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DURABILITY OF AIR-COOLED SLAG FROM ALGOMA STEEL CORPORATION

by

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SUMMARY OF RESULTS

This investigation was undertaken to determine the potential value of air-cooled blast furnace slag as an aggregate for structural concrete exposed to severe freezing and thawing conditions in the field.

A good workable concrete mixture was prepared using 5 1/2 bags of cement per cubic yard of concrete and graded all-slag aggregate. An air-entraining agent was added. Concrete test specimens moist cured for 7 and 28 days showed an average compressive strength of 2110 and 3130 psi respectively, with a concrete density in saturated, surface-dry condition of 144 lb/cu ft. Flexural strength of this concrete at 28 days age was 629 psi.

Two beam specimens of 3 1/2 x 4 x 16 in. size were exposed for 480 cycles of accelerated freezing and thawing. Measurements of ultrasonic pulse velocity before and after exposure showed a 4% increase. Flexural strength of the beams averaged 669 psi at 100 days age, which was a 6% increase over 28 days strength.

The results of these tests show that no significant damage to the air-entrained, air-cooled slag concrete resulted from the freeze-thaw exposure.

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INTRODUCTION

A bulk sample of air-cooled slag was obtained from A.B. McLean and Sons Limited of Sault Ste. Marie, Ontario, for the purpose of conducting a study of the fire resistance of concrete made with slag aggregate. As no data were available in our laboratories on the use of air-cooled slag as aggregate, investigations were made into the properties affecting its use in concrete, and its durability when exposed to accelerated freezing and thawing. The sample as received consisted of about 500 lb of blast furnace slag which had been obtained from the Algoma Steel Corporation. It had been crushed to 1 1/2 in. maximum size.

WORK PERFORMED

The following physical tests were performed on the aggregate as received: Los Angeles abrasion, sulphate soundness, and specific gravity and absorption. A portion of the aggregate as received was crushed to produce a well graded sand to combine with the coarse aggregate for concrete. Concrete specimens were made for compression and flexure testing and for the accelerated freeze-thaw durability investigation.

DESCRIPTION OF SAMPLE

The blast furnace slag consisted of a greenish-grey material with a dull rough surface. It varied in texture from fine-grained and dense through increasing degrees of porosity to highly vesicular. Most of the particles had a blocky particle shape.

PHYSICAL TESTS

Los Angeles Abrasion

The abrasion resistance was determined by the ASTM procedure C 131-51 using the "A" grading and twelve steel balls weighing 5000 grams as the charge.

-1 1/2	+ 1 in.	-	1250 g
-1	+ 3/4 in.	-	1250 g
-3/4	+ 1/2 in.	-	1250 g
-1/2	+ 3/8 in.	-	1250 g
			5000 g

Abrasion Loss - 36.2%

Specific Gravity and Absorption

Determinations were made according to ASTM procedure C 127-42.

Specific gravity, saturated, surface dry	2.52
" " oven dry	2.46
" " apparent	2.61

Absorption - 2.33%

Sulphate Soundness

Magnesium sulphate solution was used in ASTM procedure C 88-46T.

Five sizes of slag between 1 1/2 in. and 4 mesh were subjected to five cycles of submersion and drying in the sulphate solution.

Weighted average loss for five sizes - 4.1%

CONCRETE

The slag was prepared for use as aggregate by screening and crushing to the gradings shown in Table 1. The sand size was prepared in a smooth roller crusher using -3/8 in. + 4 mesh feed. A reasonably good grading was obtained directly from the crusher, although the product was screened to obtain the gradings shown in Table 1.

TABLE 1

Aggregate Gradings

Coarse		Sand	
Sieve Size	% Passing	Sieve Size	% Passing
1 1/2 in.	100	4 mesh	100
1 "	95	8 "	80
3/4 "	75	14 "	60
1/2 "	45	28 "	40
3/8 "	25	48 "	25
4 mesh	0	100 "	20

A larger proportion than normal of -100 mesh size was used because of the harsher nature of the slag compared to natural sand or crushed stone.

The air-entrained concrete was proportioned and mixed according to standard procedure for freeze-thaw investigations. Essentially the same method was used as described in ASTM procedure C 192 for preparing concrete specimens for compression and flexure testing. Concrete mix data are shown in Table 2.

TABLE 2

Concrete Proportions Per Cu Yd

Cement Factor	W/C Ratio	Sand	Cse. Ag.	Slump	Darex AEA	Air
5½ bags	0.59	1709 lb	1729 lb	2 in.	6 oz	7%

TABLE 3

Properties of Hardened Concrete

Unit Wt lb/cu ft	Comp. Str. 7 days	Comp. Str. 28 days	Flexural Str. 28 days
144.1	2110 psi	3130 psi	629 psi

FREEZING AND THAWING

Two 3 1/2 x 4 x 16 in. beams were prepared for accelerated freeze-thaw exposure. These were stripped 24 hours after moulding and placed in the moist room for a further 13 days curing. At the end of this period they were weighed, measured, and the pulse velocity was measured for each. The beams were then placed in the freezing and thawing cabinet where they were exposed to a cycle of two hours freezing in air at 0°F, and one hour thawing in water at 40°F making eight cycles in 24 hours. The freezing and thawing exposure was terminated at the end of 480 cycles. Periodical checks were made on weight, length and pulse velocity during the course of the exposure.

