Report of Concrete Investigations in Research Projects C-14; and C-15

A Study of the Effect of Fine Aggregates on the Durability of Concrete

by
S. T. Collier
Materials Engineer

Highway Materials Research Laboratory
Kentucky Department of Highways
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INTRODUCTION

Research Projects C-14 and C-15 were set up as purely laboratory studies with the same objective; that is, to study the effect upon the strength and durability of normal portland cement concrete by supplementing portions of standard concrete sand with variable amounts of "Fine" sands (sands passing Size No. 30 sieve). This investigation is not correlated with any Highway Department field projects. Project C-14 was begun June 16, 1944 and tests completed April 20, 1945. Project C-15 was begun August 2, 1944 and tests were completed August 1, 1945.

MATERIALS

Each project consists of three sets of test specimens designated as Series A, B, and C, and each set consists of three 6" x 12" cylinders and six 3" x 5" x 20" beams, with the exception of Series 14-A in which two of the beams were damaged while handling, thus making a total of 18 cylinders and 34 beams for the two projects.

The cement, a standard brand of portland, and the coarse aggregate were constant for the six mixes. The coarse aggregate was crushed limestone (Size No. 6 Department of Highways Specifications) in stock at the laboratory, the source of which is undetermined. See Table No. I for data pertaining to the coarse aggregate.

The fine aggregates were sands from four sources described as follows:

Source A - Ohio River, Cleves Ohio, a sand meeting the requirements of the Kentucky Standard Specifications (1938) for concrete and used as the basic material for Project C-14.

Source B - Ohio River, Louisville, Ky. A sand meeting the requirements of the Kentucky Standard Specifications (1938) for concrete and used as the basic material for Project C-15.

Source C - Buckhorn Creek, Breathitt County, Ky. A fine sand, 100 percent of which passed the Size No. 30 sieve, and used in Project C-14 in combination with sand from Source A.

Source D - Louisville, Kentucky. A bank sand finer than the No. 30 sieve and used in Project C-15 in combination with sand from Source B.

(Note - These source designations apply only in this report for reference and not for permanent identification).

Descriptions identifying the six mixes or series of specimens with respect to their fine aggregate content are listed as follows:

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Series A - The fine aggregate is 100 percent sand from Source A.

Series B - Sands from Sources A and C combined in the proportions of 80 - 20 percent by weight.

Series C - Sands from Sources A and C combined in the proportions of 72 - 28 percent by weight.

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Series A - The fine aggregate is 100 percent sand from Source B.

Series B - Sands from Sources B and D combined in the proportions of 90 - 10 percent by weight.

Series C - Sand from Source B processed by crushing a portion of the sizes passing the Size No. 16 sieve in order to increase the percentage passing the No. 30 sieve and obtain a final gradation comparable to that in Series B. This processing procedure was completed in three steps - (1) A sufficient quantity of the sand was selected and screened over a No. 16 sieve. (2) Twenty-five percent of that passing the No. 16 sieve was passed twice through a roll crusher and a sieve analysis made. (3) All fractions were recombined into the original amount and thoroughly mixed preparatory for use in the concrete mix.

For data pertaining to the fine aggregates see Tables II and III.

The basis of design for all the concrete mixes in the two projects is as follows:

Cement - 6 sacks per cubic yard

Free Water - 5.75 gallons per sack of cement.

Ratio of Fine to Coarse Aggregates - 40 - 60 percent by weight.

Slump - Approximately 2 inches.

TABLE I - Data for Coarse Aggregate Used in Research Projects C-14 & C-15

Aggregate	Specific Gravity	Percent Absorption	Sieve Analysis	
			Sieve Size	% Passing
Crushed Limestone Size No. 6	2.68	1.3	1-1/2 inch	100.0
			1 inch	95.7
			3/4 inch	64.7
			1/2 inch	29.1
			3/8 inch	14.3
			No. 4	7.2
			No. 8	3.6

TABLE II - Data for Fine Aggregates Used in Research Project C-14

Aggregate	Conc. Sand Source A	"Fine" Sand Source C	Combined 80% A 20% C	Combined 72% A 28% C
Used in	Series A	---	Series B	Series C
	Sieve Analyses			
Sieve Size	Percentages Passing			
3/8 inch	100.0	100.0	100.0	100.0
No. 4	99.6	100.0	99.7	99.7
No. 8	86.7	100.0	89.4	90.4
No. 16	67.8	100.0	74.2	76.8
No. 30	43.2	100.0	54.6	59.1
No. 50	12.0	71.7	23.9	28.7
No. 100	2.9	27.0	7.7	9.7
Specific Gravity	2.67	2.65	2.67	2.67
Percent Absorption	1.0	1.0	1.0	1.0

