Report of Concrete Investigation
in
Research Project C-20

Durability of Concrete as Affected by Absorbed Moisture in Tennessee River Gravel Aggregate

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INTRODUCTION

This project is more or less a preliminary investigation of Tennessee River gravel relative to the effect of the moisture condition of the aggregates upon the durability of concrete. Certain observations made in the field indicated that absorbed moisture in the aggregate could have a marked effect on concrete, so this study was made in an attempt to give quantitative significance to the observation.

During inspections made of pavements, in which Tennessee River gravel was used as the coarse aggregate, it has been observed that sizable portions of the pavement remained in good condition, despite the fact that a very large percentage had failed seriously. Furthermore, it is known that in some instances dry aggregates were used during construction with adjustments made in the concrete to compensate for the absence of absorbed moisture.

The general practice was to use the aggregates in the wet condition as delivered in daily shipments. At the same time large stockpiles were maintained for convenient storage and for a reserve supply as a safeguard against suspension of paving operations due to any delay in placing new shipments. It is not unlikely that this occurred on the majority of projects. Nor is it improbable that the moisture condition of a highly porous aggregate has some effect upon the performance of the concrete pavement.

This project was started on July 26, 1945, and completed on March 15, 1946.

MATERIALS

One standard brand of normal Portland cement was used in all mixes. The fine and coarse aggregates were Tennessee River sand and gravel. Portions of both aggregates were delivered to the laboratory in water-tight containers and covered with water in order to retain their "stream-wet" condition. Results of tests for sieve analyses, specific gravities, and percent absorption are given in Table I.

TABLE I. RESULTS OF PHYSICAL TESTS ON AGGREGATES USED IN RESEARCH PROJECT C-20.

Test	Tenn. River Gravel		Tenn. River Sand	
	Sieve Sizes	Percent Passing	Sieve Sizes	Percent Passing
Sieve Analysis (Square Openings)	1-1/2"	100.0	3/8"	100.0
	1"	92.8	No. 4	95.8
	3/4"	70.4	No. 8	85.1
	1/2"	19.2	No. 16	71.6
	3/8"	6.0	No. 30	51.3
	No. 4	0.5	No. 50	9.5
			No. 100	0.3
Specific Gravity	2.43		2.62	
Percent Absorption	6.4% (Stream Wet)		0.9	
	4.7% (Air dried and immersed 4 days)		---	
	2.3% (Air dried and Surf. wet 3 days)		---	

The aggregates were also tested for soundness by immersion in sodium sulfate solution (A.S.T.M. designation C 88-41T) and by freezing and thawing of "stream-wet" samples. Results are given in Table II.

TABLE II. RESULTS OF SOUNDNESS TESTS ON AGGREGATES USED IN RESEARCH PROJECT C-20.

Method of Test	Tenn. River Sand		Tenn. River Gravel	
	No. Alternations	Weighted Ave. Pctg. Loss	No. Cycles	Weighted Ave. Pctg. Loss
Freezing and Thawing Stream-wet Aggregates	5	5.1	2	8.6
	10	5.6	3	21.0
	-	-	5	32.2
Immersion in Na_2SO_4 Solution	5	8.0	5	5.7
	10	9.3	10	14.1
	-	-	15	15.0

The gravel broke down by splitting of the particles and some flaking. Due to lack of material no complete test could be made by freezing and thawing as prescribed by A.S.T.M. designation C 137-38T; that is, by drying out a sample in an oven, immersing it in water for 24 hours, followed by repeated alternations of freezing and thawing. However, a partial test was made with sizes available and the results obtained indicated that this method would compare with the sodium sulfate immersion test, but with hardly as much loss.

PROCEDURE

Test specimens were made up in three series differentiated by the condition of the aggregates and designated as follows:

Series "A" - Contained aggregates in the stream-wet condition.

Series "B" - Contained aggregates in the dry condition; that is, the aggregates had been allowed to dry out on the roof of the laboratory - exposed to sunlight.

Series "D" - Contained the dry aggregates that were sprinkled and maintained surface wet for three days.

Two sets of specimens were made for each series with concrete of approximately 3 inch and 5 inch slumps. Each set consisted of two 6 x 12 inch cylinders and six 3 x 5 x 20 inch beams, thus, making a total of four cylinders and twelve beams for each series and a grand total of twelve cylinders and thirty six beams.

All concrete mixes were designed on a single basis to approximate the following proportions:

Cement - 6 sacks per cubic yard.

Water - 5.75 gallons per sack of cement.

Ratio of Sand and Gravel - 35-65 percent by weight.

Slumps - $\pm$ 3 inches and $\pm$ 5 inches.

There were variations in the above proportions due to variables in added water necessary to produce the required slumps. No readjustments were made in the mix proportions to compensate for these variations. The concrete mix data are listed in Table III.

Each mix was made in one batch of sufficient quantity to cast one set of specimens. The mixing operations were conducted in the usual manner and the specimens were moist-cured for 28 days. At the end of this period evaluations were made for the sonic moduli of elasticity (Eo) for all beams. The cylinders and one half the beams in each set were tested for 28-day compressive and flexural strength respectively. The remaining beams were placed in freezing and thawing. Sonic evaluations were made periodically with the object being to remove the specimens from the test when an average decrease in 30 percent occurred for each set. This value is equivalent to approximately 50 percent loss in the modulus of rupture. All beams were broken under third point loading. Test results are listed in Table III and a graphical representation of the strength of the individual specimen is presented on Plate I.

RESULTS

All specimens subjected to the durability tests failed much too early for durable concrete, but in comparison the specimens in Series B excelled those in Series A in performance. The specimens in Series D compared somewhat favorably with those in Series B.

The beams made with the stream-wet aggregates failed almost to complete disintegration after two cycles of freezing and thawing. The final sonic modulus evaluations for those specimens proved unreliable. It has been observed previously that the greater the percentage of loss in the modulus of rupture in excess of 50 percent, the less reliable is the sonic evaluation.

Each set of specimens with the higher water-cement ratio, in both Series B and D, averaged slightly higher in 28-day strengths and in durability, which fact is contrary to normal expectations.

The specimens with the highest durability (made with the dry aggregates) resulted in an average loss of 62.5 percent in modulus of rupture at the end of only 76 cycles of freezing and thawing. This is a much poorer record than that of Portland cement concretes previously tested in this laboratory.

CONCLUSIONS

The findings in this investigation offer proof that the moisture condition of very porous aggregates does affect the durability of concrete. However, Tennessee River gravel, treated to meet the most desirable condition, remains of questionable value as an aggregate for concrete. Consideration must also be given to the fact that any treatment would add substantially to the initial cost of the aggregate.

PLATE I

RESEARCH PROJECT C-20