Results

The results of changes in weight and pulse velocity are shown in the accompanying chart. Changes in length were too small to measure with the equipment on hand ($\pm$ .01 in.). The total average loss of weight amounted to 1.9% and the ultrasonic pulse velocity showed a slight increase at 480 cycles compared to that at zero cycles. The slight increase in pulse velocity indicates that no deterioration of the concrete has occurred. Visual examination of the beams showed no impairment of the concrete as the freezing and thawing progressed. However, the top surface of the beams, where considerable bleeding had occurred, scaled badly during the first few cycles and

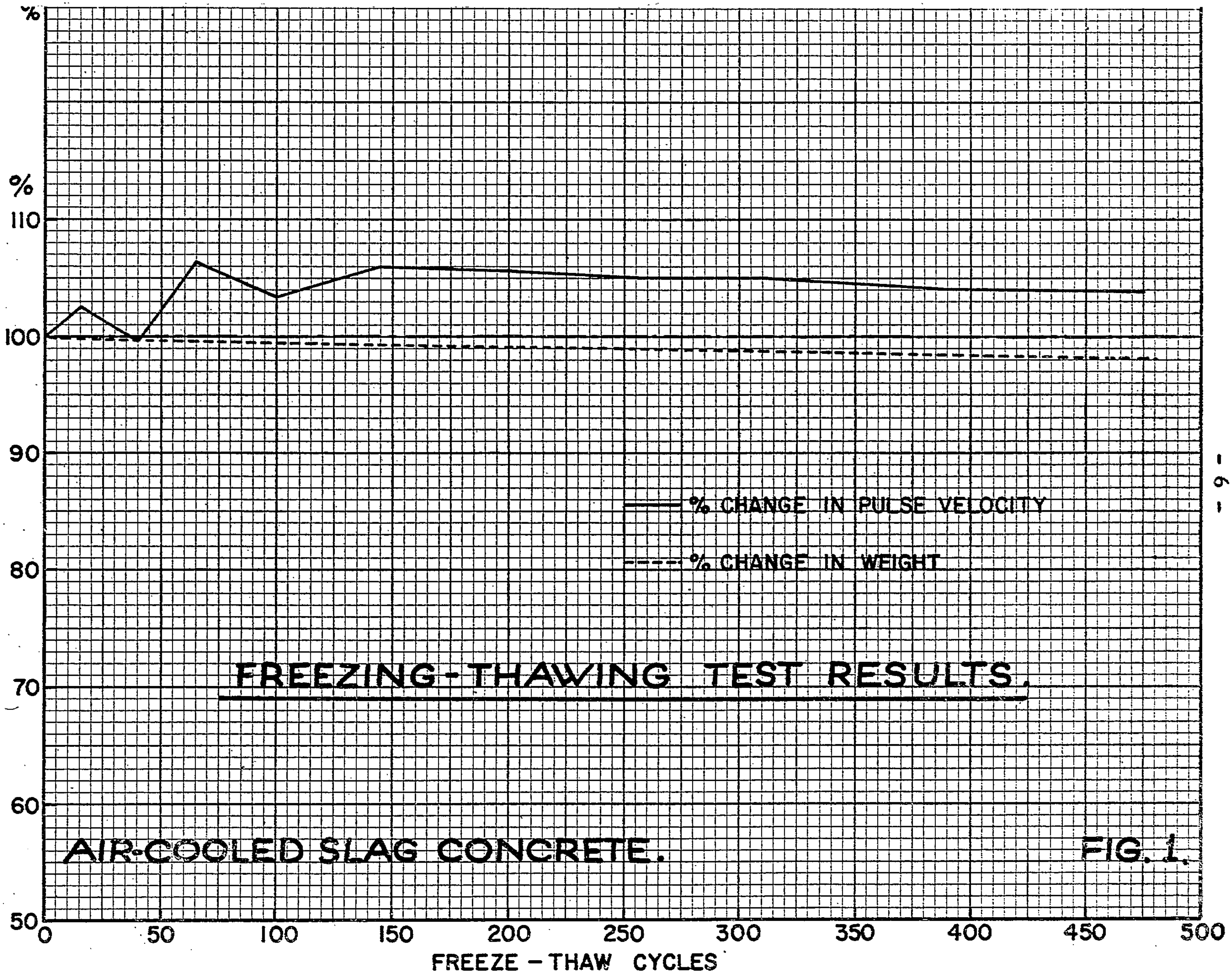
%
%
110
100
90
80
70
60
50
0
50
100
150
200
250
300
350
400
450
500
FREEZE – THAW CYCLES
% CHANGE IN PULSE VELOCITY
% CHANGE IN WEIGHT
FREEZING - THAWING TEST RESULTS.
AIR-COOLED SLAG CONCRETE.

FIG. 1.

remained in about the same condition during the balance of the run. The beams were removed from the freezing and thawing cabinet, and broken in flexure at the age of 100 days.

The average flexural strength of the two beams was 669 psi. This strength shows a 6% increase as compared with 629 psi obtained at 28 days age on beams broken prior to the freezing-thawing treatment.

Tests made at the National Slag Association, Washington, D.C., and reported by D.W. Lewis at the 65th ASTM meeting in 1958, Boston, Mass., show in Table V (*) an average flexural strength increase of 6% between 28 and 90 days. The mixes were made from 8 different slag aggregates with 6 bags of cement per cubic yard of air-entrained concrete using standard moist curing.

The fact that our beams had a similar rate of flexural strength increase (6% after 480 cycles of freezing and thawing) indicates that the air-entrained concrete made with air-cooled slag aggregates is not affected by exposure to alternate freezing and thawing.

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* D.W. Lewis and Fred Hubbard, "Flexural and Compressive Strength Properties of Air-Entrained Concrete with Air-Cooled Blast Furnace Slag Aggregate", Proc. ASTM Vol. 58, 1958

CONCLUSIONS

The physical tests and freeze-thaw investigation indicate the blast furnace slag as represented by the sample received is satisfactory for use as aggregate in concrete exposed to weathering conditions. The scaling on the top surface of the beams is a consequence of the severe bleeding which occurred on moulding and not the result of unsound aggregate.