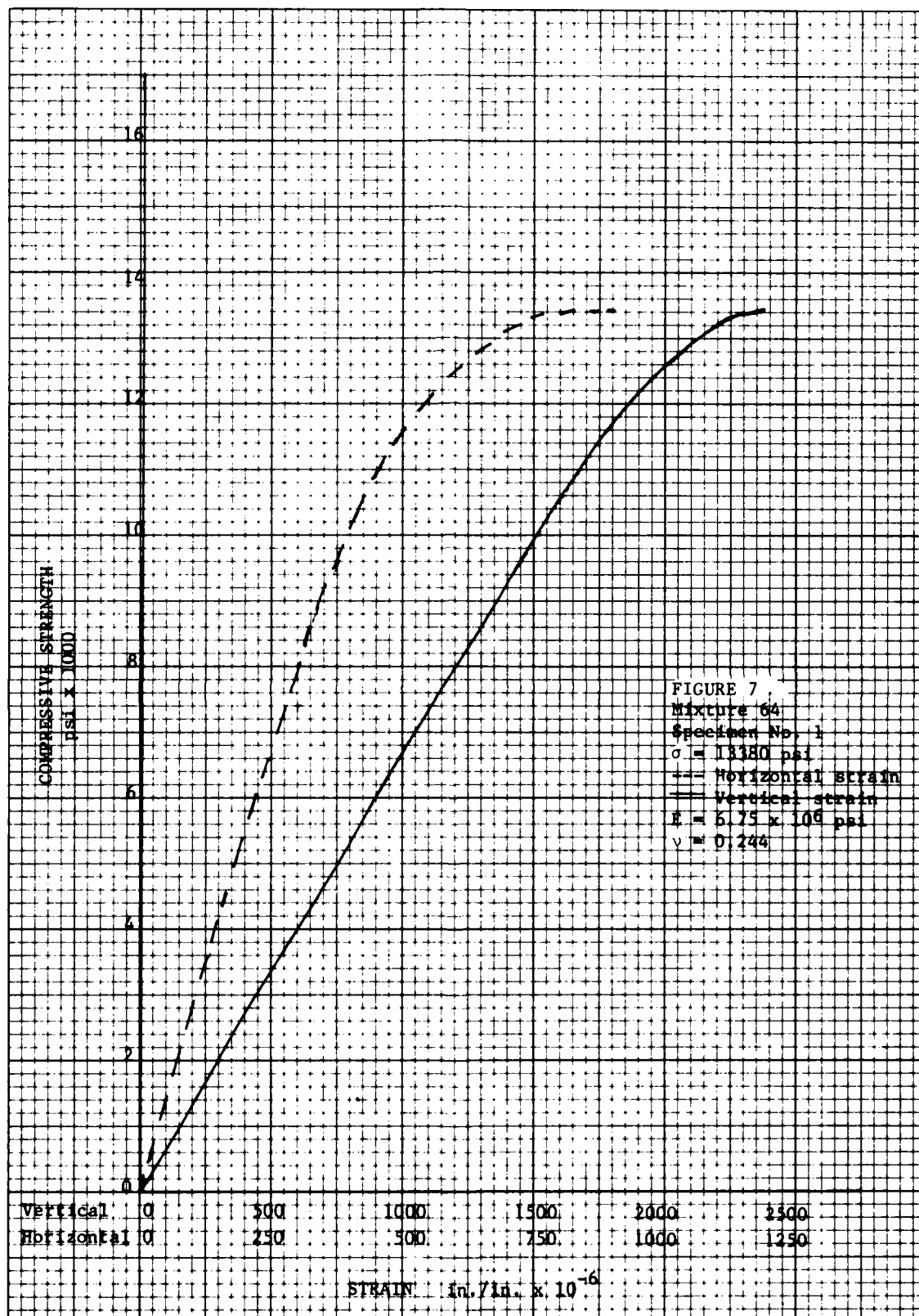
ND. 340-10 DIETZGEN GRAPH PAPER
10 X 10 PER INCH

