THE UNIVERSITY OF MICHIGAN RESEARCH INSTITUTE
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Final Report

PROPERTIES AND PROPORTIONING OF ELASTIZELL CELLULAR CONCRETE

L. M. Legatski
Professor of Civil Engineering

and

Alex E. Mansour, Jr.
Formerly Engineer, ELASTIZELL Corporation of America

UMRI Project 2326

ELASTIZELL CORPORATION OF AMERICA
ALPENA, MICHIGAN

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SYNOPSIS

ELASTIZELL cellular concrete test mixes were made having densities ranging from 40 to 120 pcf wet and with various cement contents. Dry density, compressive strength, modulus of elasticity, bond strength, and shear strength were determined. Also, the water absorption and thermal conductivity were measured. Charts are developed for the design of ELASTIZELL cellular concrete mixes to requirements of compressive strength and density. The variation of modulus of elasticity with density is shown graphically as determined by tests and a recommended expression for modulus in terms of compressive strength is given. Measured values of bond and shear strength are shown graphically together with recommended working stresses.

INTRODUCTION

ELASTIZELL is a liquid foaming agent designed especially to produce a stable foam for use in concrete. ELASTIZELL concretes are cellular concretes made by incorporating controlled amounts of ELASTIZELL foam in the mix. The foam, by replacing part of the aggregate, makes the concrete lighter in weight and modifies other properties such as strength and thermal conductivity. Thus, if the ELASTIZELL foam and the other materials can be properly proportioned,it becomes possible to control not only the strength of concrete but also its other properties, principally weight and thermal conductivity.

The prime advantage of light-weight concrete is reduced dead load. The fact that, with cellular concrete, weight reduction is achieved without the use of light-weight aggregates is of added interest.

Historically, cellular concrete has been used almost exclusively for nonstructural purposes such as light-weight floor and roof fills, for insulation of underground heating tubes, and slabs on grade. The use of cellular concretes of structural quality has been limited because of the lack of knowledge of the properties and proportioning of such mixes. Until about two years ago, ELASTIZELL concrete was mixed in a special high-speed mixer of German design. That mixing operation was not adaptable to American construction practice and was replaced by the use of ordinary concrete mixers to incorporate preformed ELASTIZELL foam in the mix. This new procedure has made ELASTIZELL cellular concrete easy to use with a minimum of special equipment but it has also made necessary a comprehensive study of the properties and proportioning of ELASTIZELL cellular concrete as made by the preformed foam method.

The results of such a study are presented in this report. The work was sponsored by ELASTIZELL Corporation of America and was carried out at The University of Michigan Research Institute as Project 2326.

OBJECTIVES AND SCOPE

As the density of ELASTIZELL cellular concrete is changed by varying the amounts of the constituents, including the air content, the physical properties change. The principal objective of this study was to determine the most significant physical properties of ELASTIZELL cellular concrete over a wide range of densities and to determine the relations between the physical properties and the composition of the mix, and thus develop a method for the design of a mix for specified physical properties.

The physical properties studied were compressive strength, shear strength (as a measure of diagonal tension), bond strength, and modulus of elasticity. The test mixes ranged in density from 40 to 120 pcf wet. In an earlier test series water absorption and thermal conductivity were determined, and those results are included in this report.

The testing program was limited to cellular concretes made with ELASTIZELL as a foaming agent and ELASTIMULSE as an integral waterproofing agent. One series of test mixes (wet density from 80 to 120 pcf) included a cement dispersing agent. A second series (wet density from 40 to 100 pcf) was made with no dispersing agent.

The program was also limited to mixes containing no coarse aggregates. The determination of the properties of ELASTIZELL concretes containing coarse aggregates, especially light-weight aggregates, is the subject of a future study.

TEST SPECIMENS

Because of the large number of specimens required, the work of mixing and casting was divided into two parts. The division was made on the basis of density.

The first group of specimens, made in a 4-day period, included mixes ranging in density (wet) from 80 to 120 pcf. From each of these mixes (with some exceptions) the following specimens were made:

(a) Three 6-in.-by-12-in. cylinders for the determination of dry weight, modulus of elasticity and compressive strength. (Total of 190 cylinders from 59 batches.) From one batch having a wet density of 113.5 pcf, 16 cylinders were made for a study of variation of strength with time.

(b) Two 6-in.-by-12-in. cylinders with reinforcing bars embedded full length for bond tests. (Total of 92 cylinders.)

(c) One singly-reinforced beam nominally 5-5/8-in.-by-6-7/8-in.-by 50-in long for determination of shear strength. (Total of 55 beams.)

(d) One slab 18 in.by 18 in. by 3-5/8-in. to help assess workability and uniformity of the mix. Most of these slabs are now being exposed to the weather at Alpena, Michigan. (Total of 73 slabs.)

The second group of specimens was also made in a 4-day period and included, principally, mixes ranging from 40 to 100 pcf. Ten mixes ranging from 100 to 120 pcf were made to supplement the first group. The test specimens made from each mix were as follows:

(a) Five 6-in-by-12-in. cylinders for determination of dry weight, modulus of elasticity, and compressive strength. Modulus was not determined for mixes with density below 80 pcf since such mixes would not commonly be used structurally. (Total of 401 cylinders from 81 batches.)

(b) One beam for shear strength - same size as for the first group. Beams were not made for densities less than 80 pcf. (Total of 12 beams.)

(c) One slab - same as for first group. The very light slabs are not intended for exposed use and therefore those slabs are not being exposed to weather. (Total of 69 slabs.)

TEST PROCEDURES

This discussion of test procedures includes the proportioning and mixing of test batches, and the casting, curing, and testing of specimens.

PROPORTIONING

Test batches were made in increments of 5 pcf throughout the density range from 40 to 120 pcf. Each batch contained one sack of cement. For a typical group of test batches, the wet density was held constant and the sand-cement ratio was varied from batch to batch. This resulted in a series of mixes having varying cement and foam content at constant density. The amount of foam was varied as required to obtain the desired density. The water-cement ratio was varied only when necessary to obtain a stable and workable mix.

The following typical example illustrates the design of a test batch that is to weigh 90 pcf wet, have a sand-cement ratio of 2.25, and a water-cement ratio of 0.45 by weight exclusive of the water in the ELASTIMULSE.

Material	Parts by Weight	Wt. per Batch, lb	Conversion Factor		Absolute Vol., cu ft
Cement	1.0	94	$\times \frac{1}{3.15 \times 62.4}$	=	0.478
Sand	2.25	211.5	$\times \frac{1}{2.65 \times 62.4}$	=	1.28
Water	0.45	42.3	$\times \frac{1}{62.4}$	=	0.678
ELASTIMULSE	0.02	1.9	$\times \frac{1}{1.05 \times 62.4}$	=	0.029
	Total =	349.7	Total	=	2.465

For a wet density of 90 pcf:

$$\frac{90}{1} = \frac{349.7}{\text{Batch Volume}} \quad \text{or Batch Vol.} = 3.885 \text{ cu ft}$$

Then, the batch volume minus solid volume = vol. of air or 3.885 - 2.465 = 1.42 cu ft of air per batch.

Entering the Typical Calibration Curve for 60-G.P.M. nozzle (Fig. 8, Appendix) it is found that 1.42 cu ft of air are delivered in 12.2 seconds and that its water content is 5.7 lb. The water content of the foam is deducted from the total water requirement to maintain a water-cement ratio of 0.45.

A further correction is made for free moisture in the sand. For example, if the sand holds 3.9% of moisture,

Wt. of water in sand = 0.039 x 211.5 = 8.25 lb.

This amount is to be subtracted from the water requirement above and added to the sand requirement. Making all these corrections, the final batch weights become:

Cement 94.0 lb
Sand .... 211.5 + 8.25 = 219.75
Water .... 42.3 - 5.7 - 8.25 = 28.35
ELASTIMULSE = 1.9
Foam (water content) = 5.7
349.7 lb

Cement Factor = 27/3.885 = 6.95 sacks per cu yd

The foam is actually added on a timed basis and its weight is added above only to show that the total batch weight is not changed by the corrections. The foam time for this batch is 12.2 seconds, using a 60-G.P.M. nozzle. In making the test batches, it was found that this theoretical foam time did not always produce a mix of the desired density and, when this occurred, the batch was repeated using a foam time corrected by estimation until the desired density was obtained. Variations from the theoretical foam time are apparently a function of water-cement ratio, sand-cement ratio and density of mix.

It is noted that the ELASTIZELL content is not considered in the calculations of mix weights. This is because its effect is insignificant as shown by the following calculation, referring to the previous example.

Water content of foam = 5.7 lb or 0.0913 cu ft

Since the foaming solution is 20 parts water to 1 part ELASTIZELL by volume, the volume of ELASTIZELL is 0.0913/20 = 0.004565 cu ft. ELASTIZELL weight = 0.004565 x 1.07 x 62.4 = 0.305 lb.

When a powdered dispersing agent is used, it may be considered insignificant and ignored in the calculations. However, if the dispersing agent is premixed with water, the water content of this solution must be deducted from the water requirement.

The proportioning of field mixes is similar to the above example except that foam time is determined from curves based on these tests. Examples of the proportioning of field mixes are given in the Appendix.

MIXING

A 7-cu-ft mixer was used for the test batches. The mixing was done as follows.

