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State of California 4431 C.1

Business and Transportation Agency

Memorandum

To : Mr. John L. Beaton
Materials and Research Engineer

Attention Mr. Carl R. Sundquist
Research Coordination

Date: April 17, 1973

File : 645207

From : **Department of Public Works—Division of Highways**
Materials and Research Department

Subject: Final Report on Research Project "Evaluation of Air Cooled Blast Furnace Slag as Aggregate for PCC"

Attached is the final memo report on Project 19503-762504-645207. This project consisted of performing laboratory tests on mortar and concrete designed to accelerate any chemical or physical action which might show any adverse affects resulting from the use of air cooled blast furnace slag in portland cement concrete. Approximately $2500 was spent on this project.

As a result of the program conducted, it is determined there is no reason to limit the use of slag because of potential chemical action in plain concrete. No attempt was made in this program to determine its effect on embedded steel. This factor has been investigated on another project. No further work is anticipated on this project.

D. L. Spellman
Supervising Materials and
Research Engineer - Concrete

APPROVED

Original Signed
JOHN L. BEATON
John L. Beaton
Materials & Research Engineer

Date 4-24-74

SNB:fp
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Attachment

FORM H-AD 37A

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FINAL REPORT

EVALUATION OF AIR COOLED BLAST FURNACE SLAG AS AGGREGATE FOR PCC

The work consisted of performing various strength and volume change tests on mortar and concrete made with slag aggregate and comparing results with mortar and concrete made with "control" aggregates in order to determine the long term effect of slag on concrete properties.

Materials Tested

Air cooled iron blast furnace slag from the Kaiser Steel Mill at Fontana, California, as processed by the Fontana Slag Company, was the material selected for the test program. The mortar specimens were tested with both aged and fresh crushed material.

The control aggregate was from the Lone Star Industries plant at Fair Oaks, California (formerly Pacific Cement and Aggregates Co.).

Testing Program

Four series of tests were performed relative to volume change and strength.

1. Concrete specimens 4"x5"x18" were cast and subjected to continuous exposure in a fog curing room (RH 100% and temperature 73°F). These specimens were measured for length change and selected specimens were broken in flexure at 1, 6, 12, and 24 months.

2. Concrete specimens 3"x3"x11-1/4" were subjected to the testing procedure in ASTM Method C227, "Potential Alkali Reactivity of Cement Aggregate Combinations". The moist

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heat involved in this series was intended to accelerate any potential effect of slag on volume change characteristics.

3. Mortar specimens 1"x1"x11-1/4" were subjected to autoclaving procedures in accordance with ASTM C151, after curing in water for 65 hours. These specimens were made with freshly crushed slag as well as the aged slag and control aggregate.

4. Mortar specimens fabricated as in Series No. 3 were subjected to alternate one week periods of drying at 100°F and soaking in a saturated solution of sodium chloride. Length changes were measured following each cycle for a period of one year.

Results

Test results of the above program are tabulated as follows:

	1 Mo.	6 Mos.	1 Yr.	2 Yrs.
Flexural Strength, PSI				
Control (Fair Oaks)	855	905	880	920
Fontana Slag	920	950	945	980
Expansion in Moist Room, %				
Control (Fair Oaks)	+0.002	+0.007	+0.007	
Fontana Slag	+0.004	+0.015	+0.017	
Expansion in Moist Heat, % (Modified Alkali-Aggregate Reactivity Test)				
Control (Fair Oaks)	0.037	0.044	0.042	
Fontana Slag	0.020	0.029	0.027	

Length Change after Cycles of Brine Soak and Oven Drying (7 days each/cycle)	6 Cycles	13 Cycles	26 Cycles
Control (Ottawa Sand)	-0.025%	-0.016%	-0.019%
Fontana Slag (Old -4)	+0.006%	+0.023%	+0.031%
Fontana Slag (fresh crushed)	-0.005%	+0.009%	+0.014%

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Autoclave Bars
Age 3 Days,
Avg. of 3 Rounds)

Control	+0.050%
Fontana Slag (Old -4)	+0.017%
Fontana Slag (fresh crushed)	+0.019%

In addition to the above testing program, more information on slag aggregate concrete can be found in an earlier study reported September 1967, entitled "Blast Furnace Slag for Use as Aggregate", M&R No. 645169.

Conclusions

Air cooled iron blast furnace slag did not adversely affect either strength or volume change properties of mortar or concrete in any of the tests included in this program. The only detrimental feature noted was a definite discoloration of specimens containing slag aggregate when exposed to moisture for extended periods of time. It was, however, noted that the discoloration disappears when the concrete dries out and is exposed to the sunlight. This material has been used in the past year (1972) on three paving contracts in District 08 and reports indicate the placing and performance of the concrete was satisfactory. However, the placing of the slag aggregate concrete was greatly improved when the 1x4 fraction was replaced with natural aggregate. The all slag concrete was reported as being harsh.