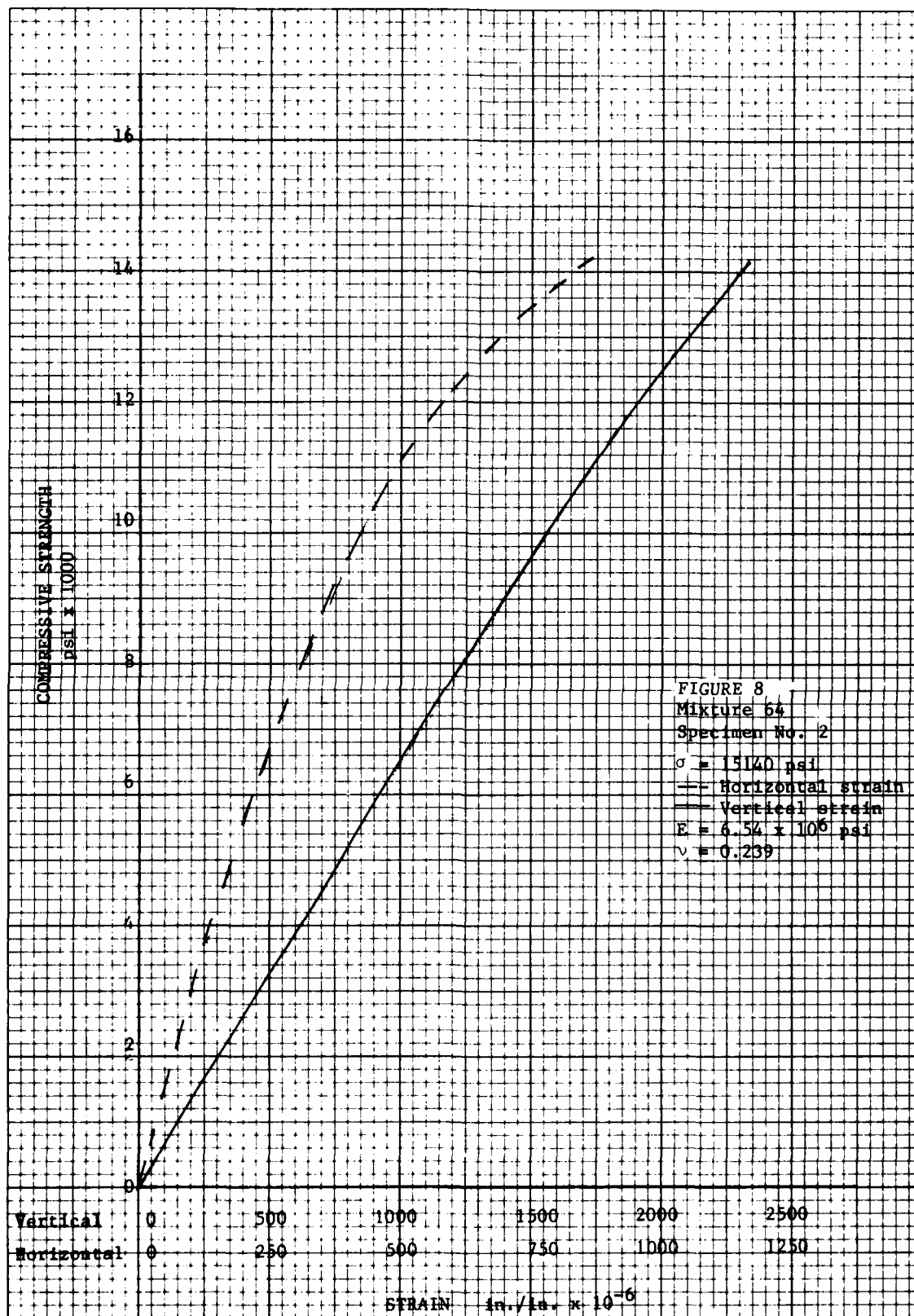


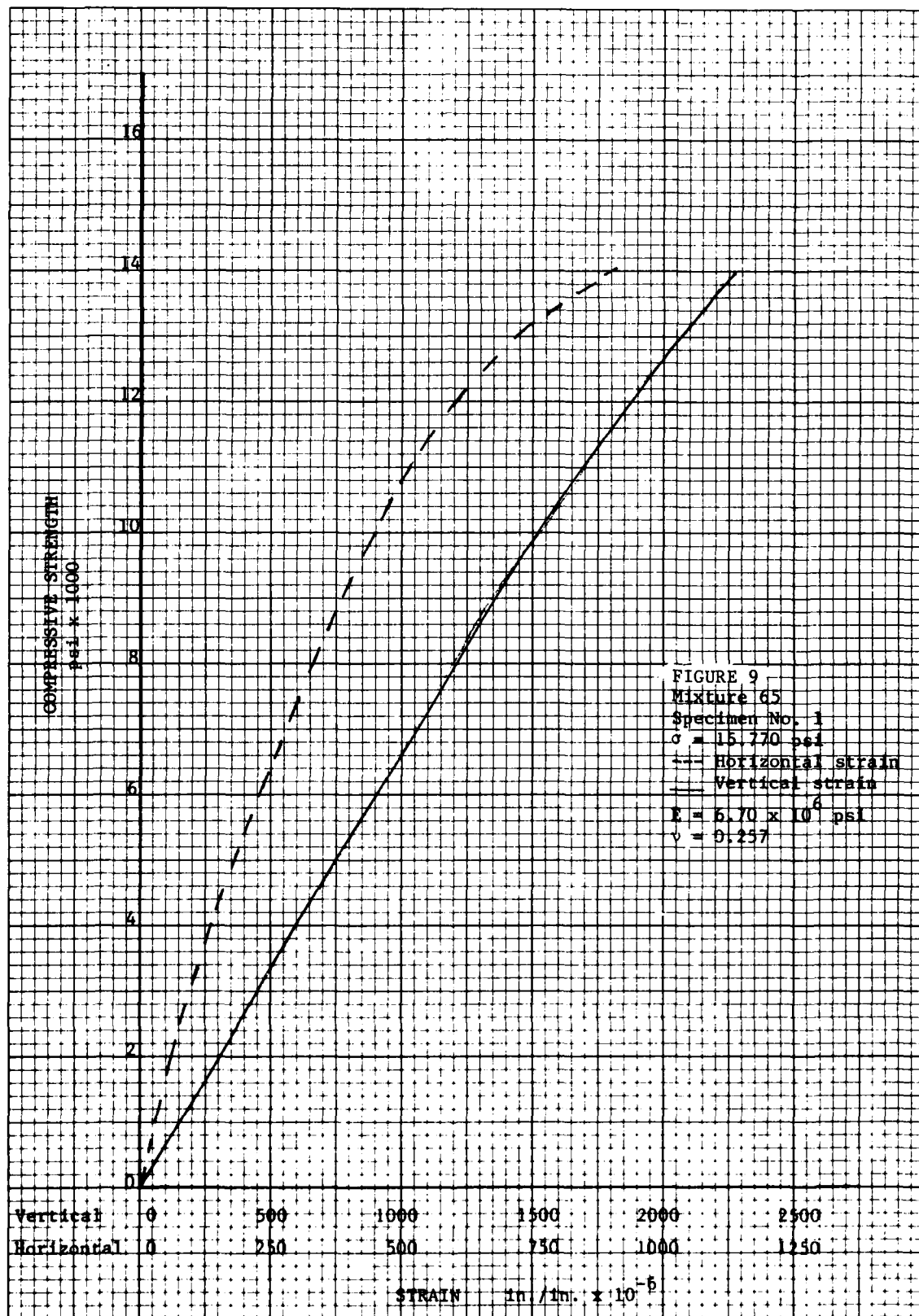
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MADE IN U. S. A.

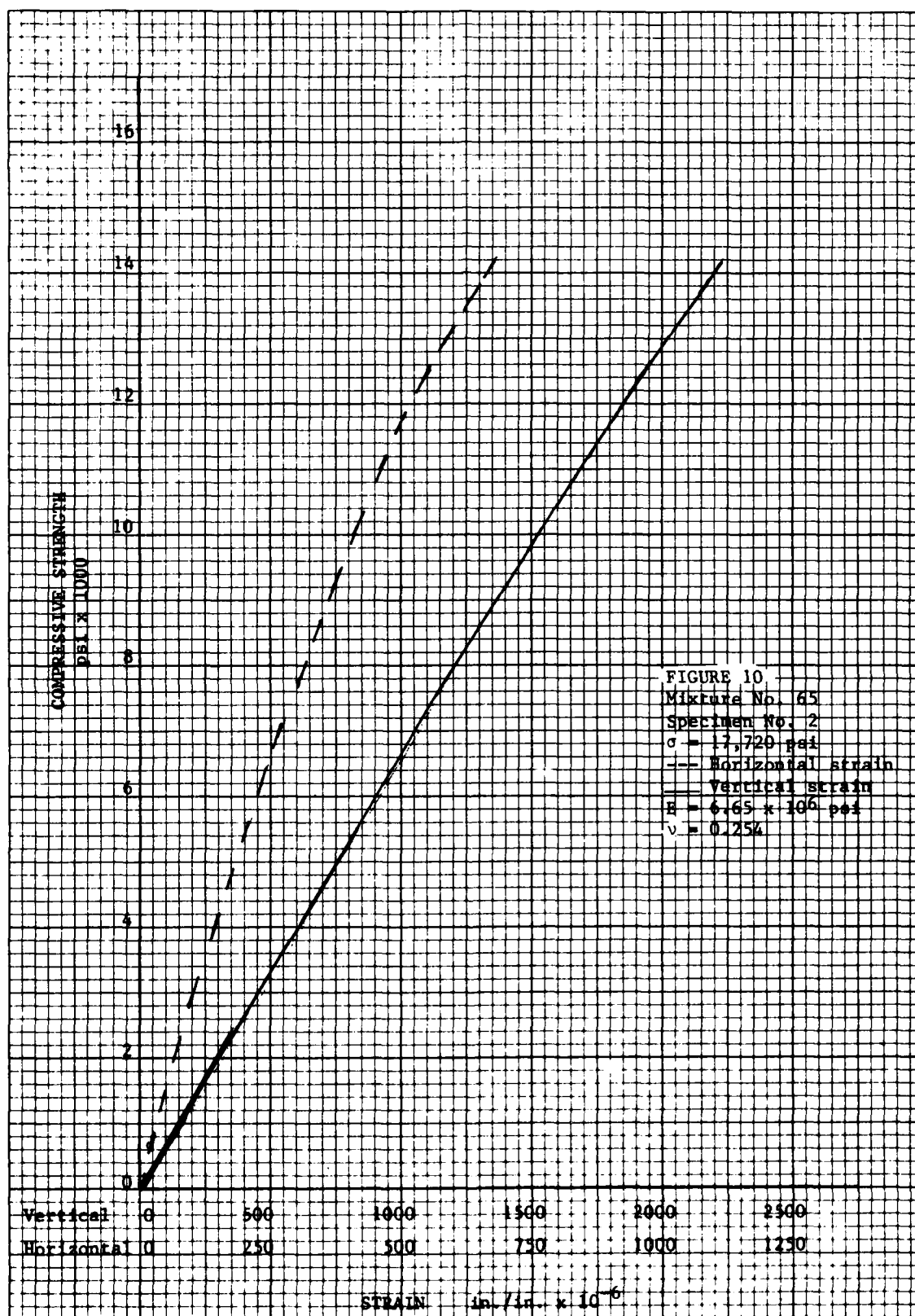
NO. 340-10 DIETZGEN GRAPH PAPER
10 X 10 PER INCH