1. Charge the foam generator tank with a thoroughly mixed solution of 20 parts water to 1 part ELASTIZELL foaming agent by volume.
2. Charge the mixer with the required amount of sand.
3. Add the cement and mix thoroughly. If a powdered dispersing agent is to be used, it is added at this time.
4. Add the water and ELASTIMULSE and mix thoroughly. If a liquid dispersing solution is used, it is added at this time.
5. Add the ELASTIZELL foam from the foam nozzle for the required time interval at an operating pressure of 90 psig. Continue mixing until the batch appears homogeneous.

The mixer need not be stopped at any time during the batching operation. The mixing procedure may be altered in any way as long as it results in a homogeneous mixture before the addition of the foam. The foam should always be added last. The mixing procedure must be such as to prevent "balling" of the cement since "balling" can greatly reduce the effectiveness of the cement in the mix.

CASTING AND CURING

The wet density of each mix was determined immediately after mixing by weighing in a calibrated container.

The specimen forms were agitated during the casting operation. Consolidation by rodding was not done and is not recommended for cellular concrete, especially for the lighter mixes, because it tends to leave large voids in the material.

All specimens were covered with wet sand and burlap 18 hours after casting and kept wet until moved to the moist room 48 hours later. The moist room was kept at 70°F and 100% relative humidity. The specimens were removed from the moist room at age 24 days and were air-dried during the preparation for testing at 28 days.

TESTING

The tests included the determination of dry density, compressive strength, modulus of elasticity, bond strength, and shear (diagonal tension) strength.

The dry density of each batch was calculated from the measured dimensions and the weight of a cylinder. The cylinders used for determination of dry density were air-dried for several weeks in a dry room. Then some were weighed and oven-dried as a check on the room-drying. It was decided that the room-dried cylinders gave a realistic value of dry density. The density determination was made at age 10 weeks.

The compressive strength and modulus of elasticity were determined from tests of 6-in-by-12-in. cylinders in a 400,000-lb capacity Tinius Olsen testing machine. For the modulus tests, strains were measured by two SR-4 strain gages mounted opposite each other on the cylinder and connected in series. Stress-strain curves were drawn, from which the secant modulus at 1/2 f'_c was determined.

Bond strength was determined from pull-out tests using No. 4 or No. 5 deformed bars (ASTM A-305-53) embedded in 6-in.-by-12-in. cylinders.

Shear (diagonal tension) strength was determined from tests of 50-in.-long beams tested on a 36-in. span. The beams were 5-5/8-in.-by-6-7/8-in.

nominal section with an effective depth of 5 in. They were reinforced with two No.4 bars and were centrally loaded. Failure was by diagonal tension. The shear stress at failure was calculated and compared to allowable value according to ACI 318-56.

TEST RESULTS

The test results are presented here as tables and curves which show the properties of ELASTIZELL concrete needed for structural design and the relationships needed for mix design. The following figures are in the Appendix.

Figure 1 shows the variation of modulus of elasticity with wet density of the mix. A fitted curve is plotted together with recommended straight-line curves relating the modulus to f'_c.

Figures 2 and 3 are taken from an earlier series of tests. Figure 2 shows the effect of the waterproofing agent, ELASTIMULSE, on the water absorption of the concrete. Figure 3 includes test results from four sources and shows the variation of thermal conductivity with density for cellular concretes and light-weight aggregate concretes.

Figures 5, 7, and 8 show the information needed for proportioning mixes to specified strength and density for mixes using a dispersing agent. Their use will be illustrated later.

Figures 4, 6, and 8 show similar mix-design data for mixes made without a dispersing agent.

Figure 9 shows the results of beam tests for shearing (diagonal tension) strength. Shear strength is plotted against f'_c. The Building Code (ACI 318-56) requirements are shown as well as recommended maximum allowable shear stress for ELASTIZELL concretes.

Figure 10 is a similar plot of bond strength vs. compressive strength with the ACI allowable stress and a recommended maximum stress for ELASTIZELL concrete superimposed. Table I shows, for one mix, the change in compressive strength and modulus of elasticity with age for a period of 12 weeks.

DISCUSSION OF TEST RESULTS

Figures 4-8 provide the means to design ELASTIZELL cellular concrete from 40 to 120 pcf. Inspection of these figures will reveal that, whenever the density is to exceed 100 pcf, a cement dispersing agent is recommended, and for densities less than 80 pcf, a cement dispersing agent is not recommended. These recommendations arise from an adverse effect of the dispersing agent upon the foam in the lower-density range and from the desirability of maintaining a low water-cement ratio and high strength in the higher-density range. Dispersing agents tend to break down foam, and the higher the foam concentration, the more serious this problem becomes. It is possible to use dispersing agents at densities less than 80 pcf if the cement content is high, but the use of these agents in this range permits no reduction in the water-cement ratio and therefore, no significant increase in strength. In the higher-density ranges dispersing agents do not harm the foam since the foam content of the mixes is low. The use of a dispersing agent in the high-density range permits the use of less water while maintaining good workability when compared with mixes containing no dispersing agent.

It may also be seen in Figs. 6 and 7 that a higher water-cement ratio is required for low- and high-density material than is required for the intermediate densities. This variation arises to provide workability in high-density material and to maintain stability of the foam in low-density material. Stability of the mix is critical when there is insufficient water present for both the hydration of the cement and the maintenance of the bubbles. In that event, the cement takes water from the foam and causes the bubbles to collapse.

Figures 6 and 7 are based upon the summation of absolute volumes up to approximately 95 pcf as illustrated in the example on page 4. This theoretical approach to mix design produces excellent results up to approximately 95 pcf at which time the theoretical and actual densities obtained begin to diverge. This divergence apparently arises from entrainment of air in addition to that furnished by the foam. This accidental entrainment increases as density is increased with a constant cement factor or as density is held constant and the cement factor reduced. Figures 6 and 7 take into account this additional entrainment for ELASTIZELL foam but do not necessarily apply to other foams. Different gradations of sand will, of course, affect the foam time as will different types of mixers. Experience to date indicates that mixers with stationary drums and moving blades will require a foam time closer to the theoretical time than will mixers with revolving drums.

In some applications, especially in precasting, it is often advantageous to vibrate ELASTIZELL concrete in the forms. Vibration tends to increase the density of the mix by destroying some of the air cells. Such loss of air can increase the density considerably. The density change can be compensated for by making the mix purposely lighter at the mixer. For a particular installation the effect of vibration and handling on the density should be measured by samples taken at the mixer and after handling and vibration. Additional foam can be added to yield the proper density in place. The study reported here did not include the effect of vibration and handling, but field experience has shown that a small amount of vibration has little effect on density, and, in any case, the density correction can be made as described above.

The design charts in the Appendix are based on tests of specimens made and cured under well-controlled conditions. Field mixes which must meet a minimum strength requirement should be designed, by the charts, for a somewhat higher strength than the minimum allowable. The amount of that strength margin should depend on the excellence of the field control but should probably be not less than 200 psi.

Figure 1 shows modulus of elasticity versus wet density and expresses modulus of elasticity as a function of compressive strength. This presentation arises from the results shown on Figs. 4 and 5 which indicate that withi the normal range of cement factors for cellular concretes, say 6 to 7.5 sacks per cubic yard, the strength of any particular density of ELASTIZELL cellular concrete is nearly constant. For the sake of simplicity, it seems best to accept a constant strength for any density concrete within the normal range of cement factors and to express the modulus as a factor times the accepted constant strength. The straight lines on Fig. 1 are the recommended moduli of elasticity for design purposes. The plotted test results on this figure are the secant moduli of the specimens tested.

Figures 9 and 10, which show, respectively, the shear and bond strengths of ELASTIZELL cellular concrete versus compressive strength, indicate that the ACI Code may be safely used with modified upper limits as shown.

Figures 11 and 12 show the relationship between wet and dry density of ELASTIZELL cellular concretes, both with and without a dispersing agent in the mix. The straight line in each case represents a weight loss of 5 pcf from wet to dry. An allowance of 5 pcf for loss in density on drying is conservative and is recommended for use throughout the range of densities.

Figure 3 shows the thermal conductivity of ELASTIZELL cellular concretes versus dry density and is taken from an earlier study. The plotted results from the various sources show substantial agreement and indicate that the Bureau of Standards curve for no-fines gravel and light-weight aggregate concrete may be used for cellular concretes.

Figure 2, which is also taken from the earlier study referred to above, shows the relationship between water absorption and the percent of ELASTIMULSE additive. ELASTIMULSE is a special asphalt emulsion. The plotted values indicate that very good results can be obtained by limiting the amount of ELASTIMULSE to 2% of the weight of cement.

The values of compressive strength and modulus of elasticity in Table I indicate that, for a typical structural grade ELASTIZELL concrete, these properties increase with age in a manner similar to ordinary dense concrete. The number of specimens tested in this series was small and therefore the average values do not show as uniform a variation as would be expected from a larger number of tests.

CONCLUSIONS

The following conclusions are justified by the tests reported herein, supplemented by earlier tests and by field experience gained during the progress of this work.

1. With reasonable field control, ELASTIZELL cellular concrete can be mixed to a specified density from 40 to 120 pcf at a specified cement factor. Loss of air due to vibration and handling can be countered by adding the proper amount of extra foam for the particular situation.

2. The mix-design charts which were developed from test results can be used to proportion ELASTIZELL cellular concrete mixes for a given compressive strength and/or density, for densities ranging from 40 to 120 pcf.

3. The modulus of elasticity, E_c, of ELASTIZELL cellular concrete is a function of both its density and compressive strength. The value of the modulus may be determined accurately enough for design purposes from the following expressions, one pair of which gives E_c in terms of wet density and the other pair in terms of compressive strength, f'_c.