The findings of this study have been implemented by the issue of a Standard Special Provision for Districts 07, 08, and 11, covering the use of slag aggregate in plain concrete. A copy of the provision is attached.

Acknowledgment

We would like to express our appreciation for the assistance given by District 08 Materials and Construction personnel who provided samples and observation on field performance.

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(To be added to Materials section for all District 07, 08, and 11 projects.)
(Delete para. 13 or 14.)

645207

Materials-M25
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8-1. _____ SLAG AGGREGATE.--Aggregate produced from slag resulting from any steel-making process shall not be used for any highway construction except for the following items:

1. Imported Borrow

2. Aggregate Subbase

3. Class 2 Aggregate Base

Aggregate produced from air-cooled iron blast furnace slag may be used in highway construction with the following exceptions: 2

Air-cooled iron blast furnace slag shall not be used to produce aggregate for: 2

1. Structure backfill material.

2. Pervious backfill material.

3. Permeable material.

4. Reinforced portland cement concrete except bridge approach slabs.

5. Any precast or prestressed portland cement concrete component or structure.

Steel slag to be used to produce aggregate for this project shall be crushed so that 100 percent of the material will pass a 3/4 inch sieve and then shall be control aged for a period of at least 6 months under conditions that will maintain all portions of the stockpiled material at a moisture content in excess of 6 percent of the dry weight of the aggregate. 3

Any supplier of steel slag aggregate shall provide separate stockpiles for controlled aging of the slag. An individual stockpile shall contain not less than 10,000 nor more than 50,000 tons of said slag. The material in each individual stockpile shall be assigned a unique lot number and each stockpile shall be identified with a permanent 4

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system of signs. The supplier shall maintain a permanent record of the dates on which stockpiles are completed and controlled aging begun, of the dates when controlled aging was completed, and of the dates tests were made and the results of said tests. Moisture tests shall be made at least once per week. No credit for aging will be given for the time period covered by any tests which show a moisture content of 6 percent or less. Such stockpiles and records shall be available to the Engineer during normal working hours for inspection, check testing and review.

The supplier shall notify the Materials and Research Engineer, 5900 Folsom Boulevard, Sacramento, California, 95819, when each stockpile is completed and controlled aging begun. No more aggregate shall be added to the stockpile unless a new aging period is initiated. A further notification shall be sent when controlled aging is completed. 5

The supplier shall provide a certificate of compliance in conformance with the requirements in Section 6-1.07, "Certificates of Compliance," of the Standard Specifications. Each stockpile or portion of a stockpile that is used in the work will be considered a lot. Said certificates of compliance shall state that the steel slag aggregate has been aged in a stockpile for at least 6 months at a moisture content in excess of 6 percent of the dry weight of the aggregate. 6

Each delivery of aggregate containing steel slag shall be be accompanied by a delivery tag for each load which will identify the lot of material by stockpile number, where the slag was aged, and the date that the stockpile was completed and controlled aging begun. 7

Air-cooled iron blast furnace slag or natural aggregate may be blended in proper combinations with steel slag aggregate to produce the specified gradings, for those items for which steel slag aggregate is permitted. 8

Aggregate containing slag shall meet all of the applicable quality requirements for the items in which the aggregate is used. 9

The combined slag aggregate shall conform to the specified grading for the item in which it is used. The grading will be determined by Test Method No. Calif. 202, modified by Test Method No. Calif. 905 when there is a difference in specific gravity of 0.2 or more between the coarse and fine portion of the aggregate or between blends of different aggregates. 10

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No aggregate produced from slag shall be placed within one foot, measured in any direction, of any non-cathodically protected pipe or structure unless the aggregate is incorporated in portland cement concrete pavement, in asphalt concrete, or in cement treated base. 11

When crushed air-cooled iron blast furnace slag is used as aggregate in asphalt concrete, the K_c factor requirements, as determined by Test Method No. Calif. 303, will not apply. 12

When slag aggregate is used for imported borrow, a layer of not less than _____ inches of topsoil, measured after compaction, shall be placed over the imported borrow in all areas where highway planting is to be performed. In all other areas, slag aggregate used for embankment construction shall not be placed within 18 inches of finished slope lines, measured normal to the plane of the slope. Full compensation for furnishing and placing topsoil and cover, as provided herein, shall be considered as included in the contract price per ton or per cubic yard paid for imported borrow and no additional compensation will be allowed therefor. 13

Slag aggregate used for embankment construction shall not be placed within 18 inches of finished slope lines, measured normal to the plane of the slope. 14

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