HIGHWAY RESEARCH RECORD

Number 73

Symposium on Fly Ash in Concrete

5 Reports

Presented at the
43rd ANNUAL MEETING
January 13-17, 1964

HIGHWAY RESEARCH BOARD
of the
Division of Engineering and Industrial Research
National Academy of Sciences—
National Research Council
Washington, D. C.
1965

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Experimental Concrete Pavement Containing Fly Ash Admixtures

RONALD D. HUGHES
Research Engineer, Kentucky Department of Highways

A 2.388-mi section of four-lane highway in Louisville, Ky., was selected for an experimental fly ash concrete pavement installation. The project was divided into three sections: a control section and two experimental sections containing 94 and 140 lb of fly ash per cubic yard, respectively. The solid-volume of fly ash in excess of that required to replace one sack of cement was considered as fine aggregate. The water was adjusted to provide a slump of approximately 2½ in., and an air-entraining admixture was proportioned at the mixer to provide an air content of approximately 4.5 percent.

Beams and cylinders were cast from various random mixtures within each section. Flexural and compressive strength tests were made at 3, 7 and 28 days, and 3, 6 and 12 mo. Beams were also cast for freeze and thaw testing. Test results to date are included in the report, as well as a description of construction procedures and mix design methods.

Early strengths for concrete placed in the experimental sections were lower than those for concrete placed in the control section. On the basis of limited 3-mo age compressive strength tests, a gain in strength at later ages was achieved through the use of fly ash. No reduction in water requirement was gained through the addition of fly ash.

•IN 1962, the Kentucky Department of Highways began an investigation of the use of fly ash in portland cement concrete for pavements. An experimental project was established to gain experience in the addition of fly ash to concrete. The project was also to serve as a basis for evaluating the performance of a cement-fly ash concrete pavement as compared to that of a normal cement concrete pavement.

Approximately 2⅓ mi of urban, four-lane, divided highway on Poplar Level Road in Louisville, Ky., was chosen for this investigation. The project was divided into three sections: Control Section, Experimental Section A and Experimental Section B. A portion of pavement was placed in one of the experimental sections early in December 1962, and paving was then discontinued due to adverse weather. The major portion of pavement was placed during the period of May and August 1963. This report contains a brief description of the project and a summary of test results to date.

DESCRIPTION OF PROJECT

Two parallel 26-ft wide dual-lane pavements, 9 in. in thickness, were placed on a 4-in. insulation course of dense-graded limestone aggregate. The major portion of concrete used in each of the three sections was placed and finished by conventional mechanical methods. Concrete was placed in two lifts to facilitate the installation of wire mesh at a plane below the final surface one-third the pavement depth. Deformed dowel bars were installed at 30-in. intervals along the centerline of each dual-lane pavement and smooth dowel assembly devices were installed at 50-ft intervals at transverse joints. All joints were sawed.

Paper sponsored by Committee on Chemical Additions and Admixtures for Concrete.

Each material that was common in all sections was invariable in nature and source. Type I normal portland cement from one producer was utilized in all mixtures. The fine aggregate was natural sand and the coarse aggregate was crushed limestone ranging from 2.5 to 0.25 in. in nominal size. The fly ash was locally supplied and specified to meet the requirements of ASTM Designation: C 350-60T. The same brand and type of air-entraining admixture was added to all mixtures at the mixer. Both the cement and fly ash were supplied in bulk.

A slump of approximately 2½ in. and an air content of 4.5 ± 1.5 percent were maintained throughout. Concrete placed in the Control Section contained 6 sk of cement per cubic yard; a ratio of fine aggregate to total aggregate of 37 percent by weight was maintained. Concrete placed in Experimental Section A was proportioned to contain 5 sk of cement and 94 lb of fly ash per cubic yard. All mixtures for Experimental Section A were proportioned on a solid volume basis and the fly ash in excess of that required to replace one sack of cement was considered as fine aggregate. Thus, by deducting a weight of sand equal to this excess, the ratio of fine aggregate to total aggregate combination was maintained at 37 percent by weight. Concrete placed in Experimental Section B was proportioned to contain 5 sk of cement and 140 lb of fly ash per cubic yard. The mixtures for Experimental Section B were proportioned in a manner similar to that used for Experimental Section A.

Materials were dry batched at a plant near the projects and were transported in dry-batch trucks to a Twinbatch mixer at the site. All batches were mixed for a 1-min period. The mixer was rated at 34 cu ft and was operated at a 10 percent overload, giving 37.4 cu ft per batch. All concrete was cured with wet burlap for a minimum of 3 days. Transverse and longitudinal joints were sawed within a 24-hr period after placement of the concrete. Joints were sawed to a depth equal to one-fourth the pavement depth.