For density from 80 to 100 pcf:

$$E_c = 560{,}000 + (WD - 80)\ 22{,}000$$

or

$$E_c = 308{,}000 + 420\ f'_c$$

For density from 100 to 120 pcf:

$$E_c = 1{,}000{,}000 + (WD - 100)\ 50{,}000$$

or

$$E_c = 110{,}000 + 540\ f'_c\ .$$

4. The shear (diagonal tension) strength and the bond strength of ELASTIZELL cellular concrete may be expressed as percentages of the compressive strength in accordance with Table 305(a) of the ACI Building Code, ACI 318-56, except that the limiting maximum values recommended are reduced from the Code maximums as shown on Figs. 9 and 10.

5. The loss of weight of ELASTIZELL cellular concrete on drying may be taken as 5 pcf. This value is somewhat less than the test results indicate and is thus conservative. Refer to Figs. 11 and 12 for test results.

6. The use of cement dispersing agents is advantageous for densities ranging from 80 to 120 pcf. Their use permits a lower water-cement ratio and thereby increases strength. At densities less than 80 pcf, the dispersing agent has an adverse effect upon the foam. Dispersing agents can be used in neat cement mixes less than 80 pcf, but the water-cement ratio cannot be less than that required when no dispersing agent is used and strength does not increase appreciably.

7. The optimum water-cement ratio of ELASTIZELL cellular concrete is a variable dependent upon density and cement content. A high water-cement ratio is required in the low-density range to maintain stability of the foam and in the high-density range to maintain workability of the mix. The water-cement ratio must be increased for any specific density as the cement factor is decreased.

8. Proportioning of mixes up to about 95 pcf is done on a theoretical basis, using the summation of absolute volumes and weights. Above 95 pcf, the proportioning deviates from theory due to arching of sand particles which entrains air. The graphs developed have taken this arching effect into account; however, sand gradation and type of mixer may affect the foam time somewhat. It is recommended that the mix be designed as described in this report and that the foam time be modified in the field if required.

APPENDIX

TABLE I. VARIATION OF COMPRESSIVE STRENGTH AND MODULUS OF ELASTICITY WITH AGE

Batch Ja 29-13
Sand-Cement Ratio = S/C = 3.00
Water-Cement Ratio = W/C = 0.53 (by wt.)
Cement Content = 7.17 Sack per cu yd
Additive - Pozzolith No. 3, 1/4 lb per sack cement
Wet Density = 113 pcf
Avg. Dry Density = 106 pcf.

Number of Specimens	Age at Test, Weeks	Compressive Strength, psi	Young's Modulus, E, psi
2	2	2650	--
3	4	2810	1,435,000
3	6	2965	--
3	8	3100	1,905,000
2	10	3130	1,770,000
2	12	3078	2,120,000

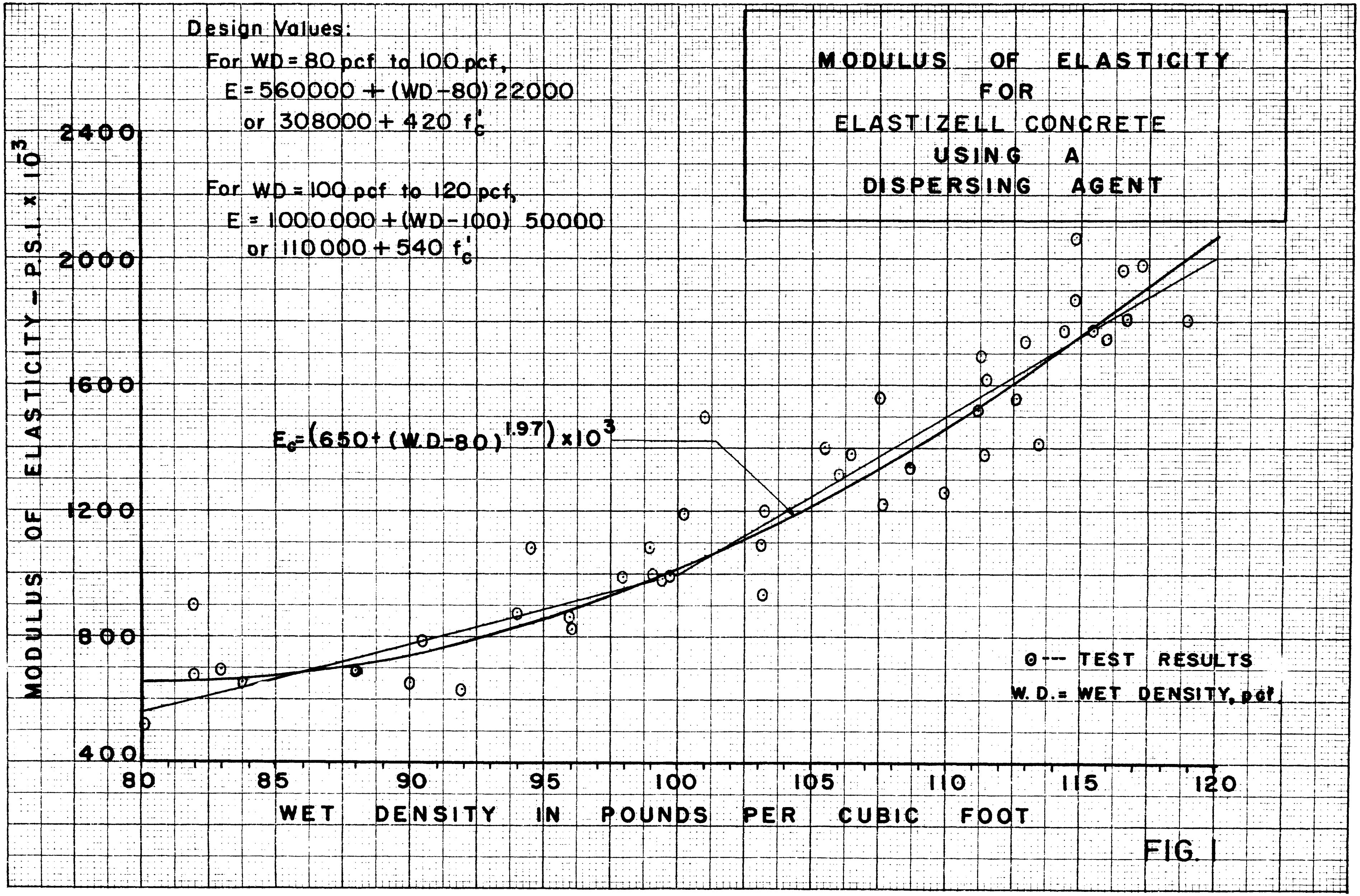
MODULUS OF ELASTICITY
FOR
ELASTIZELL CONCRETE
USING A
DISPERSING AGENT
Design Values:
For WD = 80 pcf to 100 pcf,
E = 560000 + (WD-80) 22000
or 308000 + 420 f'c
For WD = 100 pcf to 120 pcf,
E = 1000000 + (WD-100) 50000
or 110000 + 540 f'c
Ec = (650 + (W.D-80)^1.97) x 10^3
O --- TEST RESULTS
W. D. = WET DENSITY, pcf.
MODULUS OF ELASTICITY - P.S.I. x 10^3
2400
2000
1600
1200
800
400
80
85
90
95
100
105
110
115
120
WET DENSITY IN POUNDS PER CUBIC FOOT

