IOWA STATE HIGHWAY COMMISSION

MATERIALS DEPARTMENT

SPECIAL INVESTIGATIONS SECTION

FINAL REPORT OF R-259

A STUDY OF

Methods to Increase Durability of Reactive ("D" Cracking) Coarse Aggregate in Portland Cement Concrete

AUGUST 15, 1973

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Research Project R-259
Final Report

METHODS TO INCREASE DURABILITY OF REACTIVE ("D" CRACKING) COARSE AGGREGATE IN PORTLAND CEMENT CONCRETE

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Ames Laboratory

By

Ronald D. Less

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METHODS TO INCREASE DURABILITY OF REACTIVE ("D" CRACKING) COARSE AGGREGATE IN PORTLAND CEMENT CONCRETE

1.0 Introduction

The coarse aggregates used for Portland Cement concrete in southwest Iowa have exhibited a poor serviceability. This early failure is attributed to a characteristic commonly referred as "D" cracking. "D" line cracking is a discolored area of concrete caused by many fine, parallel hairline cracks. "D" line cracking is primarily caused by the movement of water in and through coarse aggregate with a unique pore structure. The presence of the water in the aggregates at the time of freezing causes the "D" cracking to occur and early failure.

By making the pore structure less permeable to moisture, it is thought the durability factor of the concrete should increase. By drying the aggregate before mixing and then mixing with the cement, the particles of cement should enter the outer pore structure, and upon hydration make the pore structure less permeable to moisture.

2.0 Purpose

The purpose of this project, R-259, is to determine a feasible way of coating coarse aggregate prior to and during the mixing operation in order to increase the durability of the freeze and thaw beams.

3.0 Materials

The Type I cement used in this project was a blend of seven different cements tested under Lab No. AC2-95.

The fine aggregate from Hallett's pit at Ames (Sp. G. 2.67) complied with the standard specification 4110. This sand has been used as a standard for the ASTM C-291 durability work.

The coarse aggregates are limestone samples from the Argentine Limestone formations (Menlo Quarry) and the Winterset Limestone formations (Crescent Quarry). These samples, assigned Lab No. AAC2-19,20,524, and 539, used an AASHO 57 gradation.

The only admixture used was Ad Aire ACA9-24 for air entrainment. This Ad Aire is a vinsol resin produced by Carter Waters of Kansas City, Missouri.

4.0 Laboratory Procedure

Three different mixing procedures were used for both the Menlo and Crescent stone. Each of these mixing procedures was also incorporated in two different mix proportions, B-3 and C-3, as shown in the Standard Specifications.

The coarse aggregate for the standard mixing procedure (1) was soaked for a minimum of 20 hours prior to being spread out and dried to a surface dry condition before mixing. The coarse aggregate for the comparative test specimens (mixing procedure 2 and 3) was oven dried at 225°F. for a minimum of 20 hours and then allowed to come to room temperature before mixing. Proportioning allowances for predetermined absorption of the coarse aggregate were made.

The fine aggregate was air dried and assumed to have an absorption of 0.5%.

4.1 Mixing And Molding Procedure

Mixing Procedure 1:

The mixing procedure for the standard specimens was:

1) Weigh and add the fine aggregate
2) Weigh and add the cement

3) Mix for one minute
4) Weigh and add the coarse aggregate
5) Mix for one minute
6) Mix for three minutes while adding the air entraining agent in approximately one half of the required water and then adding water to yield a slump of 2-1/2 $\pm$ 1/2 inches. The air was adjusted to yield 6 $\pm$ 1%. All tests were conducted after step seven was completed.
7) The mix was allowed to stand for 15 minutes and was then mixed for three minutes before checking slump and air and making the specimens.

Mixing Procedure 2:

The first mixing procedure for the dry coarse aggregate was:

1) Weigh and add the dry coarse aggregate
2) Weigh and add cement
3) Mix for one minute
4) Mix for four minutes while adding mixing water with air entraining agent and then adding the proportioned sand.
5) The mix was allowed to stand for 15 minutes and was then mixed for three minutes before checking slump and air and making the specimens.