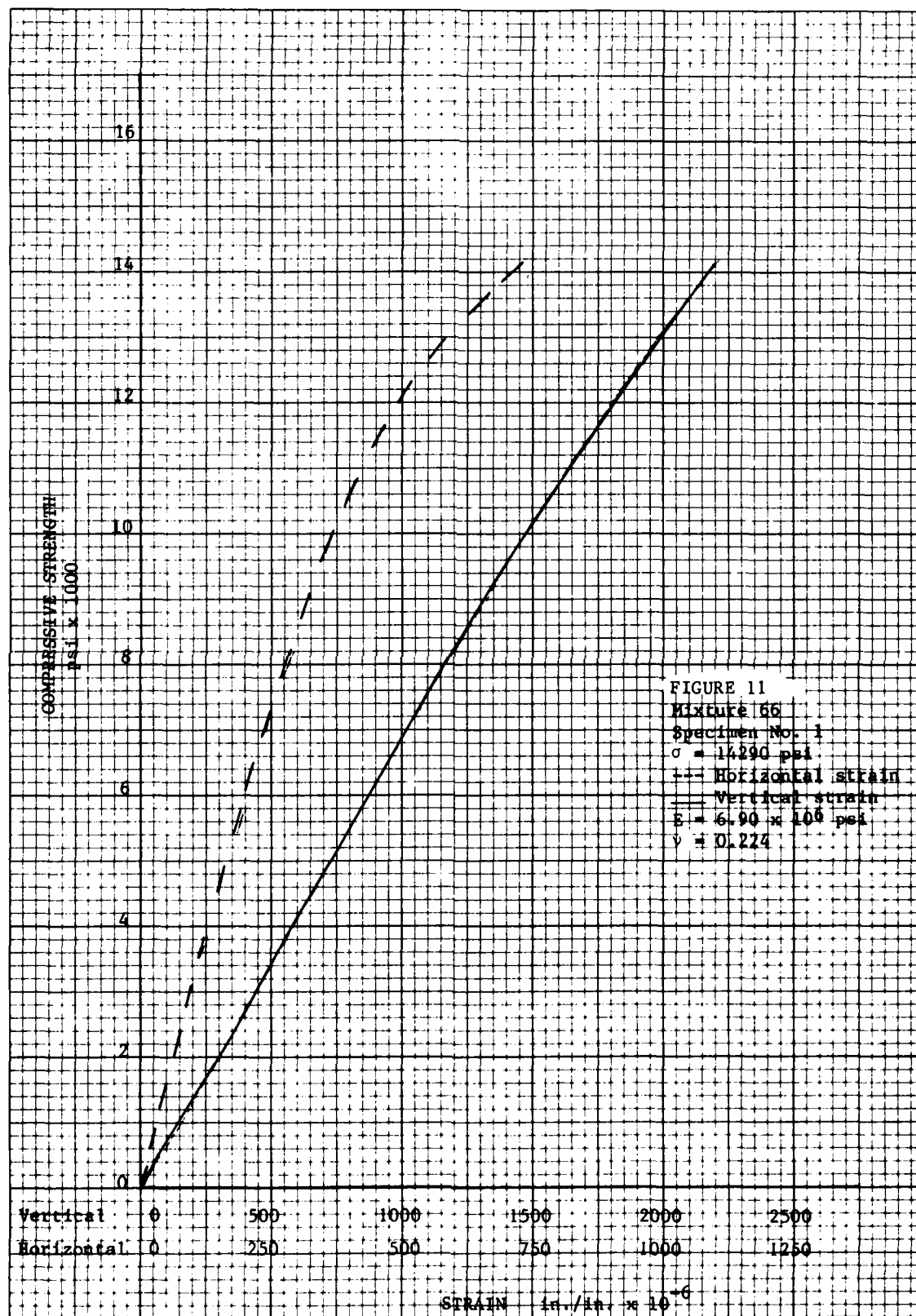


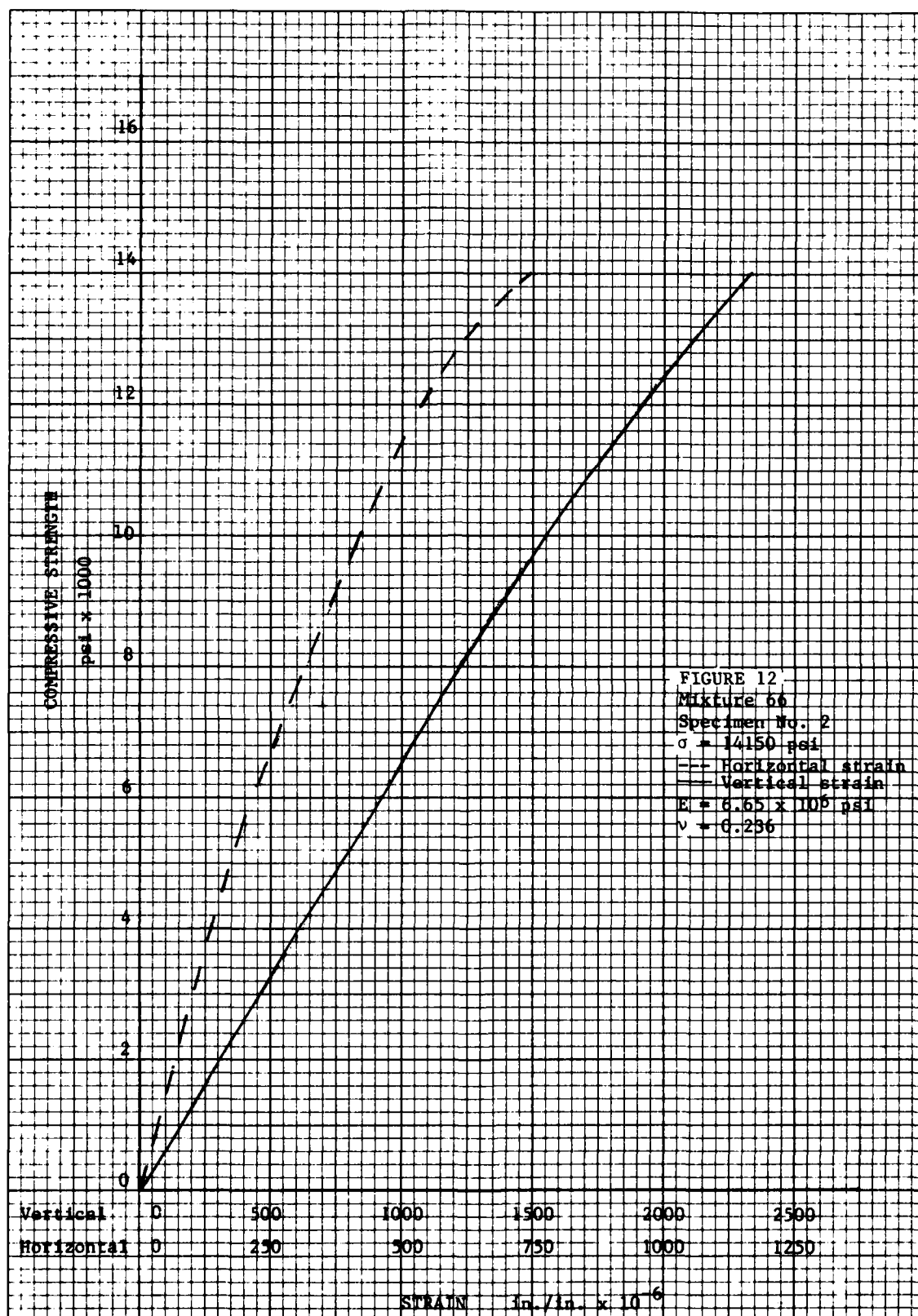


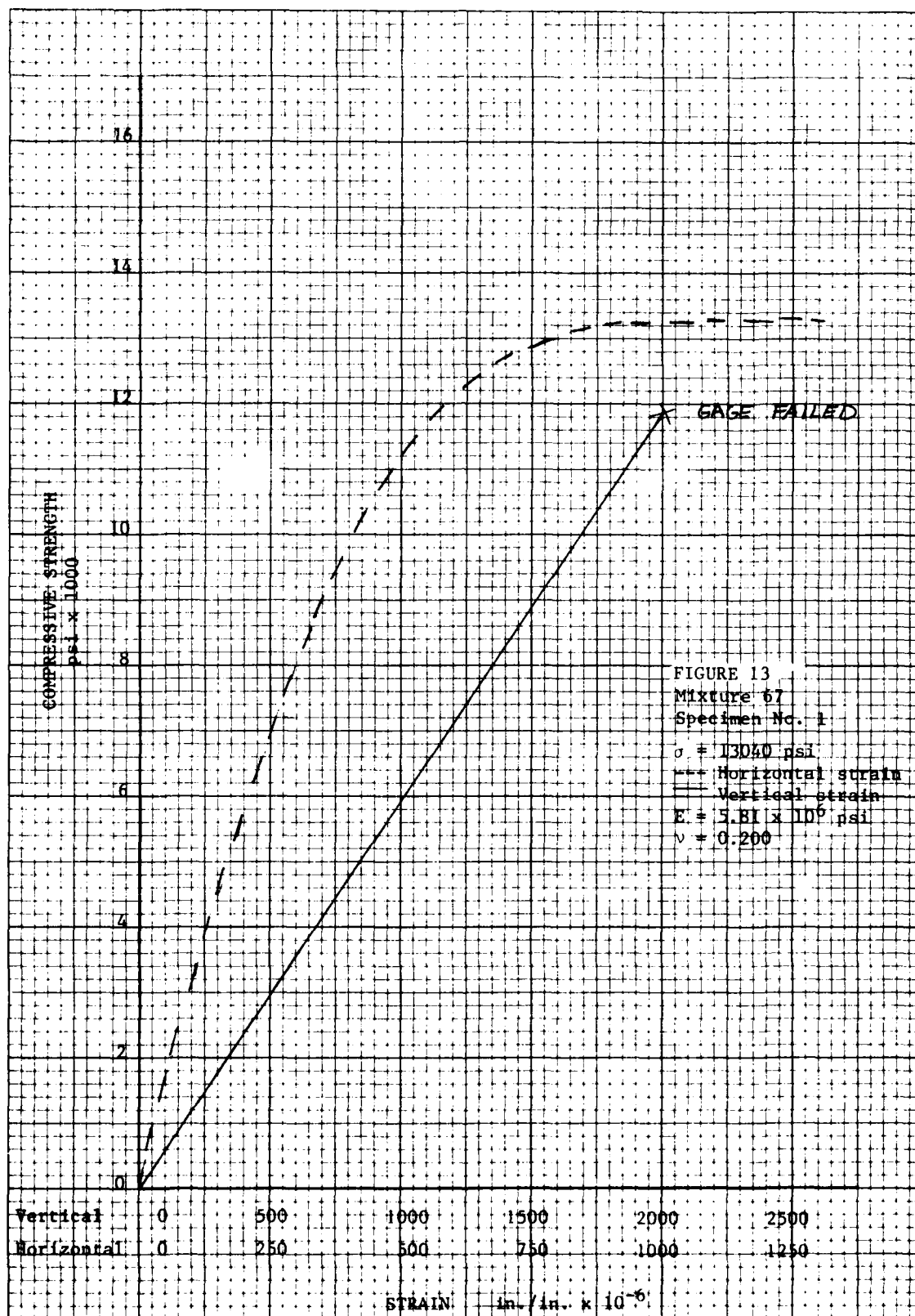