FIG. I

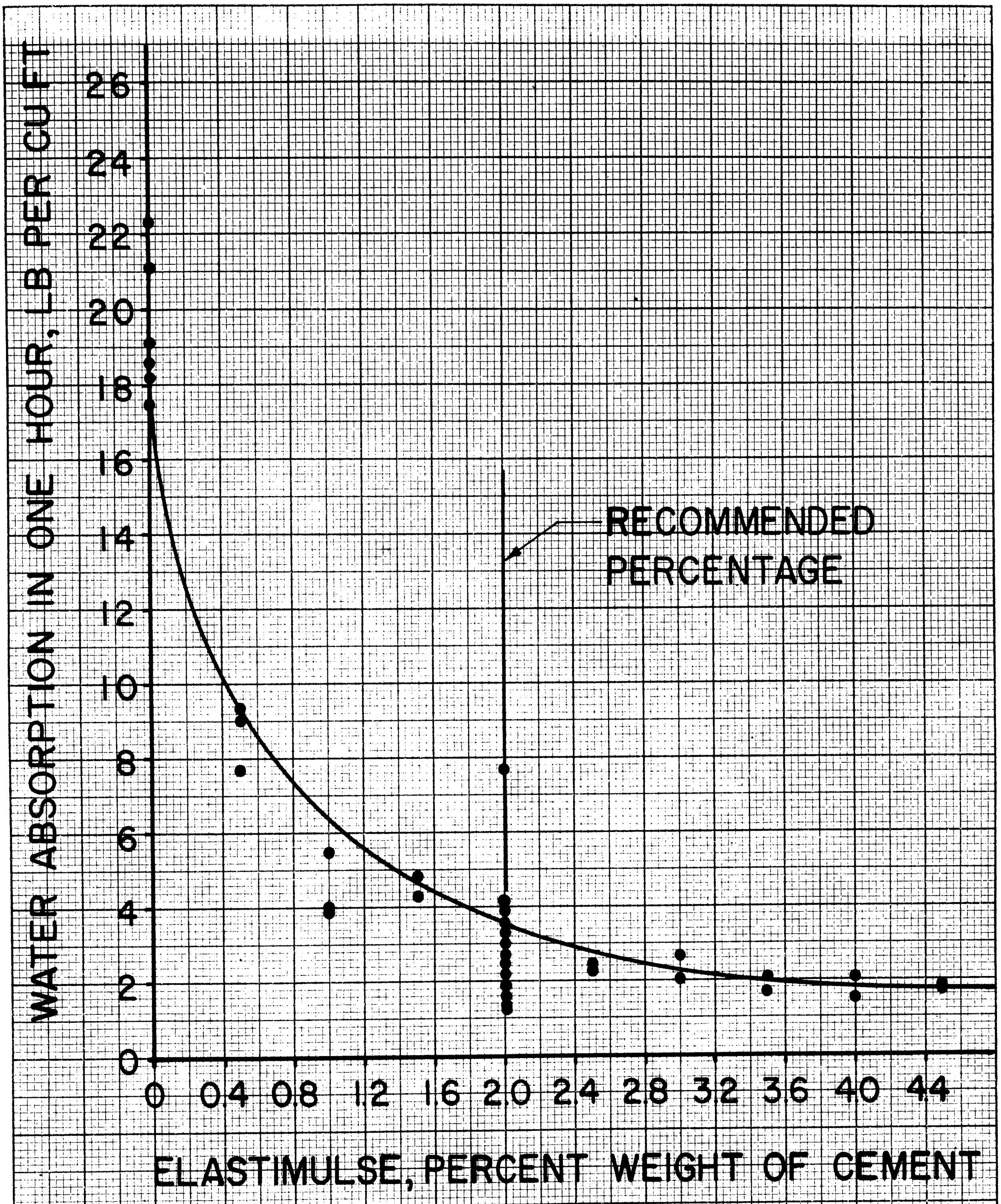

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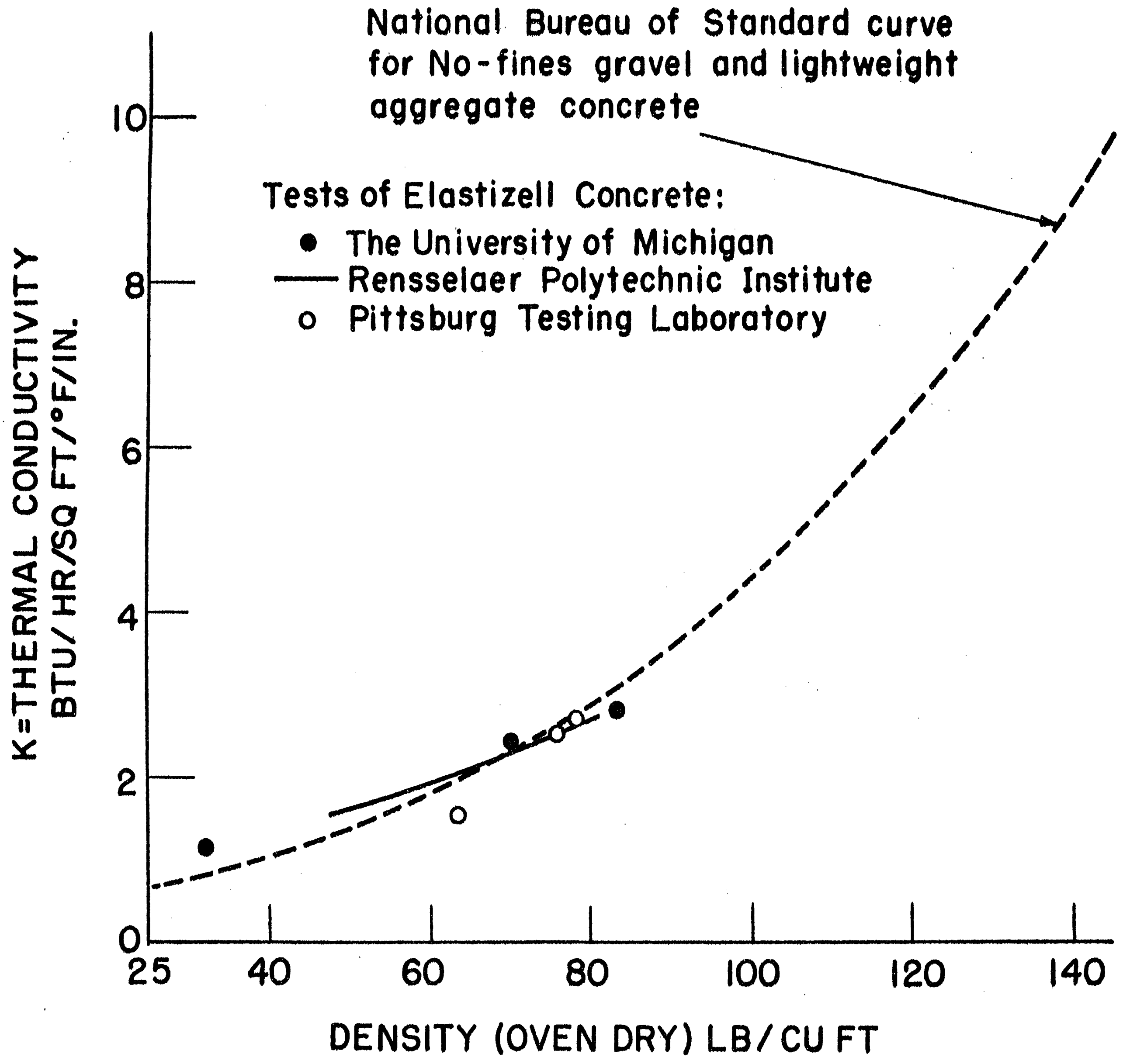
FIGURE 2



THERMAL CONDUCTIVITY VS. DRY DENSITY

FIGURE 3

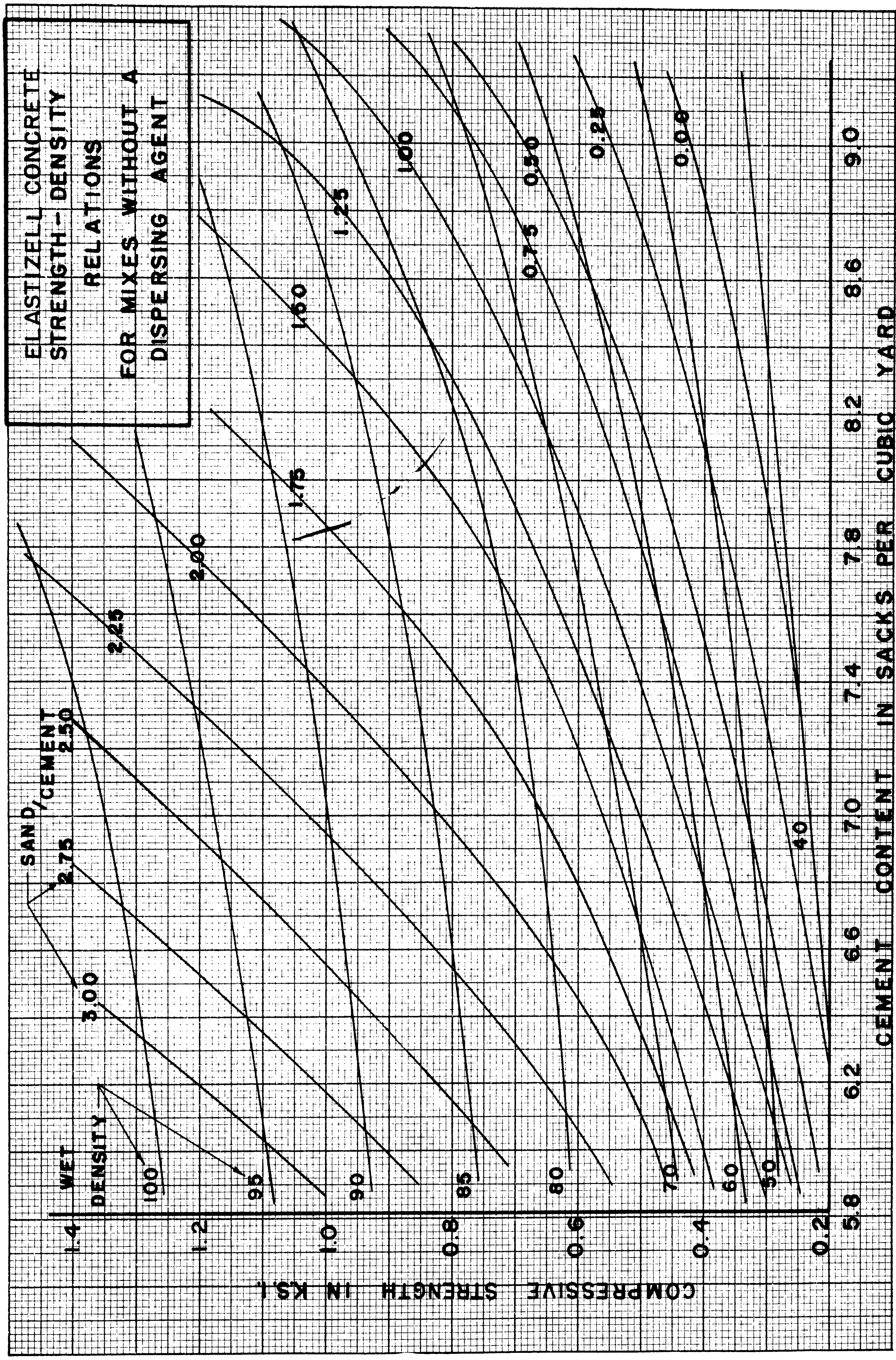

ELASTIZELL CONCRETE
STRENGTH - DENSITY
RELATIONS
FOR MIXES WITHOUT A
DISPERSING AGENT
SAND/CEMENT
3.00
2.75
2.50
2.25
2.00
1.75
1.60
1.25
1.00
0.75
0.50
0.25
0.00
WET DENSITY
100
95
90
85
80
70
60
50
40
COMPRESSIVE STRENGTH IN K.S.I.
1.4
1.2
1.0
0.8
0.6
0.4
0.2
CEMENT CONTENT IN SACKS PER CUBIC YARD
5.8
6.2
6.6
7.0
7.4
7.8
8.2
8.6
9.0