Mixing Procedure 3:

The second mixing procedure for the dry coarse aggregate was:

1) Weigh and add the mixing water with the proper amount air entraining agent
2) Weigh and add the cement
3) Mix for one minute
4) Weigh and add dry coarse aggregate
5) Mix for one minute
6) Weigh and add the fine aggregate
7) Mix for three minutes
8) Allow the mix to rest for 15 minutes and then remix for three minutes before checking slump and air and making the specimens.

Molding Procedure:

1) Determine and record low pressure air test
2) Determine and record slump test
3) Mold three 4"x4"x18" Conrad freeze thaw durability specimens by the standard procedure (consolidated in two layers.)
4) Mold four 6"x12" horizontal compression specimens by the standard procedure (consolidated in two layers.)

4.2 Curing Methods

The curing of concrete compression specimens was:

1) Cover with polyethylene film for 20 to 24 hrs.
2) Store in moist room (ASTMC-511) for 25 days.
3) Soak in water tank for 48 hours.

The curing of the durability specimens was:

1) Cover with polyethylene film for 20 to 24 hrs.
2) Store in moist room 89 days (ASTMC-511).
3) Soak in 40°F. water bath one day.

4.3 Testing Procedure

Testing for compressive strength will be at 28 days.

Testing for durability was in accordance with ASTM C-666 Procedure B except that:

1) The beams were 18" long.
2) The beams were not weighed.

5.0 Interpretation of Results

The durability factors, compressive strengths, and growth in percent are tabulated in Table II. The durability test (freezing in air and thawing in water ASTM C-666 Procedure B) was continued for 300 cycles, or until the dynamic modulus was reduced to 60% of the original dynamic modulus, whichever occurred first.

Figure No. I and II are comparisons of the durability factors for the three mixing procedures. The Crescent stone showed a decrease in durability factor from the standard mix (1) for both mixing procedure 2 and 3 and mixes, B-3 and C-3. The Menlo stone exhibited the same decrease in durability factor for C-3 mix. The B-3 mix did show a slight increase in durability factor when compared with mixing procedure 1 (D.F. = 78) to mixing procedure 2 (D.F. = 80).

The comparisons of the compressive strengths are shown on Figures 3 and 4. For both the Menlo and Crescent stone, the compressive strength (P.S.I.) increased above the standard (1) for mixing procedures 2 and 3. This increase would indicate the cement has entered the pores of the coarse aggregate and has caused much better matrix-aggregate bond. Also mixing procedure 3 with the cement, water and air entraining agent mixed together before mixing with the coarse aggregate showed increased strengths over mixing procedure 2 with the coarse aggregate and cement mixed together before adding water.

From Table II, the comparison of growth of the test beams can be made. The Menlo stone showed an increase in growth from mixing procedure 1 through 3 for both the B-3 and C-3 mix. The Crescent stone reached the 60% of original frequency before the 300 cycles were complete. However, the same general trend can be realized when the number of cycles are considered.

7.0 Summary

In Conclusion:

1) The durability results of mixing procedures 2 and 3 did not indicate a feasible way of coating the coarse aggregate prior to or during the mixing operation.

2) Mixing procedures 2 and 3 did improve compressive strength, but due to construction problems and the decrease in durability mentioned above, both procedures can not be utilized.

TABLE I

Absolute Volume and Batch Weights

	Mix Number					
	B-3			C-3		
Material	Absolute Volume		Weights 1 cu. yd.	Absolute Volume		Weights 1 cu. yd.
Cement	.090539		479	.114172		604
Water	.152017		256	.153840		259
Air	.060000		**	.060000		**
Fine Aggregate	.313850		1412	.301895		1358
Coarse Aggregate	.383594	Menlo	1719	.370093	Menlo	1659
		Crescent	1707		Crescent	1647

** Air agent at 1 fluid ounce per sack of cement.

TABLE NO. II

Durability Factor, Compressive Strengths, and Growths

Quarry	Mixing Procedure	Mix	Durability Factor	Compressive Strength (PSI)	Growth at Cycles (In.)	*
Menlo	1	B-3	78	3780	.051	300
		C-3	70	4530	.047	300
	2	B-3	80	4230	.054	300
		C-3	63	4900	.089	300
	3	B-3	56	4305	.085	282
		C-3	44	4910	.098	220
Crescent	1	B-3	66	4025	.114	300
		C-3	59	4590	.153	295
	2	B-3	39	4290	.098	196
		C-3	52	4900	.140	261
	3	B-3	58	4490	.132	290
		C-3	40	5280	.125	198

* Growth was measured at 300 cycles or 60% of original frequency, whichever occurred first.