Construction supervision and inspection were in accordance with standard departmental procedures for all construction projects. Division of Construction personnel made necessary adjustments in mixture proportions, sampled materials, supervised construction and provided necessary inspectors. Beams and cylinders were cast independently by research personnel for flexural and compressive strength testing at ages of 3, 7 and 28 days and 6 and 12 mo. Three-month compressive strength tests were also made on cylinders and freeze-thaw tests were conducted on 14-day-old beams. Each set of specimens cast consisted of 18 beams and 18 cylinders. All tests were in triplicate. Four such sets of specimens were cast from concrete placed in each of the three sections on the project.

All beams and cylinders were cast and cured in accordance with procedures outlined under ASTM Designation: C 31, Making and Curing Concrete Compression and Flexure Test Specimens in the Field. Compression test specimens, 6 in. in diameter and 12 in. in length, were cast. The specifications designate that coarse aggregate for specimens

TABLE 1

MIXTURE WEIGHTS PER CUBIC YARD—SLUMP AND AIR TEST RESULTS

Section	Date Placed	Material Weight (lb)[a] Free Water	S.S.D. Sand	S.S.D. Stone	Fly Ash	Slump (in.)	Air Content (%)
Control	6-13-63	252.7	1,167	1,987	-	3, 2.5, 2, 2.5	5.2, 4.7, 4.8, 4.6
	7-17-63	264.2	1,156	1,970	-	2.5, 2.5, 2.25, 2.25	4.3, 4.5, 4.5, 4.6
	7-24-63	255.6	1,164	1,983	-	3, 2.5, 3, 3	4.7, 5.0, 4.8, 4.6
	8- 8-63	260.6	1,158	1,973	-	3, 3, 2.5, 3	2.3, 6.2, 6.2, 5.4
Avg.		258.3	1,161	1,978		2.64	4.7
Expr. A	12-5-62	238.9	1,175	2,012	94	2.5, 2.75, 2.5, 2.5	3.7, 4.3, 4.1, 4.7
	6-3-63	261.3	1,146	1,973	94	2, 2.25, 2.5, 2	6.2, 6.1, 5.0, 4.7, 4.9
	6-11-63	253.4	1,138	1,983	94	3, 3, 2, 2.25, 2.25	5.2, 4.8, 4.9, 4.7, 4.6
	8-21-63	250.5	1,157	1,992	94	3, 3, 3, 2.75, 3	
Avg.		258.3	1,161	1,978	94	2.56	4.8
Expr. B	7- 1-63	259.9	1,104	1,976	140	2, 2.25, 2.5, 2.25, 2.5	4.5, 4.9, 5.1, 4.7, 4.6
	7- 3-63	264.2	1,097	1,965	140	2.5, 2.75, 2, 2.25, 2.25	4.8, 4.5, 4.7, 5.0, 4.8
	7-15-63	259.9	1,104	1,974	140	3, 3, 2.5, 3	4.0, 6.5, 4.4, 4.7
	8- 1-63	257.0	1,107	1,978	140	3, 2.5, 2.25, 2.5, 2.5	2.8, 6.0, 4.9, 5.4, 5.6
Avg.		260.2	1,103	1,973	140	2.50	4.8

[a]Cement—564 lb for all control, 470 lb for all experiments.

TABLE 2

STRENGTH TEST DATA

Section	Date Placed	Free Water (lb/cu yd)	Compressive Strength[a] (psi)			Flexural Strength[a] (psi)		
			3 Day	7 Day	28 Day	3 Day	7 Day	28 Day
Control	6-13-63	252.7	3,249	3,806	4,914	806	850	1,050
	7-17-63	264.2	2,882	4,082	4,562	813	938	1,125
	7-24-63	255.6	2,963	4,073	5,453	725	956	1,075
	8- 8-63	260.6	3,447	3,776	4,949	735	1,062	1,263
Avg.		258.3	3,135	3,935	4,970	770	952	1,128
Expr. A	12- 5-62	238.9	1,958	3,872	4,868	385	813	1,106
	6- 3-63	261.3	2,952	3,570	4,619	738	988	1,188
	6-11-63	253.4	2,330	3,270	4,572	550	700	1,015
	8-21-63	250.5	2,896	3,759	4,551	738	900	1,012
Avg.		251.0	2,534	3,620	4,653	603	850	1,080
Expr. B	7- 1-63	259.9	2,855	3,349	5,208	719	863	1,138
	7- 3-63	264.2	2,445	4,124	5,496	687	925	1,275
	7-15-63	259.9	2,460	3,420	4,622	756	731	1,038
	8- 1-63	257.0	3,129	3,414	3,788	773	963	1,250
Avg.		260.2	2,727	3,577	4,799	734	871	1,175