FIG. 4

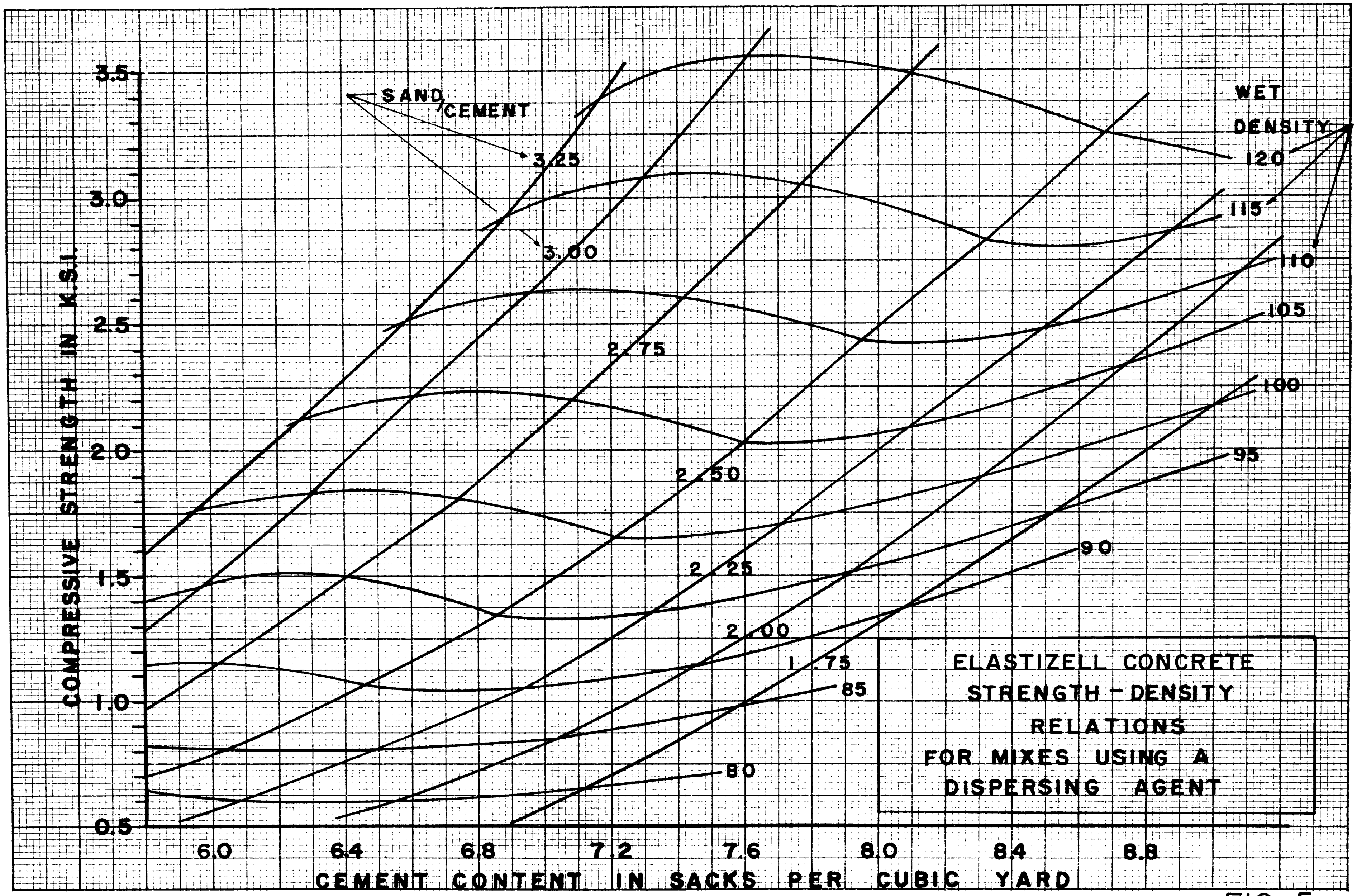

ELASTIZELL CONCRETE
STRENGTH - DENSITY
RELATIONS
FOR MIXES USING A
DISPERSING AGENT
COMPRESSIVE STRENGTH IN K.S.I.
3.5
3.0
2.5
2.0
1.5
1.0
0.5
CEMENT CONTENT IN SACKS PER CUBIC YARD
6.0
6.4
6.8
7.2
7.6
8.0
8.4
8.8
SAND/CEMENT
3.25
3.00
2.75
2.50
2.25
2.00
1.75
WET DENSITY
120
115
110
105
100
95
90
85
80

FIG. 5

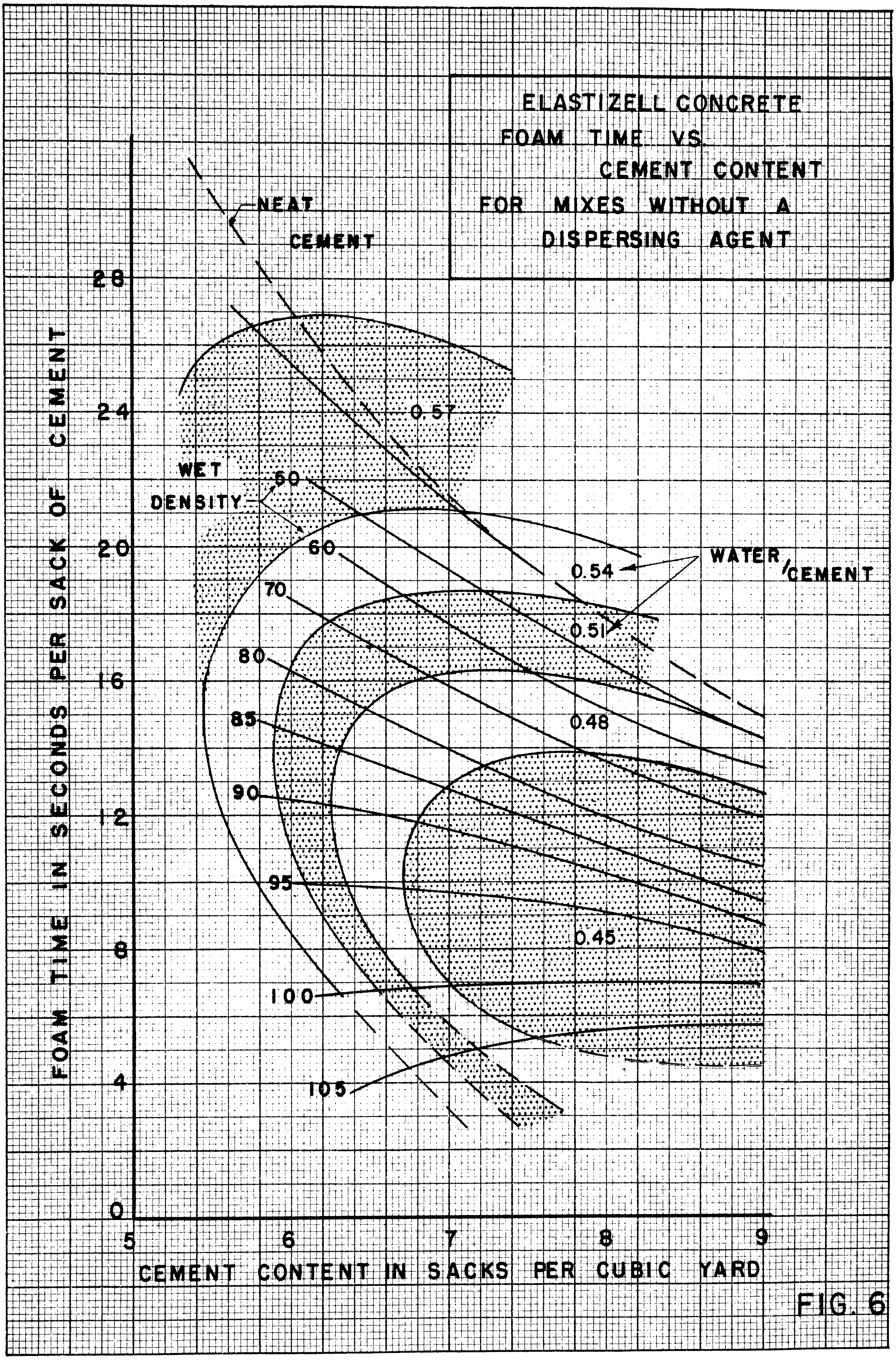

ELASTIZELL CONCRETE
FOAM TIME VS. CEMENT CONTENT
FOR MIXES WITHOUT A DISPERSING AGENT
NEAT CEMENT
WET DENSITY
50
60
70
80
85
90
95
100
105
0.57
0.54
0.51
0.48
0.45
WATER/CEMENT
FOAM TIME IN SECONDS PER SACK OF CEMENT
0
4
8
12
16
20
24
28
5
6
7
8
9
CEMENT CONTENT IN SACKS PER CUBIC YARD