FIGURE I

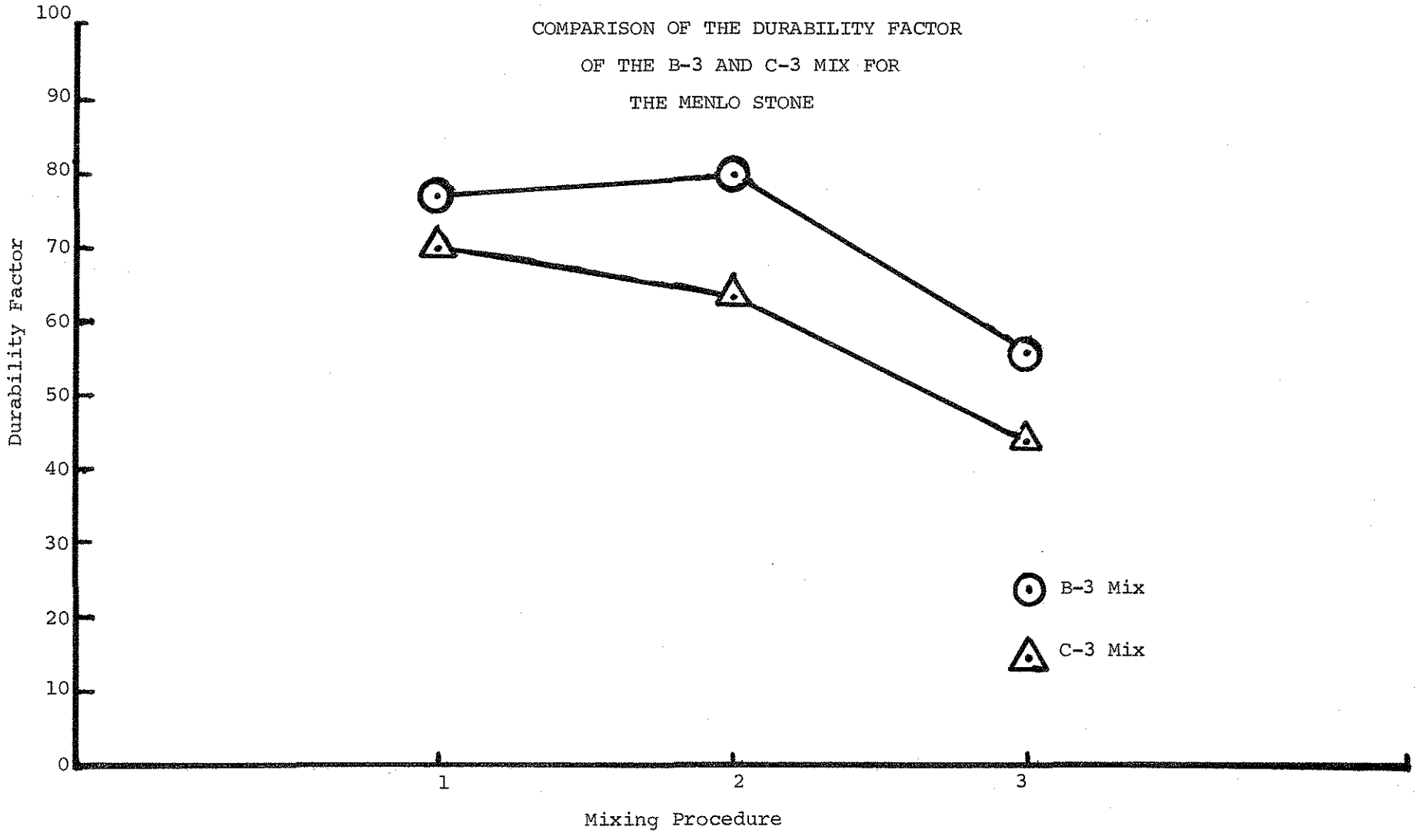
COMPARISON OF THE DURABILITY FACTOR
OF THE B-3 AND C-3 MIX FOR
THE MENLO STONE
Durability Factor
100
90
80
70
60
50
40
30
20
10
0
1
2
3
Mixing Procedure
B-3 Mix
C-3 Mix

