FLYASH IN CONTINUOUS REINFORCED PCC PAVEMENT AND LEAN CONCRETE BASE

Experimental Features
Interim Report
OR 85-01

by

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INTRODUCTION

Flyash is a byproduct of the coal combustion process in modern power stations. It is extracted from exhaust gases by electro-static precipitators, leaving relatively clean air to pass up the smoke stacks. In the presence of moisture, flyash combines with calcium hydroxide to produce a cementitious material which, when used as a replacement for a percentage of cement, is reported to enhance certain qualities of hardened concrete. Since flyash is actually a waste product, it costs considerably less than traditional materials for which it can be substituted.

Nationwide, state highway departments are heeding a recent Federal Highway Administration directive to allow the use of flyash in Portland Cement Concrete (PCC) construction or risk the loss of federal funds. State agencies must remove any restrictions on using flyash modified PCC where technically appropriate, unless they can show why its use would be unsuitable.

Considering this, the Materials Section of the Oregon State Highway Division (OSHD) launched an experimental program in 1984 to evaluate the characteristics of flyash as an admixture in PCC, and develop recommendations for its suitability in Oregon construction. The program, documented in "Evaluation of Flyash as an Admixture in Portland Cement Concrete" (1), was based on tests conducted at the OSHD Engineering Laboratory and a review of available literature pertaining to flyash concrete. Properties studied included durability, strength, time of set, and alkali-aggregate reaction of concrete containing flyash. While results indicated flyash was suitable for use in PCC construction, the report concluded by recommending construction of test sections to evaluate the in-service performance of flyash in PCC pavements.

REPORT OBJECTIVES

This report documents the performance to date of a test section constructed in the summer of 1985 using flyash in lean concrete base (LCB) and continuously reinforced portland cement concrete (CRC).

(1) "Evaluation of Flyash as an Admixture in Portland Cement Concrete" by Michael Maloney, Materials and Testing Specialist, Oregon Department of Transportation, July, 1984.

The objectives of this test section were:

1. To test and evaluate the physical characteristics of flyash concrete in comparison to non-flyash concrete. Tests will be conducted to see if flyash concrete meets OSHD specifications for compressive and flexural strength, and if the current specifications for flyash can be used without modification in flyash concrete.

2. To document the differences in construction characteristics, if any, between flyash concrete and non-flyash concrete, and to determine if the use of flyash concrete poses any significant construction problems.

3. To document the differences in construction costs between flyash concrete and non-flyash concrete.

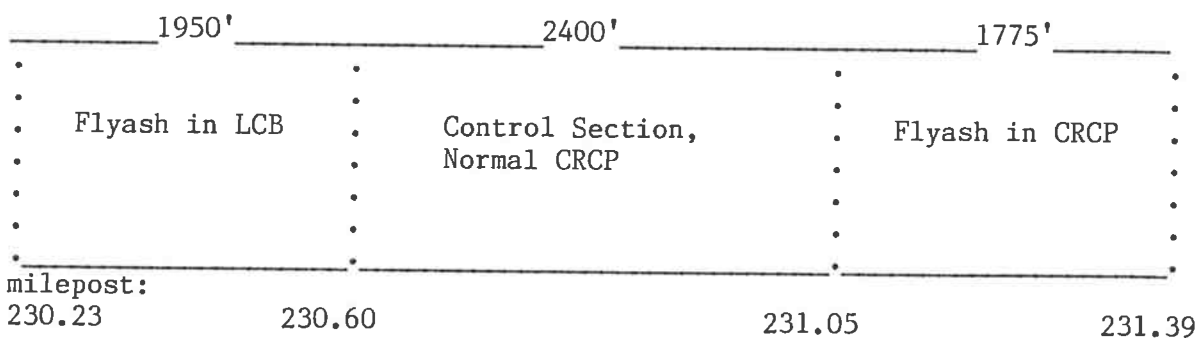
4. To evaluate the long term performance of flyash concrete compared to non-flyash concrete over a period of 5 years to determine if there are any significant differences in durability.

5. To determine if the current procedures for designing non-flyash concrete pavements are applicable to the design of flyash concrete pavements.

PRE-CONSTRUCTION

The test sections were included in the recently completed North Albany - Corvallis/Lebanon Interchange Section on Interstate 5 in Linn County, Oregon. Both test sections are located in the southbound lanes, separated by a 2400 foot control section (see diagram below). The 1950 foot LCB test section, from m.p. 230.23 to m.p. 230.60, was placed on August 29, 1985. The 1775 foot CRC test section, from m.p. 231.05 to m.p. 231.39, was placed on September 4, 1985.

SOUTHBOUND I-5, FLYASH TEST SECTION



The LCB and CRC flyash mix designs used for the test sections were similar to those mix designs without flyash, except for cement content. Basically, the amount of cement was reduced and replaced by flyash at a rate of 1:1.25 (by weight), with 20% of the cement for the LCB, and 15% of the cement for the PCC paving, replaced by flyash.

The portland cement used in the test section, as well as in most of the project, was Ideal, Type I-II. The flyash was Class F, from Centralia, Washington (see Appendix A). The lean concrete mixture consisted of recycled pcc materials run through a crusher and graded to cement treated base gradation.