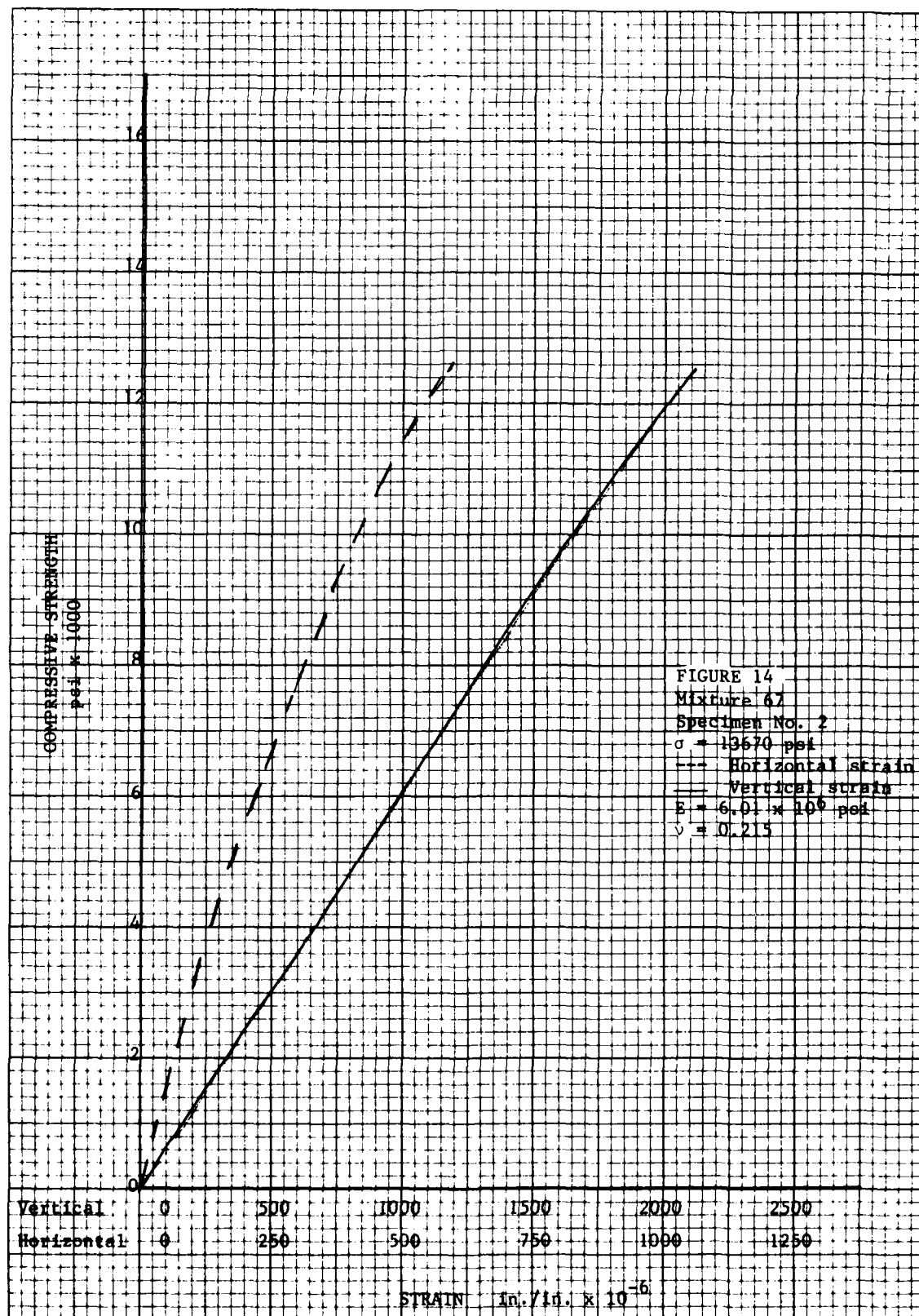


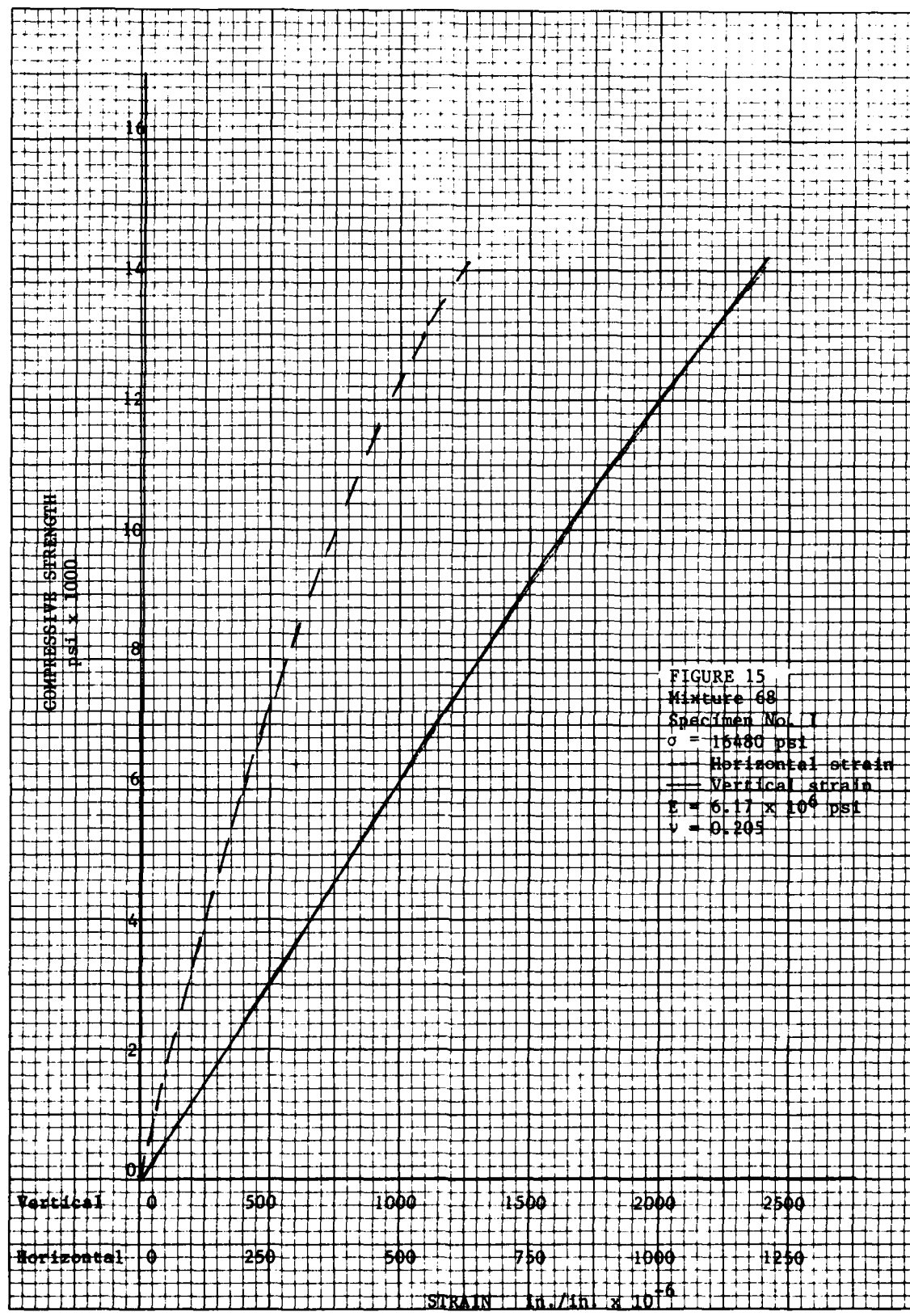






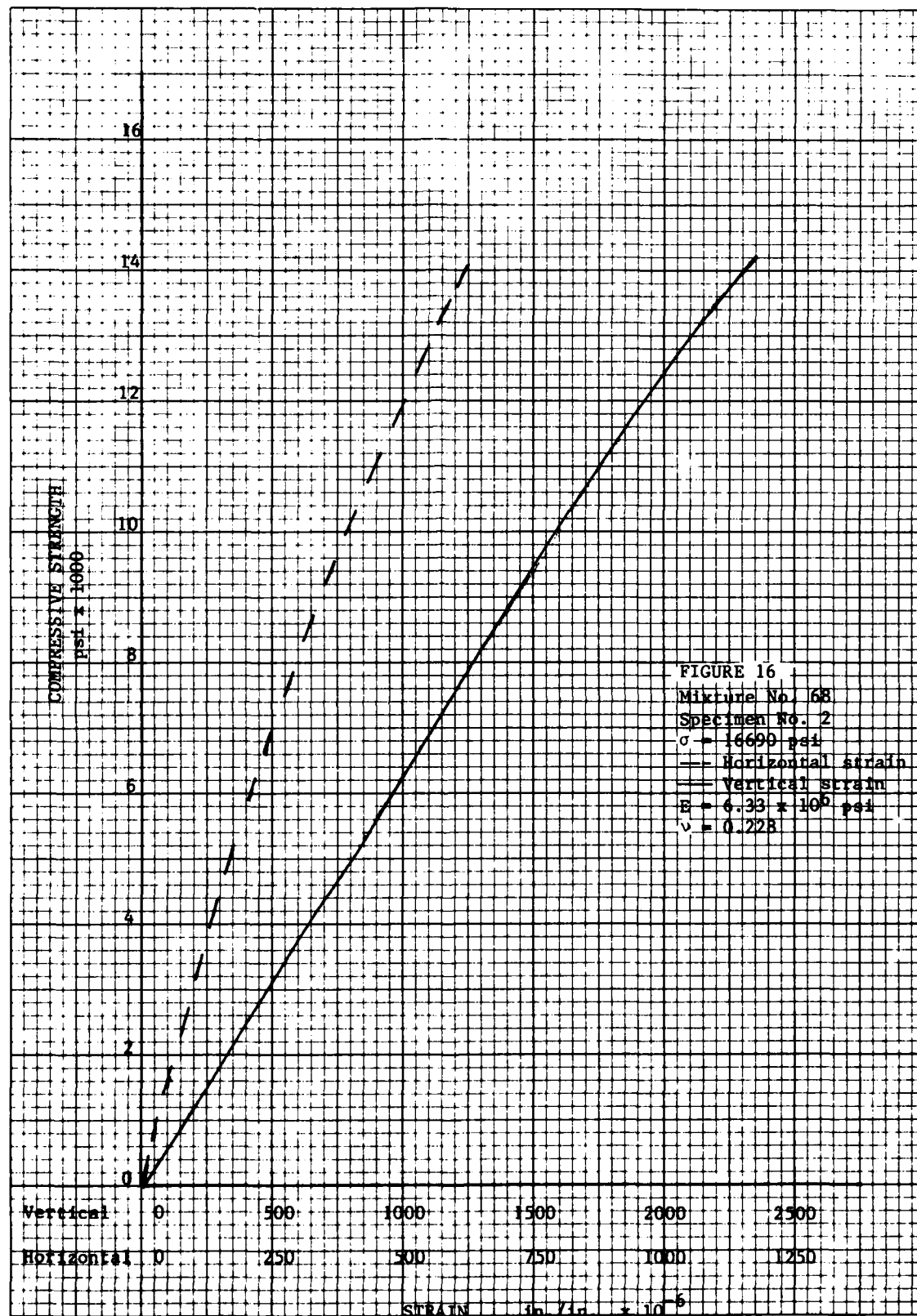






EUGENE DIETZGEN CO.