FIG. 6

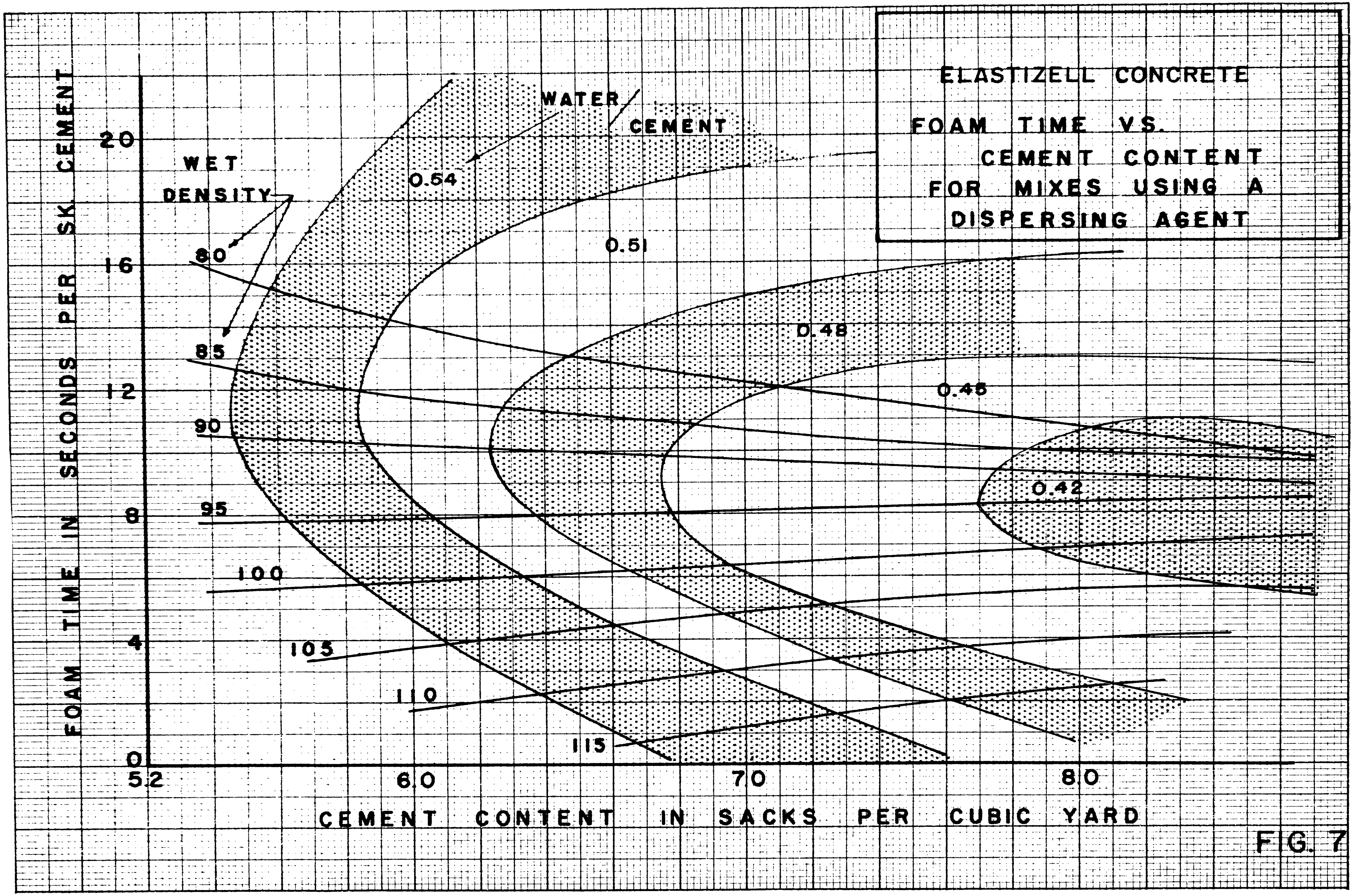
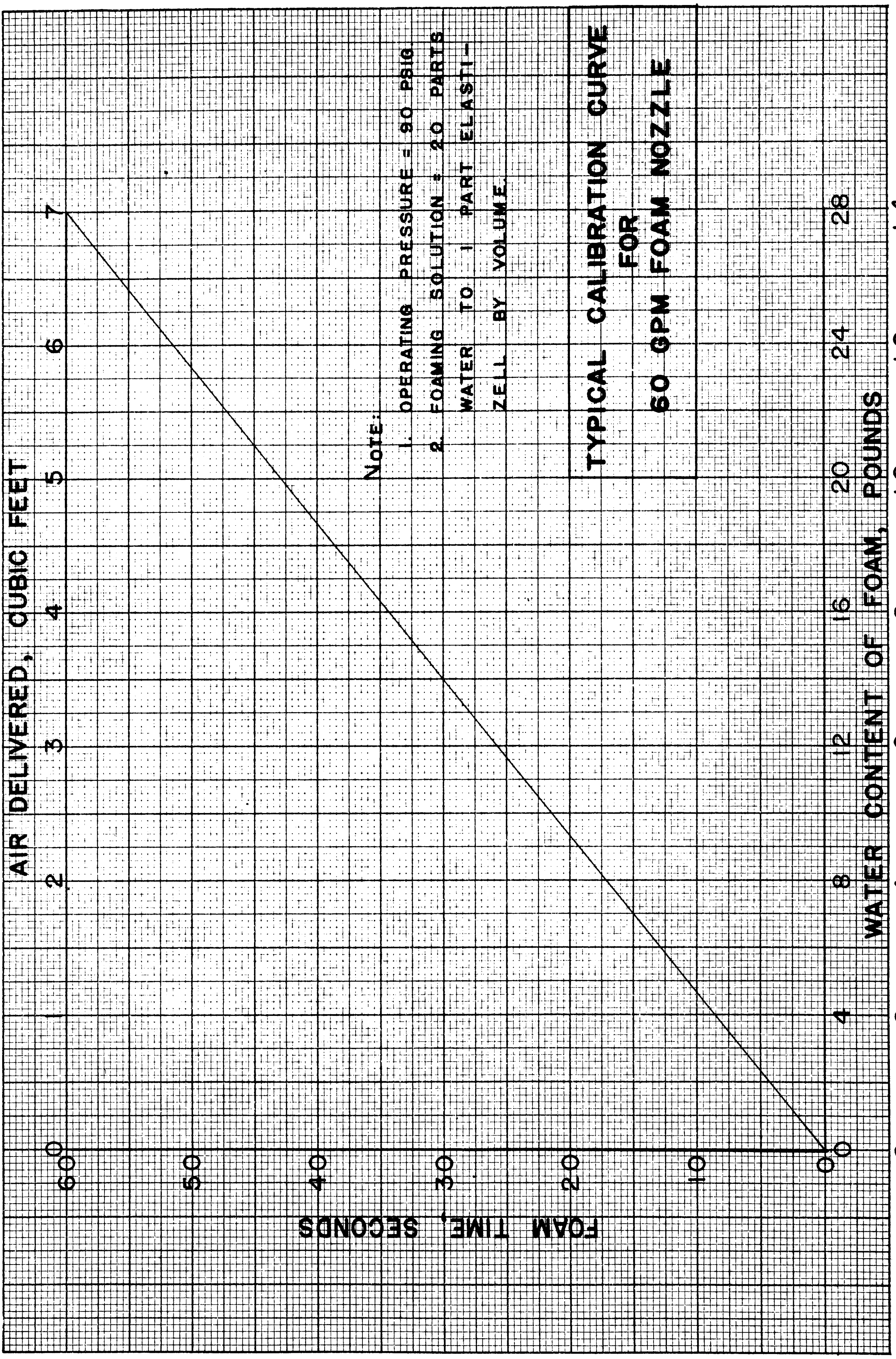

ELASTIZELL CONCRETE
FOAM TIME VS. CEMENT CONTENT FOR MIXES USING A DISPERSING AGENT
FOAM TIME IN SECONDS PER SK CEMENT
0
4
8
12
16
20
CEMENT CONTENT IN SACKS PER CUBIC YARD
5.2
6.0
7.0
8.0
WATER CEMENT
0.54
0.51
0.48
0.45
0.42
WET DENSITY
80
85
90
95
100
105
110
115

FIG. 7



TYPICAL CALIBRATION CURVE
FOR
60 GPM FOAM NOZZLE

NOTE:
1. OPERATING PRESSURE = 90 PSIG.
2. FOAMING SOLUTION = 20 PARTS WATER TO 1 PART ELASTIZELL BY VOLUME.