TABLE III - Data for Fine Aggregates Used in Research Project C-15

Aggregate	Conc. Sand Source B	"Fine" Sand Source D	Combined 90% B 70% D	Processed Sand Source B
Used in	Series A	---	Series B	Series C
	Sieve Analyses			
Sieve Size	Percentages Passing			
3/8 inch	100.0	100.0	100.0	100.0
No. 4	99.3	100.0	99.4	99.3
No. 8	93.2	100.0	93.9	93.2
No. 16	75.9	100.0	78.3	75.9
No. 30	46.9	100.0	52.2	52.2
No. 50	7.2	97.9	16.3	15.0
No. 100	0.6	64.1	7.0	5.8
Specific Gravity	2.63	2.63	2.63	2.63
Percent Absorption	1.0	1.0	1.0	1.0

PROCEDURE

The concrete was mixed in single batches of sufficient size to complete each series. Water was added in varying amounts to the several mixes as was necessary to maintain the desired slump, more water being required for those mixes containing the "Fine" sands. No adjustments were made in the mix proportions to compensate for any deviation in the cement

content from the design proportions, due to these water variables (See Table IV under Concrete Mix Data).

The specimens were cast in steel molds in accordance with standard methods. After about 24 hours they were removed from the molds and placed in the moist room and cured at temperature of 70 $\pm$ 2°F. until 28 days of age. At the end of this period the cylinders were tested for compressive strength and the initial sonic moduli of elasticity for the beams were evaluated. One half of the group were selected as control specimens and broken immediately in flexure under third point loading. The remaining beams were placed directly into Freezing and Thawing (Frozen in air at 0°-F. and thawed in water at approximately 40°F.). The sonic modulus evaluation was made periodically for the beams in Freezing and Thawing for purpose of estimating a 50 percent loss in the moduli of rupture for the specimens - the criterion for removing them from the test. This percentage of loss was exceeded in some instances due to the increase in rapidity of deterioration near the end of the test. Upon their removal from Freezing and Thawing these beams were also broken in flexure under third point loading. See Table IV for test results and Plates I and II for graphic representation of the relative strengths of the individual specimens.

RESULTS

With reference to the test results summarized in Table IV it is noted that these values are rather consistent for the specimens in each series; that is, the test results for the individual specimens, in most instances, do not vary appreciably from the averages for the series. This fact is an indication that these results are representative of the relative values of the six mixes. However, considerable variations occur between the results of the several series.

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Research Project

No.	Thar Specimens al d. nic Mod. x10-6 P.S.I.	Modulus of Rupture P.S.I.	Per Cent Change in E	P Per Cent Change in Mod. Rup.
1	15	16	17	18
	5.10	888	+0.6	+8.8
	5.28	768	-0.8	-5.9
	-	-	-	-
	5.19	828	-0.1	+1.5
C-1	2.06	96	-57.0	-82.5
	0.00	0	-100.0	-100.0
	2.00	48	-52.4	-91.2
	1.35	48	-69.8	-91.2
	2.26	72	-55.9	-87.5
	3.43	96	-37.7	-83.3
	1.72	96	-64.2	-83.3
	2.47	88	-52.6	-84.7
	3.85	360	-35.3	-51.1
	4.10	360	-31.4	-51.1
	4.29	336	-29.4	-54.3
	4.08	352	-32.0	-52.2
	4.12	312	-30.1	-60.2
C-1	3.71	288	-35.6	-63.3
	3.91	336	-34.2	-57.1
	3.91	312	-33.3	-60.2
	1.74	96	-70.3	-87.5
	2.03	120	-63.4	-84.4
	2.58	168	-53.9	-78.1
	2.12	128	-62.5	-83.3

ns 14 & 15.
g values in Columns 11 & 16.

Normally it would be expected that somewhat equal values would have resulted from the tests for the specimens in Series 14A and 15A. This is true for the control specimens, but the beams subjected to freezing and thawing tests in the 14A series, evidently, were unaffected for the number of cycles exposed. On the other hand, those in the 15A series show an average of 52.2 percent loss in modulus of rupture for essentially the same exposure. There is no wide difference in the physical characteristics of the sands in the two series, the latter having a lower specific gravity. The physical tests were limited to sieve analysis, specific gravity, and absorption.

The records of Series 14B and 14C are relatively poor, for the control specimens as well as those in Freezing and Thawing. This is partially attributed to the increase in free water. The fine aggregate was 80 percent and 72 percent, respectively, of the sand used in the 14A supplemented with the fine creek sand.