MADE IN U. S. A.

NO. 340-10 DIETZGEN GRAPH PAPER
10 X 10 PER INCH



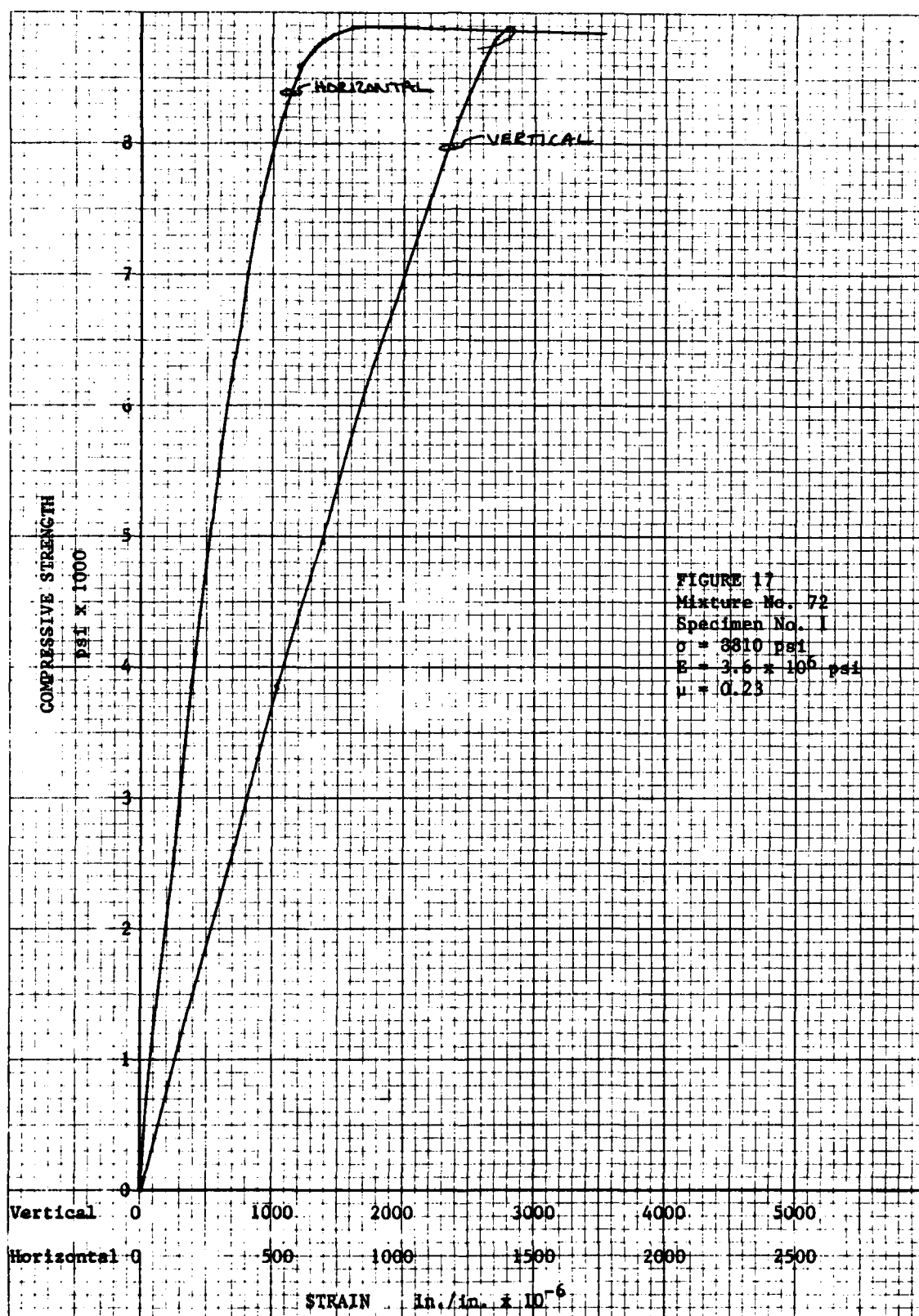
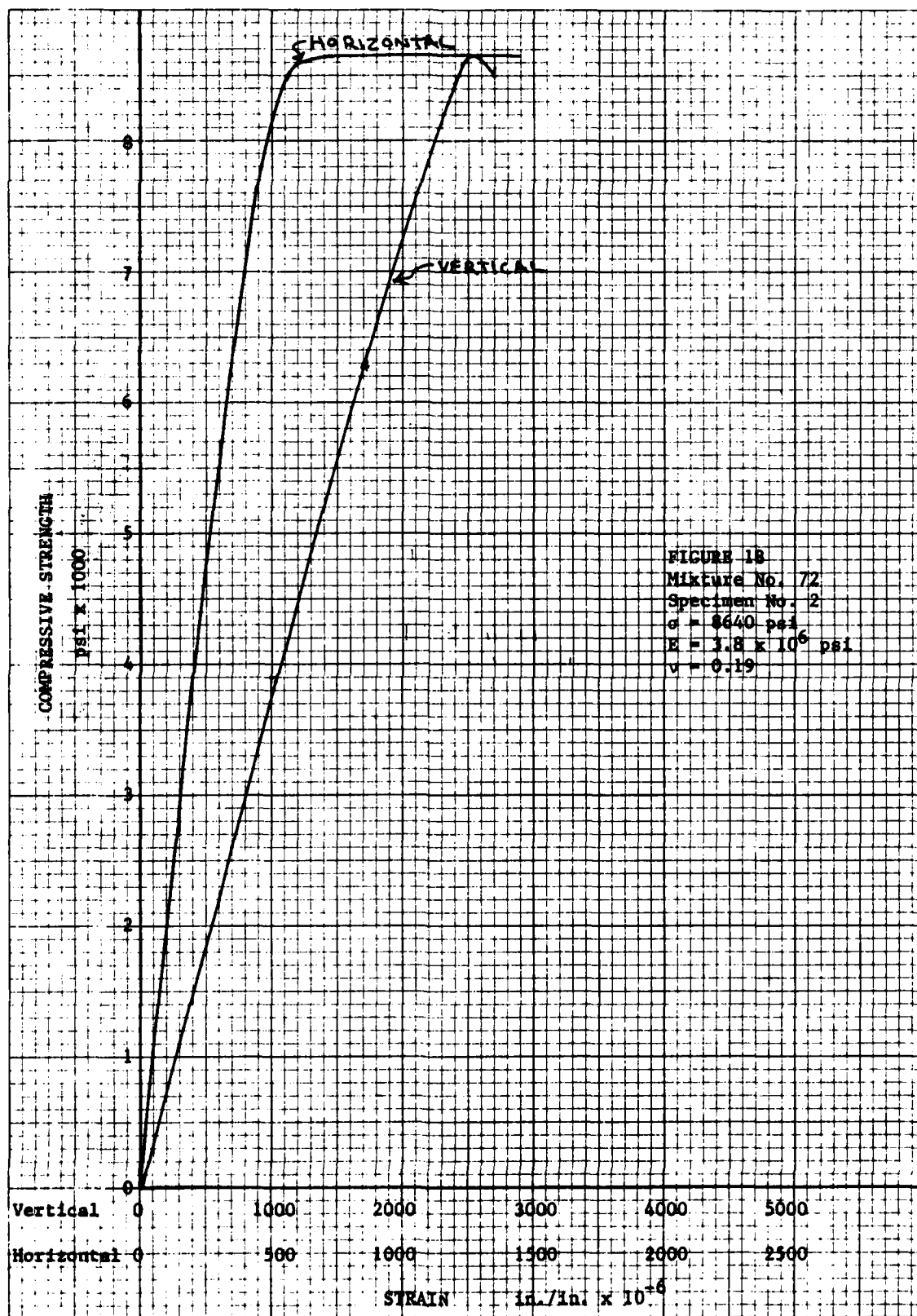