FIG. 8

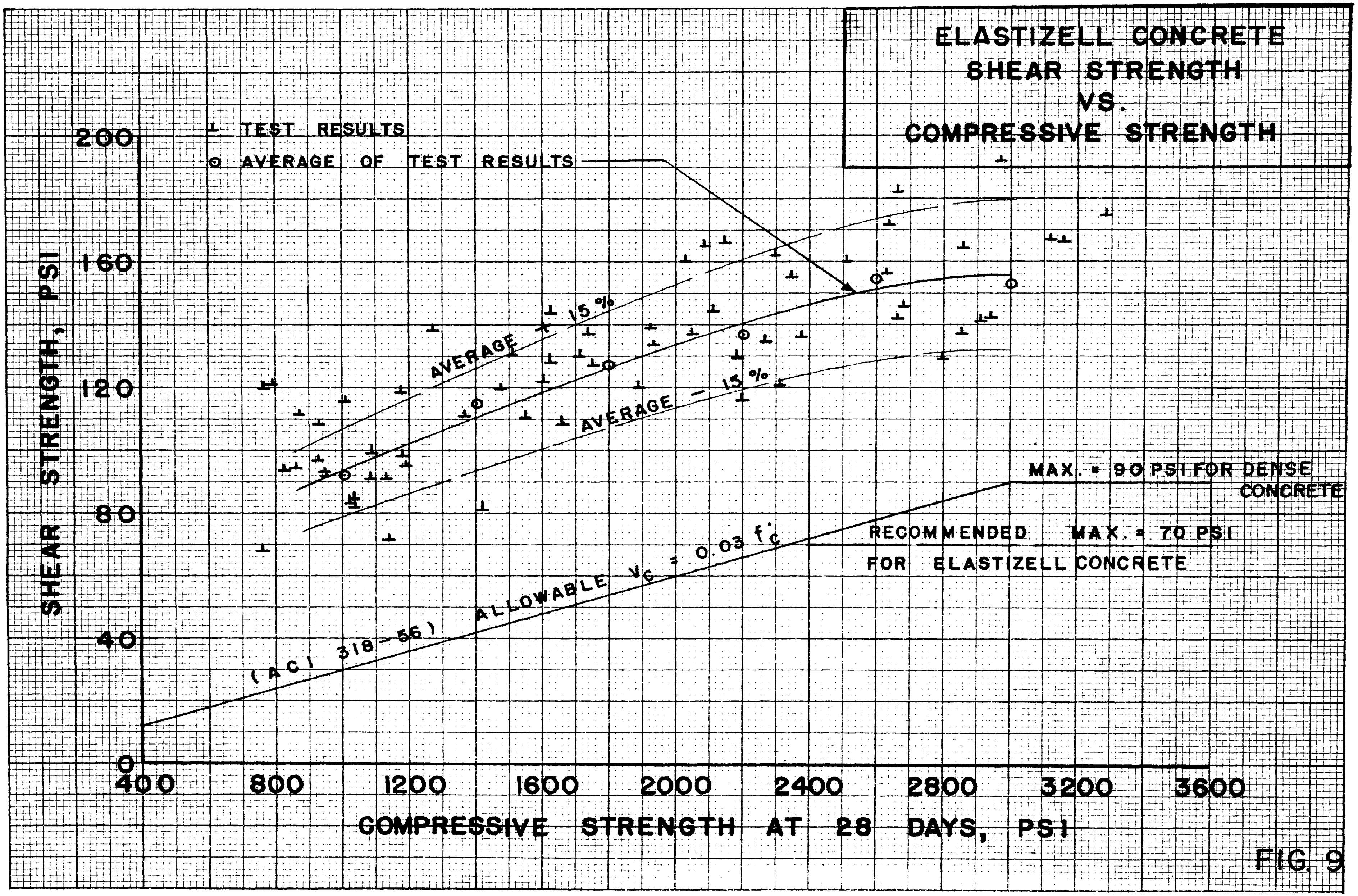

ELASTIZELL CONCRETE
SHEAR STRENGTH
VS.
COMPRESSIVE STRENGTH
⊥ TEST RESULTS
⊙ AVERAGE OF TEST RESULTS
AVERAGE + 15 %
AVERAGE
AVERAGE − 15 %
MAX. = 90 PSI FOR DENSE CONCRETE
RECOMMENDED MAX. = 70 PSI
FOR ELASTIZELL CONCRETE
(ACI 318-56) ALLOWABLE $v_c = 0.03 f'_c$
SHEAR STRENGTH, PSI
0
40
80
120
160
200
400
800
1200
1600
2000
2400
2800
3200
3600
COMPRESSIVE STRENGTH AT 28 DAYS, PSI