CONSTRUCTION

An independent silo and feed system was brought onto the job to incorporate flyash into the mixtures. Due to the limited number of weigh hoppers on the batch plant, the flyash was weighed in the cement hopper after the cement had been added. The feed mechanism for the flyash was wired into the computer, and the new mix design was entered. This allowed for double weighing in the hopper at the proper rates.

The nature of the flyash material caused uneven feeding into the weigh hopper. Occasionally, the flyash would not start feeding for several seconds, then would come out in surges. This was not a serious problem, but it did cause slight fluctuations from mix design weights on some batches.

The flyash concrete load batching times showed an increase, in seconds, over normal concrete batching times, resulting from the momentary change-over time from the cement and flyash silos. Also, additional time was spent weighing the total weight of flyash plus cement, which was greater than the weight of cement in the normal mix.

From the plant, the flyash mixtures were hauled by dump truck to the work site. The mix was then dumped, conveyed, spread, vibrated and laid to grade with conventional PCC paving equipment.

As the material was pushed ahead of the paver, the flyash modified mixtures were very homogeneous. In contrast, the mix without flyash appeared segregated and crumbly, due to the larger aggregate separating slightly from the mass.

The roundish flyash particles reduced the water required in the mix, and created a lubricating effect that was demonstrated by how easily the paving machine moved through a large head of flyash material. Behind the finishing machine the surface texture of the flyash mixtures appeared to be more sealed than the normal mix. This made the hand finishing and floating noticeably easier. The finish workers said they could tell the difference between the mixtures, and preferred the flyash modified mixtures.

The increase in workability was most evident in the LCB mixture, where the recycled aggregate materials had caused harshness throughout the job in the non-flyash mix.

POST-CONSTRUCTION

The tining and cure compound application did not follow finishing as soon in the flyash mixtures as it did in the normal concrete. This was anticipated, due to the retarded curing rate of the flyash. However, the additional cure time required was not detrimental to the operation.

The retarded curing times in the mixtures were reflected in test cylinder breaks. The 28 day compressive strengths recorded from flyash cylinders were lower than normal strengths, but still exceeded design strength limits (3300 psi for PCC paving, 600 to 1000 psi for LCB). At 60 days, the flyash concrete strengths were comparable to the normal concrete strengths (see Table A, page 5). It appears the 20% cement replacement rate used in the LCB may have been too high, as the strength did not meet that of the mixture without flyash. The PCC flyash mixture with a 15% replacement rate did come up to strength.

COST ANALYSIS

Cement for the project was bid at $70/ton, while flyash used in the test section cost $39/ton plus a $3/ton charge for handling. Clearly, paving concrete costs can be reduced by using flyash in highway construction, even as much as 40%. The savings were not realized on this project, however, as the contractor, unfamiliar with flyash, had equipped his bid with a "margin of safety" percentage in case of construction difficulties. Because the flyash concrete was actually easier to work than normal concrete, the safety margin ended up as pure profit for the contractor. Without this extra percentage, approximately $1736 was saved using the flyash. Had flyash been used in the paving concrete mixture throughout the entire project, a cost savings in excess of $47,000 could have been realized.

CONCLUSIONS

At this time, based on the 1984 program and this project, the use of flyash in lean concrete base and continuously reinforced concrete pavement cannot be classified as "technically inappropriate". It appears adding flyash to PCC doesn't cause construction difficulties, but in fact increases the concrete's workability.

Due to the time delay in attaining strength, traffic cannot be allowed on the flyash concrete as soon as on a normal concrete surface. This may result in as much as four days' delay. In projects where four or five stages are necessary, this could be significant.

TABLE A

N.ALBANY - CORVALLIS/LEBANON INTERCHANGE COMPRESSIVE STRENGTHS

CONCRETE MIX STRENGTHS (psi averages) days	7	14	28	61	90	++ 180
Lean Concrete Base (compressive strengths)						
with flyash* (20% cement replaced)	605	737	952	1118	1180	1117
without *	845	1020	1298	1367	1395	N/A
without ***	951		1850			N/A
PCC Paving (compressive strengths)						
with flyash * (15% cement replaced)	3882	4573	5130	5900	5720	6175
without*		4904		5772	6155	6511
without**	4167		5209			
Lean Concrete Base (flexural strengths)						
with flyash*			185			
without***			283			
PCC Paving (Flexural strength of single samples)						
with flyash*		535	635	530		
without***		550	560	655		

* Data from cylinder breaks from test section.
** Data from averages of cylinder breaks from July 10, 1985 until September 3, 1985.
*** Data from cylinder breaks throughout project.
++ Data from cores taken in center of travel lane at six months.

While not equal at early ages, the strengths of the flyash modified lean and paving concretes are acceptable. Some available literature (2,3) shows flyash modified concrete attaining ultimate strengths greater than normal concrete within 120 days. Results from this test section are contrary to those findings, as in almost all cases the flyash modified concrete strengths are lower than the plain concrete. The reason(s) for this contradiction are not known at this time. However, it is hoped that with continued monitoring, the resulting data will provide answers.