FIGURE 17
 Mixture No. 72
 Specimen No. 1
 $\sigma = 3310 \text{ psi}$
 $E = 3.6 \times 10^6 \text{ psi}$
 $\mu = 0.23$



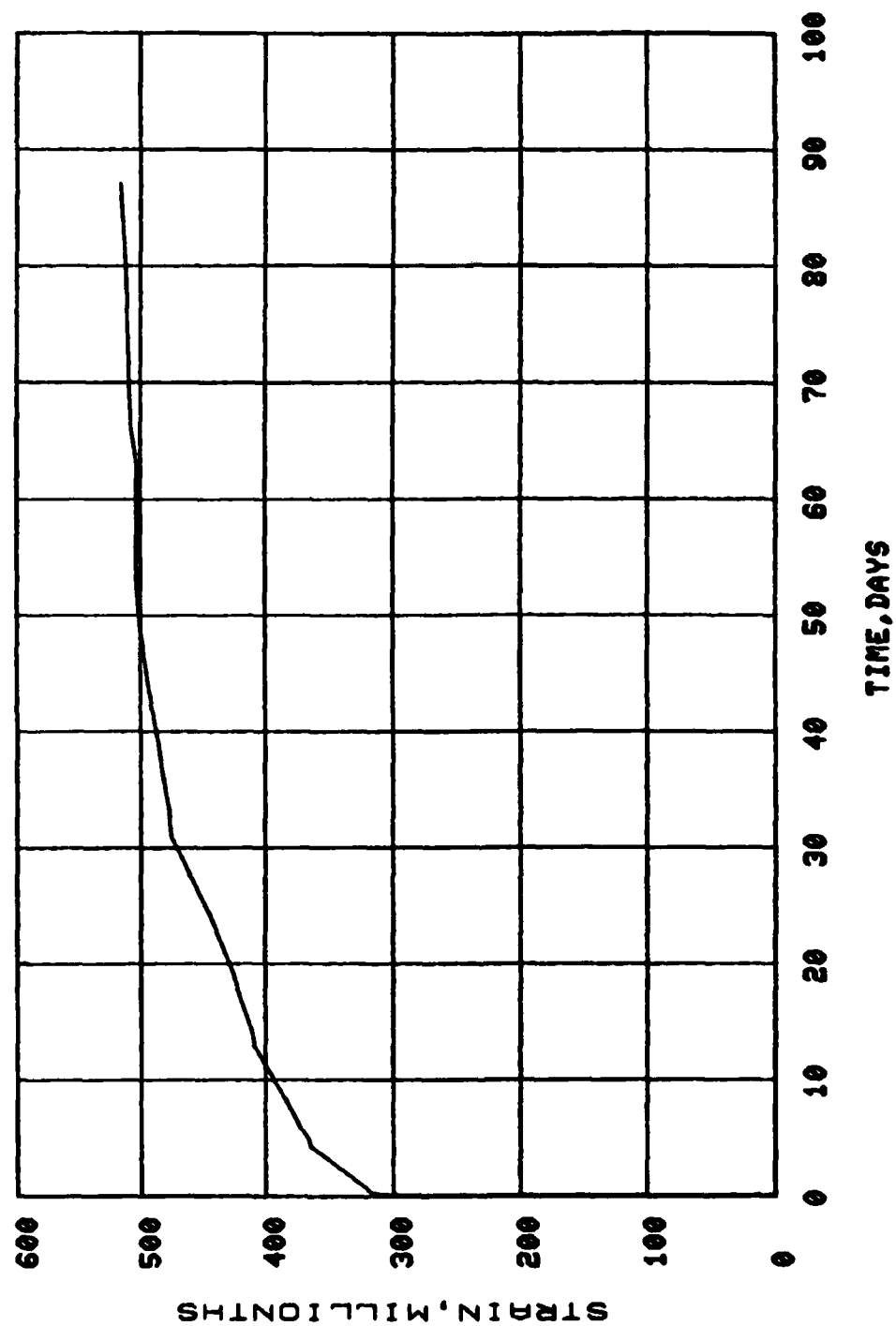


Figure 19. Total strain during loading period for mixture 22 with silica fume

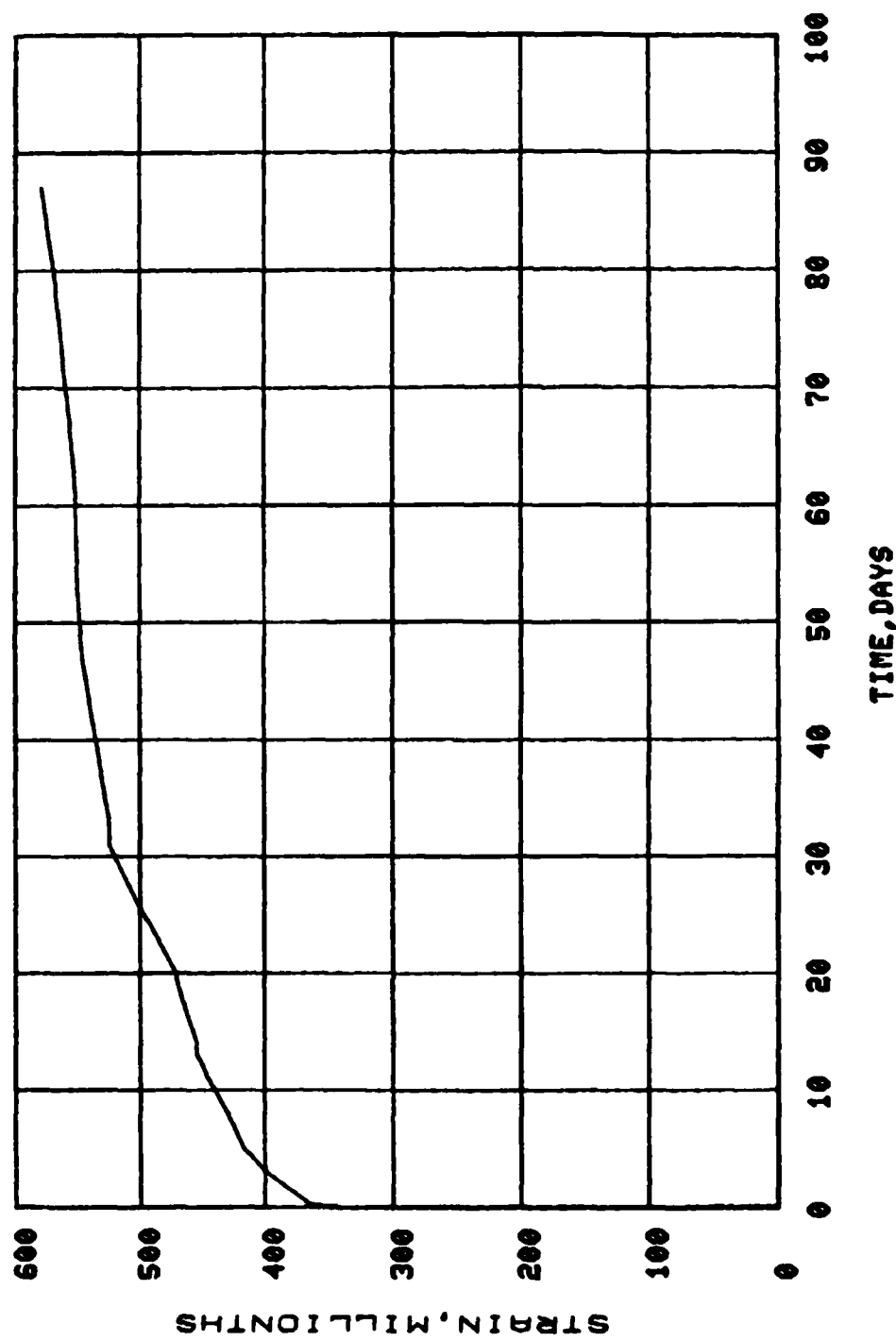


Figure 20. Total strain during loading period for mixture 22 without silica fume