FIG. 9

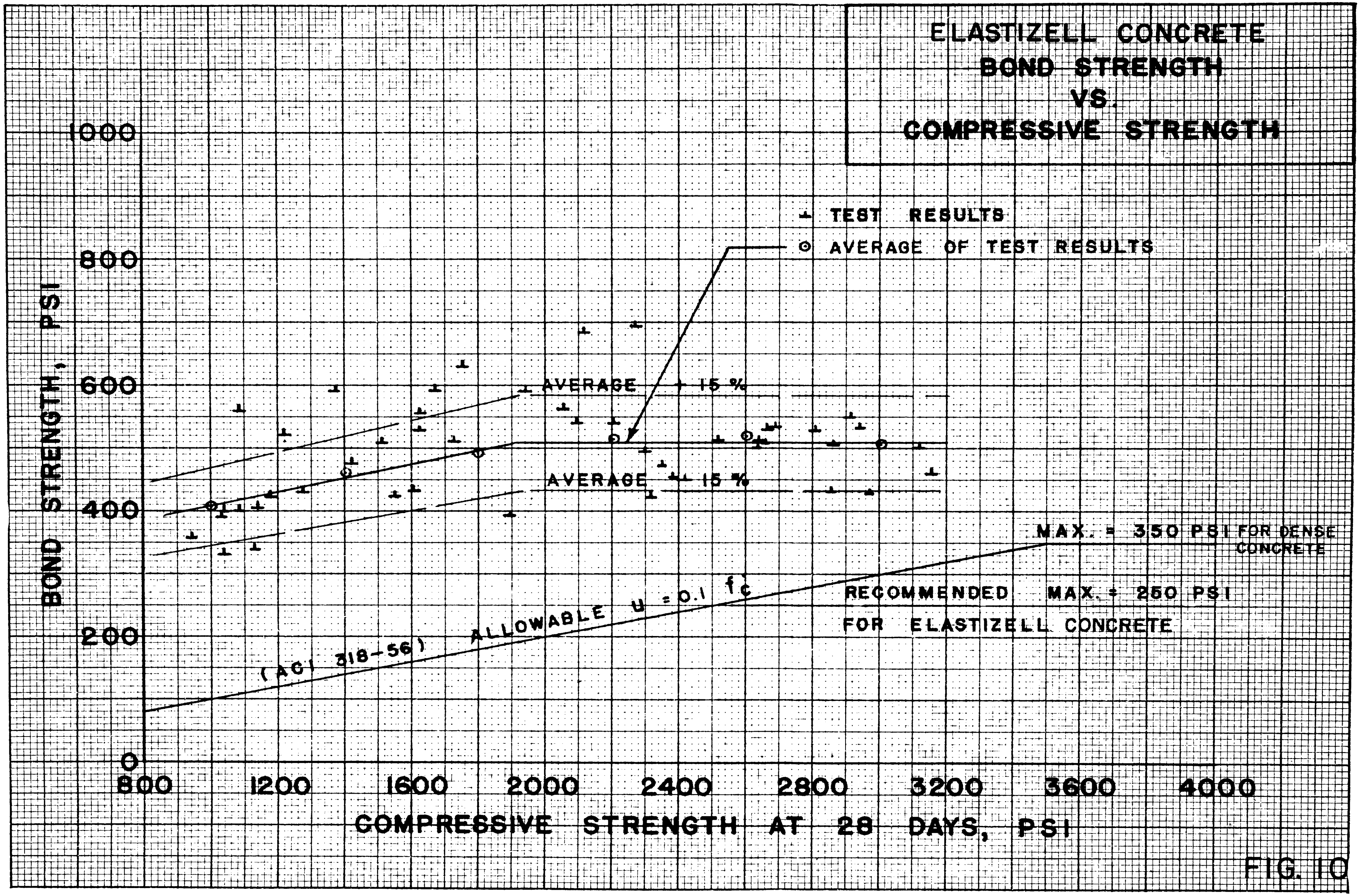

ELASTIZELL CONCRETE
BOND STRENGTH
VS.
COMPRESSIVE STRENGTH

FIG. 10

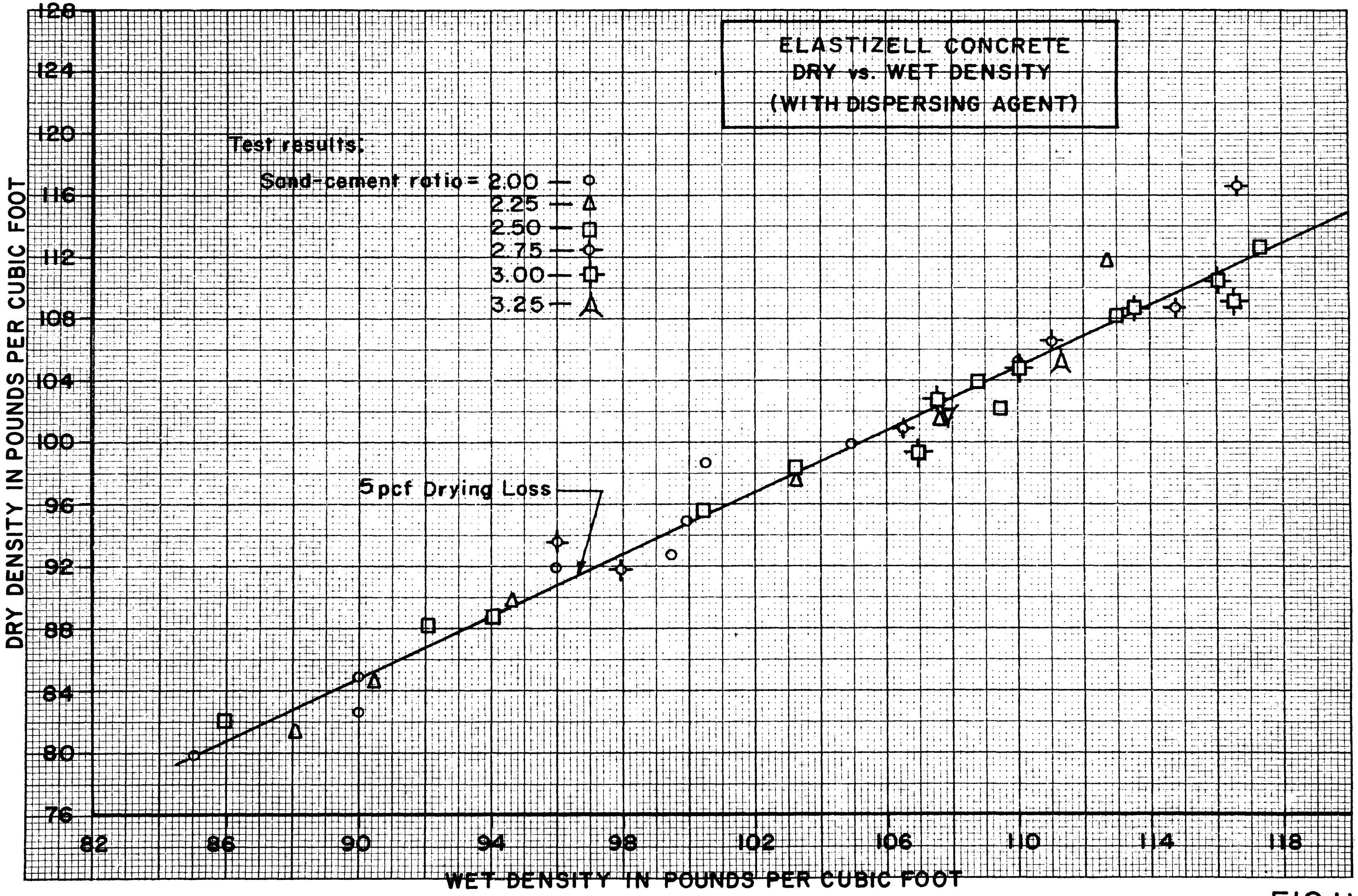

ELASTIZELL CONCRETE
DRY vs. WET DENSITY
(WITH DISPERSING AGENT)
Test results:
Sand-cement ratio = 2.00 — ○
2.25 — △
2.50 — □
2.75 —
3.00 —
3.25 —
5 pcf Drying Loss
DRY DENSITY IN POUNDS PER CUBIC FOOT
128
124
120
116
112
108
104
100
96
92
88
84
80
76
WET DENSITY IN POUNDS PER CUBIC FOOT
82
86
90
94
98
102
106
110
114
118

FIG. 11

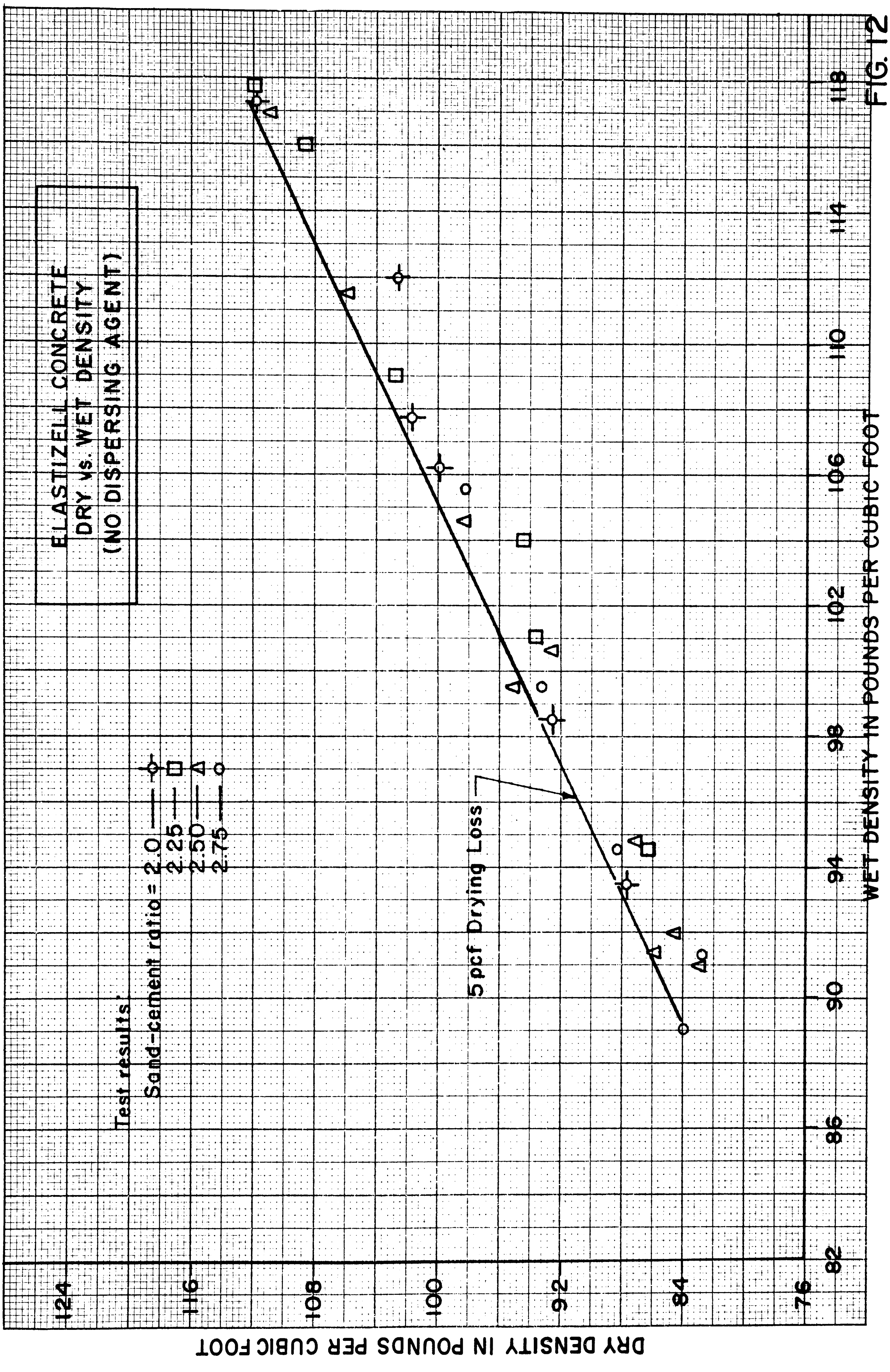

ELASTIZELL CONCRETE
DRY vs. WET DENSITY
(NO DISPERSING AGENT)
Test results:
Sand-cement ratio = 2.0
2.25
2.50
2.75
5 pcf Drying Loss
WET DENSITY IN POUNDS PER CUBIC FOOT
82
86
90
94
98
102
106
110
114
118
DRY DENSITY IN POUNDS PER CUBIC FOOT
76
84
92
100
108
116
124

FIG. 12

EXAMPLE NO. 1

Mix Design for Structural ELASTIZELL Cellular Concrete

Required: f'_c = 2500 psi at 28 days
Solution: Entering Fig. 5 at 2500 psi on the ordinate, it is found that 110 pcf concrete will satisfy the requirement with a cement content as low as 6.6 sacks per cubic yard. For economy, select 6.6 sacks per cubic yard. The sand-cement ratio is 3.25.

Entering Fig. 7 on the abscissa at 6.6 sacks per cubic yard, it is found that the foam time required to produce 110 pcf concrete is 2.6 seconds per sack of cement and that the water-cement ratio is 0.54 parts by weight. The mix proportions are:

Material	Parts by Weight	Weight Per Cubic Yard (lb)
Cement	1.0	6.6 x 94 = 620
Water	0.54	0.54 x 620 = 335
Sand	3.25	3.25 x 620 = 2015
ELASTIMULSE	0.02	0.02 x 620 = 12
		= 2982 lb

Foam time = 6.6 x 2.6 = 17.2 seconds per cu yd
Check: 110 lb/cf x 27 cf/cy = 2970 lb

The insignificant error of 12 lb arises from the reading of Fig. 5 which gives a net density of about 110.5 for a cement content of 6.6 and a S/C ratio of 3.25. The mix may be corrected to a density of 110 by reducing the weight of sand by 12 lb.

Two corrections should be made in the weight of material required:

1. The water content of the foam must be deducted from the water requirement. Entering Fig. 8, it is found that in 17.2 seconds of foam production, 8.0 lb of water is used.

2. The moisture content of the sand must be deducted from the water requirement. An equal weight of sand must be added to maintain the proper sand-cement ratio.
   Assuming 5% moisture in the sand, the correction is

   .05 x (2015 - 12) = 100 lb

The corrected proportions become

			Weight per cubic yard
Cement			620
Water	335-100-8.0	=	227
Sand	2015-12+100	=	2103
ELASTIMULSE			12

Foam time = 17.2 seconds
Dispersing agent at 1/4 lb/sack cement =
6.6 x 0.25 = 1.6 lb.

The insulation, modulus of elasticity, shear, and bond values are found in Figs. 3, 1, 9, and 10, respectively, to be

K = 4.9 Btu/hr/sq ft/°F/in.
E_c = 1,460,000 psi
v_c = 70 psi
u = 250 psi

EXAMPLE NO. 2

Mix Design for Nonstructural ELASTIZELL Cellular Concrete

Required: K = 3.0 Btu/hr/sq ft/°F/in.
Solution: Entering Fig. 3, it is found that the oven-dry density of the concrete may not exceed 81 pcf. Since 5 pcf is lost upon drying, the wet density of the concrete may not exceed 86 pcf. After determining the strength requirement, a mix may be designed as illustrated in Example No. 1 with a maximum wet density of 86 pcf.