Series 15B compares favorably with Series 15A throughout, the fine aggregate being 90 percent of the sand used in 15A and 10 percent fine bank sand.

Series 15C also has a relatively poor record in which there was a considerable increase in the free water added to the mix. The fine aggregate was the processed sand from the same stock as that used in 15A.

This investigation hardly establishes the relative merits of the various sands or combination of sands, with consideration given to the differentials in the cement factors and water-cement ratios for the several mixes, but the results seem to be of enough significance to warrant further and more comprehensive studies of this nature.

PLATE I

RESEARCH PROJECT C-14

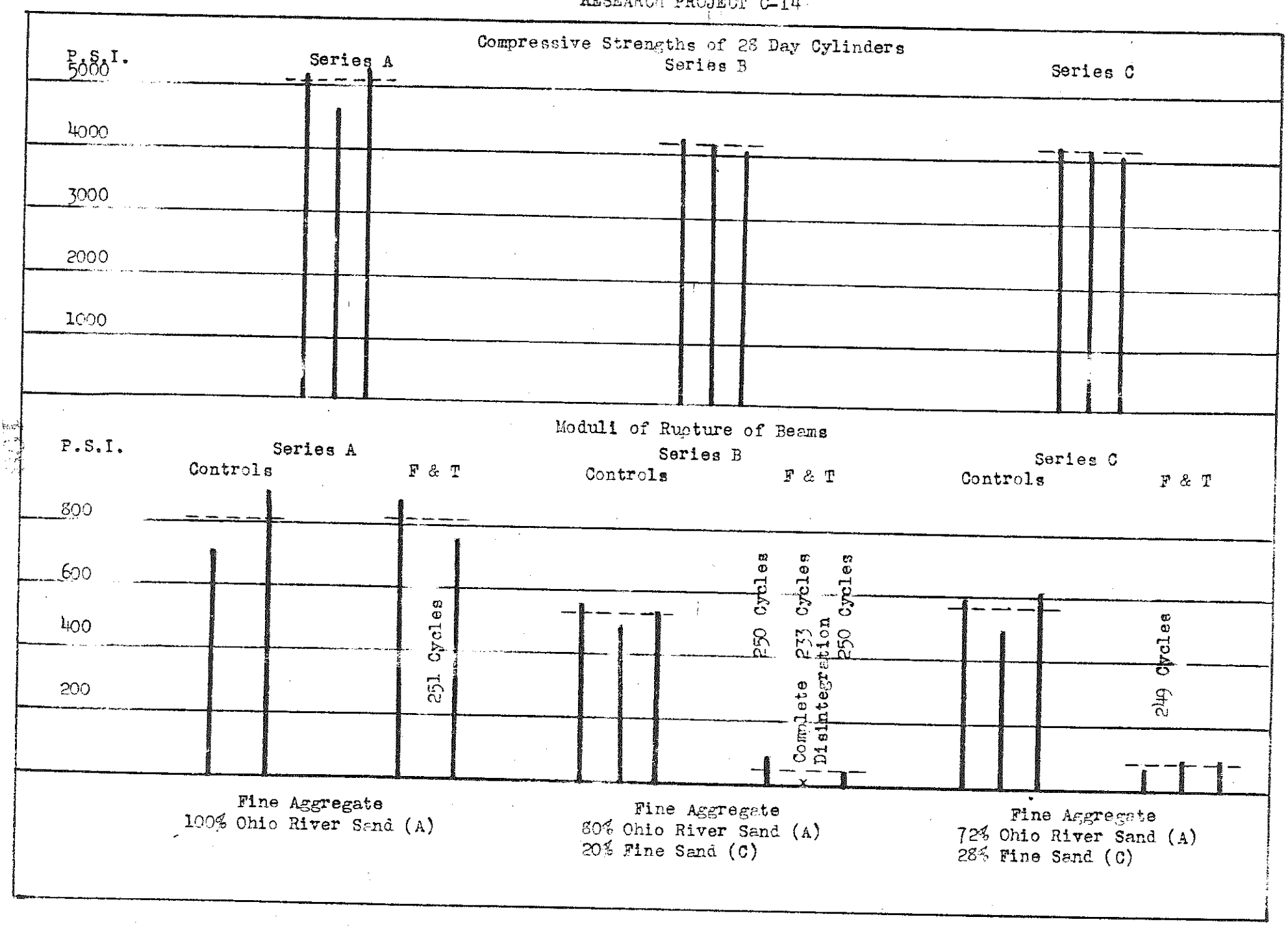

PLATE II

RESEARCH PROJECT C-15