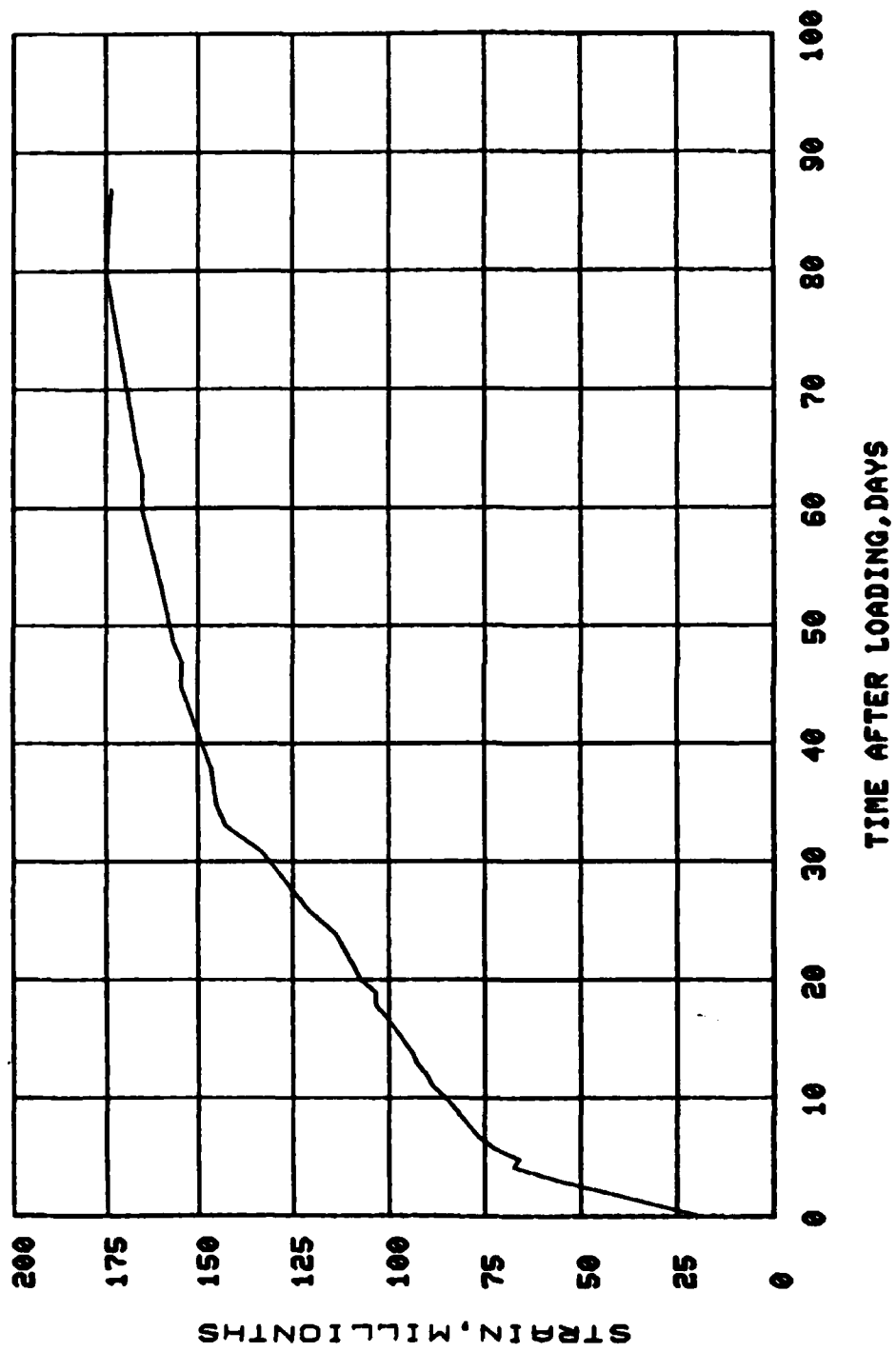


Figure 21. Corrected creep strain for mixture 22 with silica fume; loaded to 2000 psi at 14-day age (unconfined)

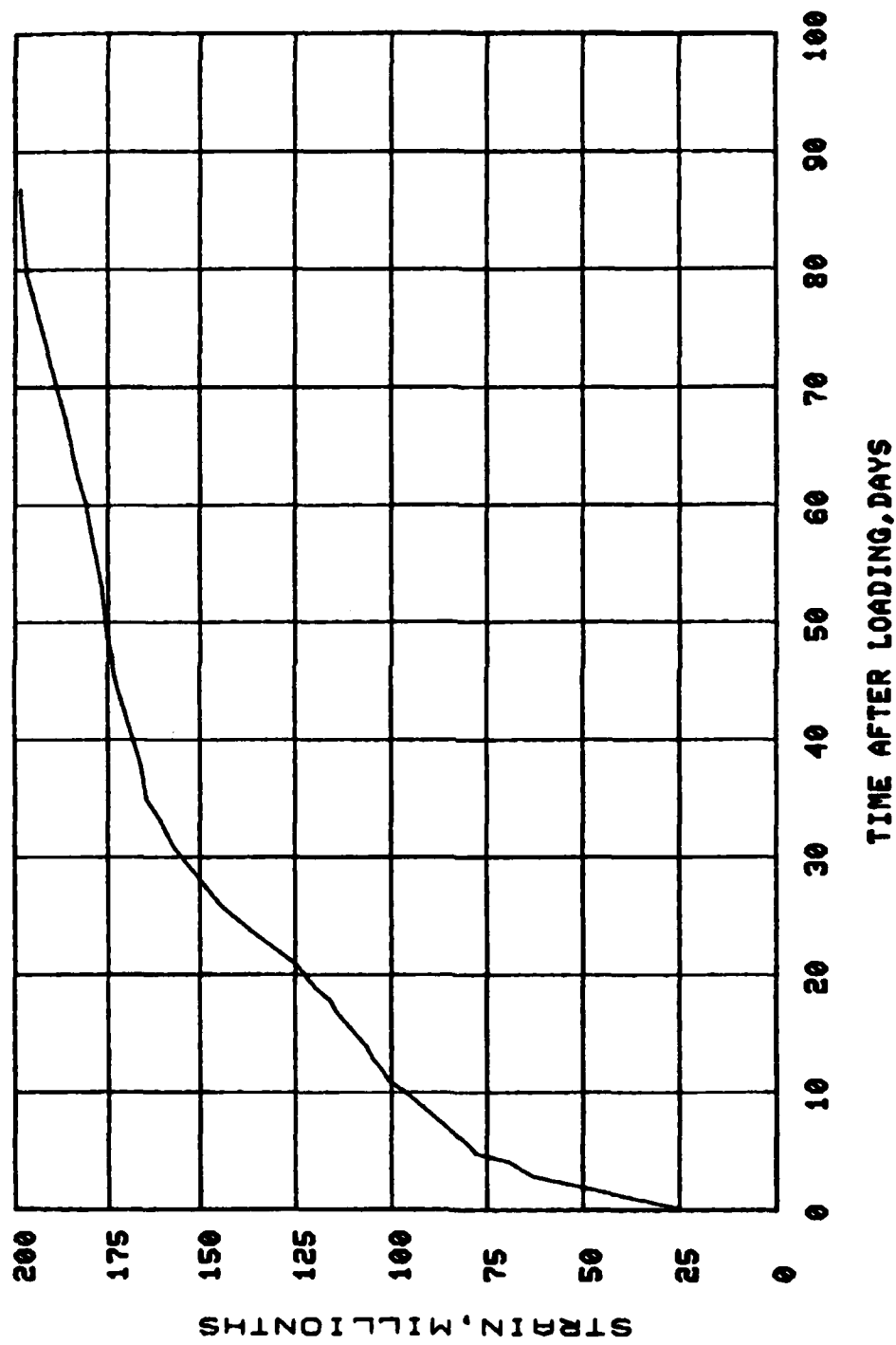


Figure 22. Corrected creep strain for mixture 22 without silica fume; loaded to 2000 psi at 14-day age (unconfined)