[a] Average of three specimens.

of the size cast shall not exceed 2 in. in nominal size. To comply with that requirement, the fresh concrete used for casting all cylinders was passed through a 2-in. screen so as to eliminate stone greater than 2 in. in nominal size from the mixes. Flexure test specimens, 3- by 4- by 16-in., were cast and the fresh concrete used in the casting of these specimens was passed through a 1-in. screen to meet specification requirements.

RESULTS

The average free-water requirement for those mixtures from which beams and cylinders were cast were 30.99 gal/cu yd for the Control Section, 30.12 gal/cu yd for Experimental Section A, and 31.23 gal/cu yd for Experimental Section B. Slump and air-content tests were conducted four or five times per day during placement. Slumps ranged from 2 to 3 in. and averaged $2\frac{5}{8}$ in. Air contents ranged from 2.3 percent, an exceptional case, to 6.5 percent and averaged 4.78 percent. The quantity of air-entraining admixture required to entrain the desired percent of air was quite variable for mixtures placed within given sections, and no definite quantity of air-entraining agent to be added to mixtures for the various sections could be established. Table 1 gives weights of materials used in the various mixtures from which beams and cylinders were cast. Results of slump and air-content tests are included.

The fine aggregate used throughout the project was dredged river sand, somewhat deficient in fines. It was anticipated that sweetening of the mixtures in the experimental sections through the addition of fly ash would result in a reduction of the free-water requirement below that of the control mixtures. Tests on laboratory mixtures made before the start of construction indicated such a reduction in the free-water requirements for the experimental mixtures. The approximate free-water requirements for the laboratory mixtures were 31, 29, and 28.5 gal/cu yd, respectively, for the Control, Experimental A and Experimental B mixtures. However, no significant difference in free-water requirement was obtained in actual production of mixtures. In fact, the mixtures for Experimental Section B required slightly more water than those for the Control and Experimental A Sections.

The minimum expected strength of portland cement concrete for pavements as required by the Kentucky Department of Highways is 3,500 psi in compression and 600 psi, modulus of rupture, at 28 days. Specimens from all mixtures placed in the various sections met those designated minimum strength requirements. Strength test results for 3, 7, and 28 days on beams and cylinders cast and tested by Research Division personnel are listed in Table 2. Compressive and flexural strength tests were made in accordance with ASTM Designations: C 39-61 and C 293-59.

The average 3-mo compressive strength for cylinders cast on three various dates from concrete placed in Experimental Section A was 6,030 psi, the average for cylinders cast from concrete placed in Experimental Section B for the one date was 6,812 psi, and the average for cylinders cast from concrete placed in the Control Section for one date was 5,155 psi. Beams from all sections have shown excellent performance in freeze and thaw. Freeze and thaw tests were conducted in a manner similar to that outlined under ASTM Designation: C 310-61T.

CONCLUSIONS

Early strengths for concrete placed in the experimental sections were expected to be somewhat lower than that for the Control Section, unless a significant reduction in the water requirement could be achieved in the experimental sections. The reduction in the water requirement was not achieved, and the strengths through 28 days of concrete in the experimental sections were less than those for the control mixtures. This observation is in accordance with the general conception that pozzolanic benefits develop slowly and do not appear within the first month. On the basis of the limited 3-mo test data, the strengths for the experimental sections are higher than those of the Control, as was expected.

The major difficulty encountered during construction was in dispensing the correct amount of fly ash from the hopper at the batch plant. This problem was corrected by the installation of new rollers in the fly ash hopper. Finishers stated that concrete placed in the experimental sections had about the same finishing characteristics as that placed in the Control Section; however, occasional gumminess or stickiness was encountered when the concrete in the experimental sections was not finished immediately after placement. No definite requirements for the quantity of air-entraining admixture to be used in mixtures for various sections could be established because the quantity for various mixtures for a given section was quite variable.

Approximately 500 ft of pavement were placed in Experimental Section A on December 5, 1962. The temperature dropped below 32 F during the night and remained below freezing for several days thereafter. This section has been observed several times to date, and there is no indication of any detrimental effects therefrom. Extensive performance surveys are to be conducted periodically to evaluate all sections. Recommendations are forthcoming on completion of analysis of data from these performance surveys.