FIGURE II

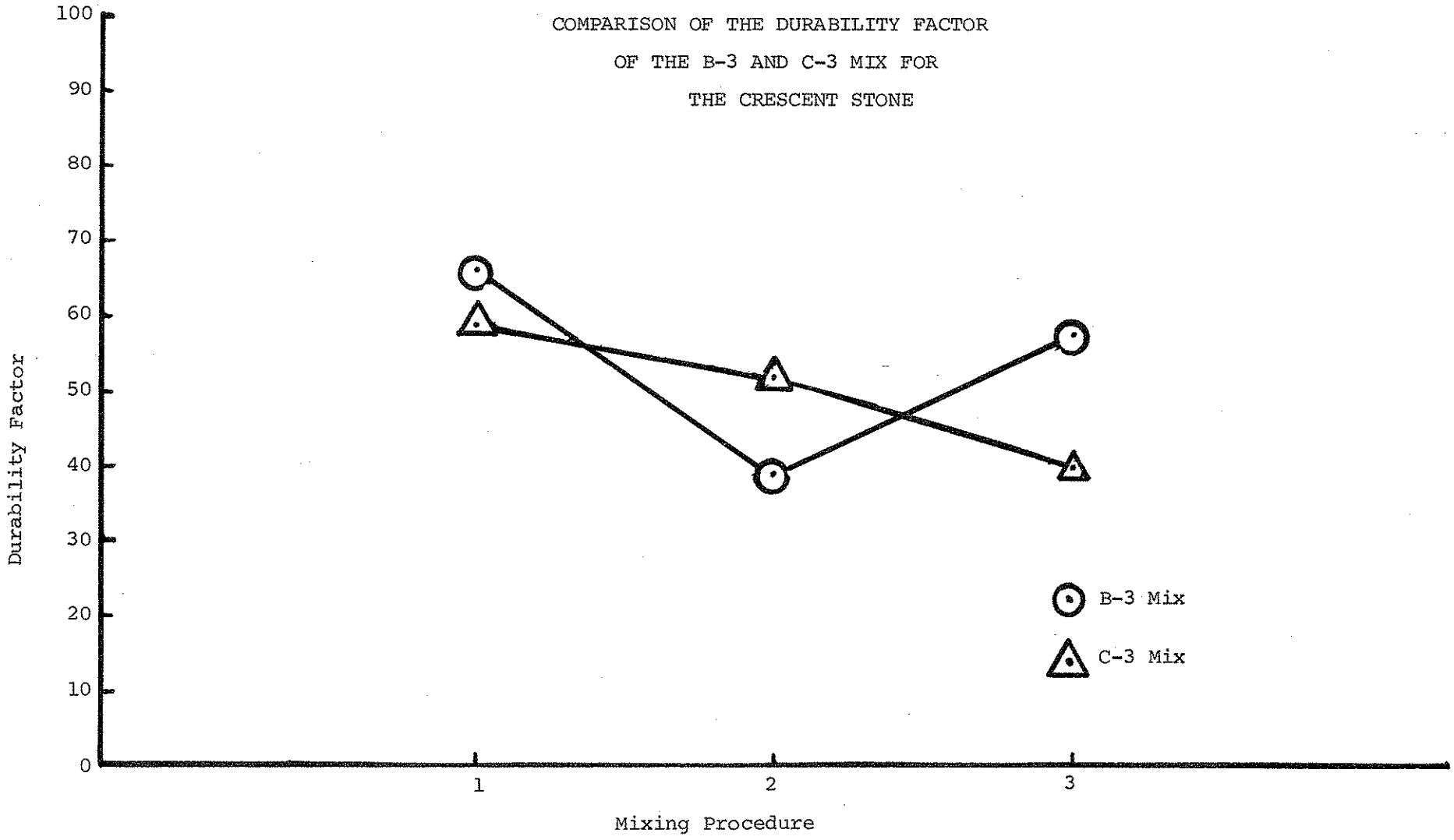
COMPARISON OF THE DURABILITY FACTOR
OF THE B-3 AND C-3 MIX FOR
THE CRESCENT STONE
Durability Factor
100
90
80
70
60
50
40
30
20
10
0
1
2
3
Mixing Procedure
B-3 Mix
C-3 Mix