The Materials Section of OSHD determined, from laboratory test results and this project, that current design procedures for non-flyash pavements are applicable for flyash modified mix designs. Additionally, flyash specifications have now been incorporated into the Standard Highway Specifications (See Appendix B).

FUTURE ACTIVITIES

The durability of flyash concrete will be tested at six months using cores taken from the roadway test section. The cores not broken for compressive strength testing will be tested for surface permeability, chloride intrusion, abrasion resistance, and resistance to freeze-thaw. An addendum to this report containing these test results will then be submitted.

Monitoring of the flyash concrete test section will continue with yearly evaluations until 1990. These evaluations will include observation and documentation of levels of cracking, weathering, spalling and rut depths. A final report summarizing the entire project will conclude this Experimental Feature.

This report concludes the first stage of this experimental project.

(2) "Fly Ash for Use in Concrete - A Critical Review" by E. E. Berry and V. M. Molhotra, ACI Journal, March-April 1980, pp 59-73.

(3) "Fly Ash Use by The California Department of Transportation" by James Woodstrom, Senior Materials & Research Engineer, Fly Ash in Highway Construction Seminar Proceedings, November 1985, Section 11, pp 1-7.

APPENDIX A
CHEMICAL AND PHYSICAL ANALYSES OF FLY ASH

Laboratory No. 85-12
Sample Ident: Centralia Steam Plant, Comp #134, Dockets #17447-17502, 1-4-85
Date Received: 1-15-85

			ASTM: C618 Class F Specs.
CHEMICAL COMPOSITION (%):			
Silicon Oxide (SiO_2)	46.6		
Aluminum Oxide (Al_2O_3)	24.6		
Iron Oxide (Fe_2O_3)	6.6		
Total ($SiO_2 + Al_2O_3 + Fe_2O_3$)		77.8	70.0 min.
Sulfur Trioxide (SO_3)		.63	5.0 max.
Calcium Oxide (CaO)		8.8	
Moisture Content		.06	3.0 max.
Loss on Ignition		.11	12.0 max.
PHYSICAL TEST RESULTS:			
Fineness			
Retained on #325 Sieve (%)		16.59	34 max.
Pozzolanic Activity Index			
w/Portland Cement (%)			
Ratio to Control @ 28 days		97	75 min.
w/Lime @ 7 days (psi)		1107	800 min.
Water Requirement, % of Control		97	105 max.
Soundness			
Autoclave Expansion (%)		.05	0.8 max.
Specific Gravity		2.26	

APPENDIX B
SPECIFICATIONS

SECTION 701 - HYDRAULIC CEMENT, WATER, ADMIXTURES AND CURING MATERIALS

701.07 Fly Ash:

Types - Flyash shall be Class C or Class F conforming to AASHTO M 295 including Tables 1, 2 and 2A except that:

1. Loss on ignition (LOI) shall be 1.5% maximum.

2. Moisture content shall be 1% maximum.

3. Amount retained on the No. 325 sieve shall be 30% maximum.

4. Available alkalies, as Na_2O shall be 1.5% maximum except this maximum may be increased to 2.0% when the flyash is to be used in areas considered free of potentially reactive aggregates, as determined by the Engineer of Materials.

5. In Table 2, the Pozzolanic Activity Index shall be 75% minimum of control.

6. In Table 2A, Mortar Expansion for the job mixture at 14 days shall be less than or equal to the control at 14 days.

Prequalification of Flyash - The sources of flyash shall be prequalified by the Engineer of Materials before use on this project. The prequalification shall not be more than one year old. Sampling and testing of flyash for prequalification shall conform to ASTM C 311 except that one 20 pound test sample shall be submitted in a sealed container and shall be a composite sample representing 2000 tons of flyash production. The sample shall be received at the Engineering Lab at least 8 weeks before its proposed use on the project.

Flyash that has been prequalified will be accepted for immediate use provided the requirements of certification as set forth in subsection 106.08 of the Standard Specifications are met.

Job Control - For each 50 tons of each class of flyash used on this project, a 10 pound sample will be tested for fineness, moisture content, specific gravity, loss on ignition, soundness and air entrainment of mortar. A minimum of one sample will be tested for each class of flyash.

701.08 Blended Hydraulic Cement:

Types - Blended hydraulic cement shall be either portland pozzolan cement or pozzolan-modified cement conforming to AASHTO M 240, supplemented and /or modified as follows:

1. The cement constituent of the blended cement shall conform to subsection 701.01.

2. The pozzolan constituent of the blended cement shall be a flyash conforming to subsection 701.07.

3. The pozzolan constituent shall be between 10 and 20% by weight of the blended cement.

4. The contractor shall supply certifications for blended hydraulic cements in conformance with AASHTO M 240, Section 14.

Job Control - For each 50 tons of blended hydraulic cement used, a 10 pound sample will be tested for fineness, specific gravity, and loss on ignition.

At the request of the Engineer, a 10 pound sample of the flyash and a 10 pound sample of the cement used in the blended hydraulic cement shall be provided the Engineer.