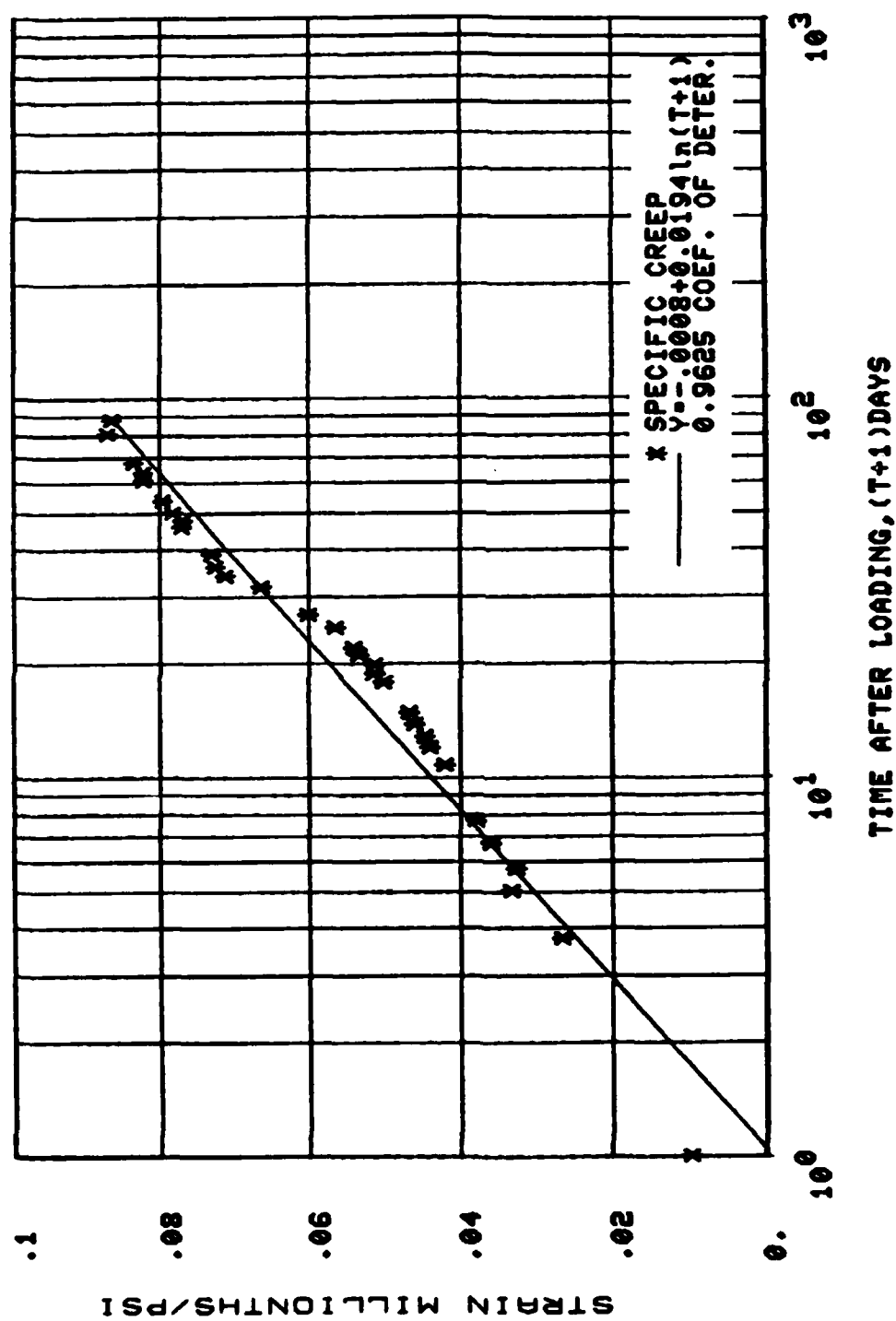


Figure 23. Specific creep for mixture 22 with silica fume; loaded to 2000 psi at 14-day age (unconfined)

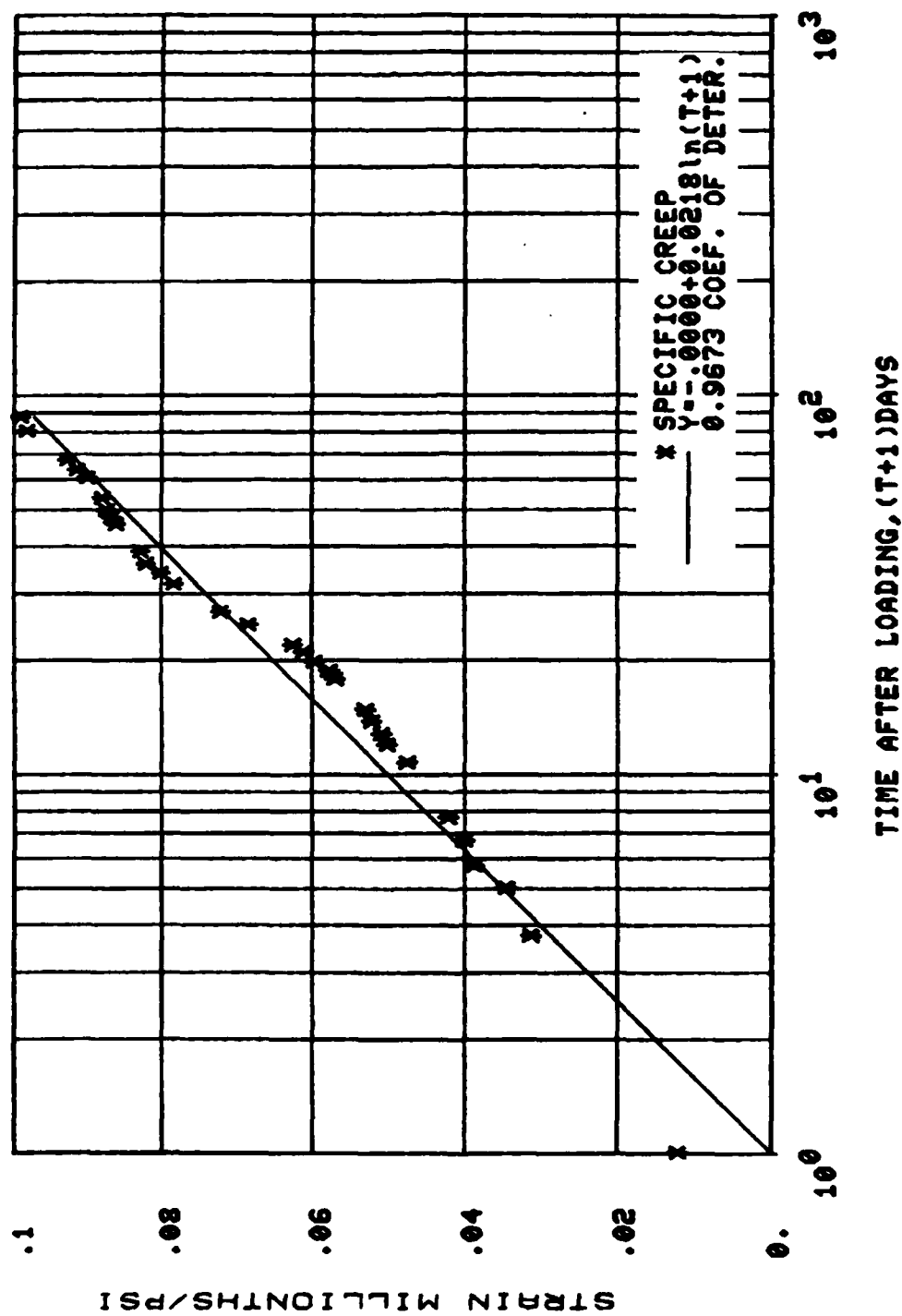


Figure 24. Specific creep for mixture 22 without silica fume; loaded to 2000 psi at 14-day age (unconfined)

END

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