FIGURE III

COMPARISON OF THE COMPRESSIVE STRENGTH
OF THE B-3 AND C-3 MIX FOR
THE MENLO STONE

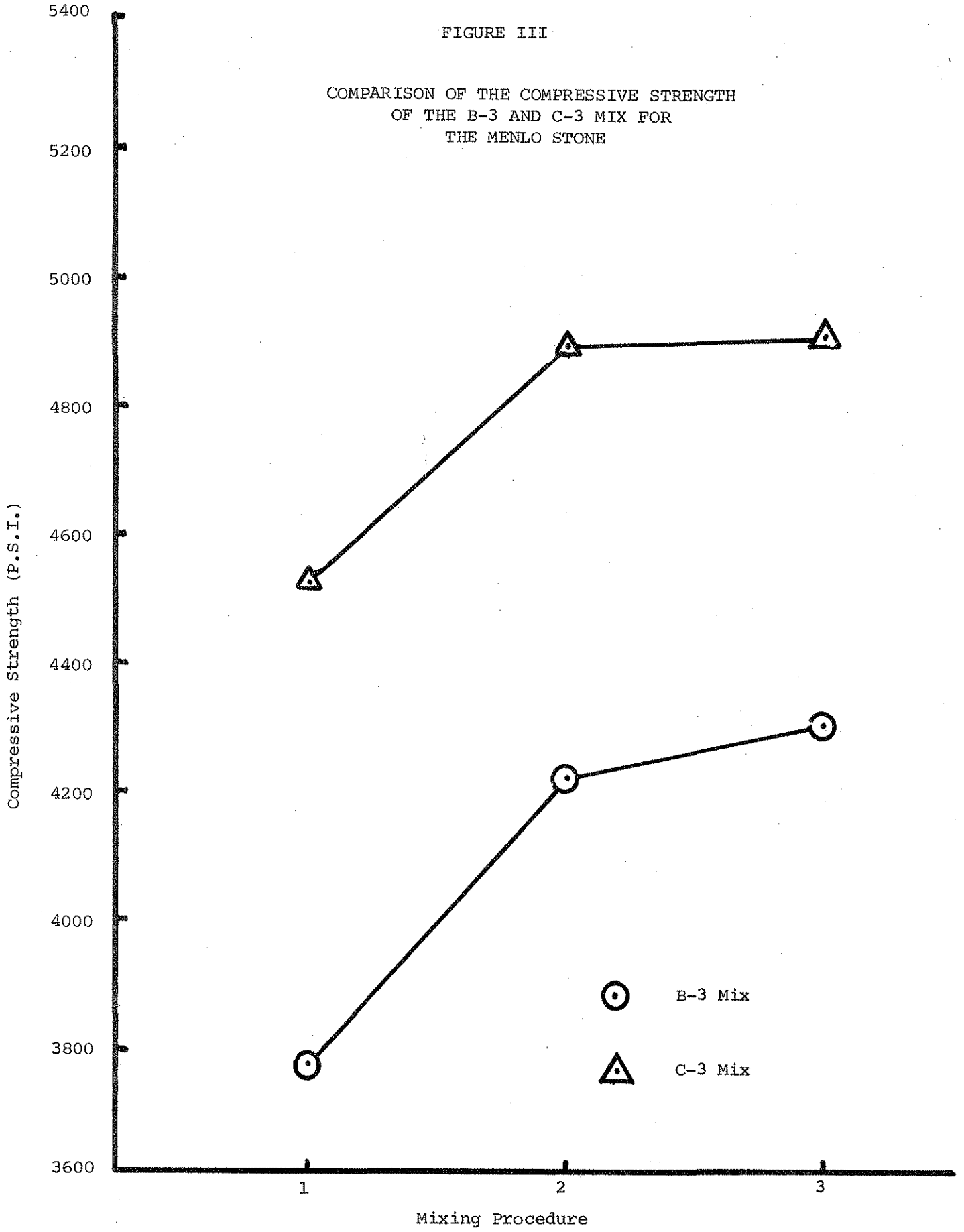

FIGURE IV

COMPARISON OF THE COMPRESSIVE STRENGTH
OF THE B-3 AND C-3 MIX FOR
THE CRESCENT STONE