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UTILIZATION OF WASTE: EVALUATION OF A SLAG COOLING-POND RESIDUE FOR USE IN CONCRETE

by

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MINERAL PROCESSING DIVISION

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EVALUATION OF A SLAG-COOLING POND RESIDUE FOR USE IN CONCRETE

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RESUME

Test results on both dredged and re-washed sludge samples indicate that the material does not conform to the ASTM C618 specification requirements for pozzolans and shows unsatisfactory performance as a pozzolanic admixture for use in concrete.

Chemical analyses revealed that the sludge had a relatively low silica-alumina content, less than 45 per cent, instead of the 70 per cent minimum requirement.

The amount of material retained on the No. 325-mesh sieve by wet-sieving was 28.3 per cent for the dredged sample and 36.0 per cent for the re-washed one. The pozzolanic activity indices with portland cement were 57.2 and 64.8 per cent for the above two samples, respectively, which is well below the 85 per cent specified by ASTM. There was no significant strength development when the sludge was used with lime.

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INTRODUCTION

The National Slag Company of Hamilton, Ontario processes and distributes crushed air-cooled and expanded lightweight slag for use as concrete aggregate.

Molten slag from the blast furnaces is dumped into a water pond, where it bloats from the expanding pressure of vaporizing trapped water. The cooled lumps of expanded slag are dredged, but much unbloated fine residue is left in the form of a sludge at the bottom of the water pond.

The company wished to know if this waste product, named "pond sludge", could be used as a pozzolanic material in concrete mixes, and submitted two 40-lb samples for testing. One sample (CM496-A) was the material as dredged from the pond; the other (CM496-B) was the same sludge which had been washed to remove soluble sulphates and foreign matter.

This investigation report gives the results of the study made to evaluate the pond sludge as a material for partially replacing portland cement in concrete.

TESTS

The following analyses and tests were made on the sludge samples.

1. Petrographic and X-ray analyses to determine phase composition.
2. Tests for determining pozzolanic properties:
   a) Chemical analyses
   b) Physical tests, including determination of pozzolanic activity indices.

Test results were compared with the ASTM specification requirements for pozzolanic materials (1).

TEST RESULTS

1. Mineralogical Composition

Samples of the sludge powders were examined optically and X-ray diffraction patterns were obtained for identification of the crystalline phases.

The results showed that both the dredged and re-washed sludges are mineralogically similar. The sizes of particles range from 0.01 to 1.0 mm. Their forms, illustrated in Figure 1, are mostly irregular, sub-conchoidal to rounded, or prismatic when the silicate fragments are large. The principal compounds identified were gehlenite-akermanite ($2CaO.Al_2O_3.SiO_2$-$2CaO.MgO.2SiO_2$), about 50 per cent of each sample, and monticellite ($CaO.Al_2O_3.SiO_2$), about 20

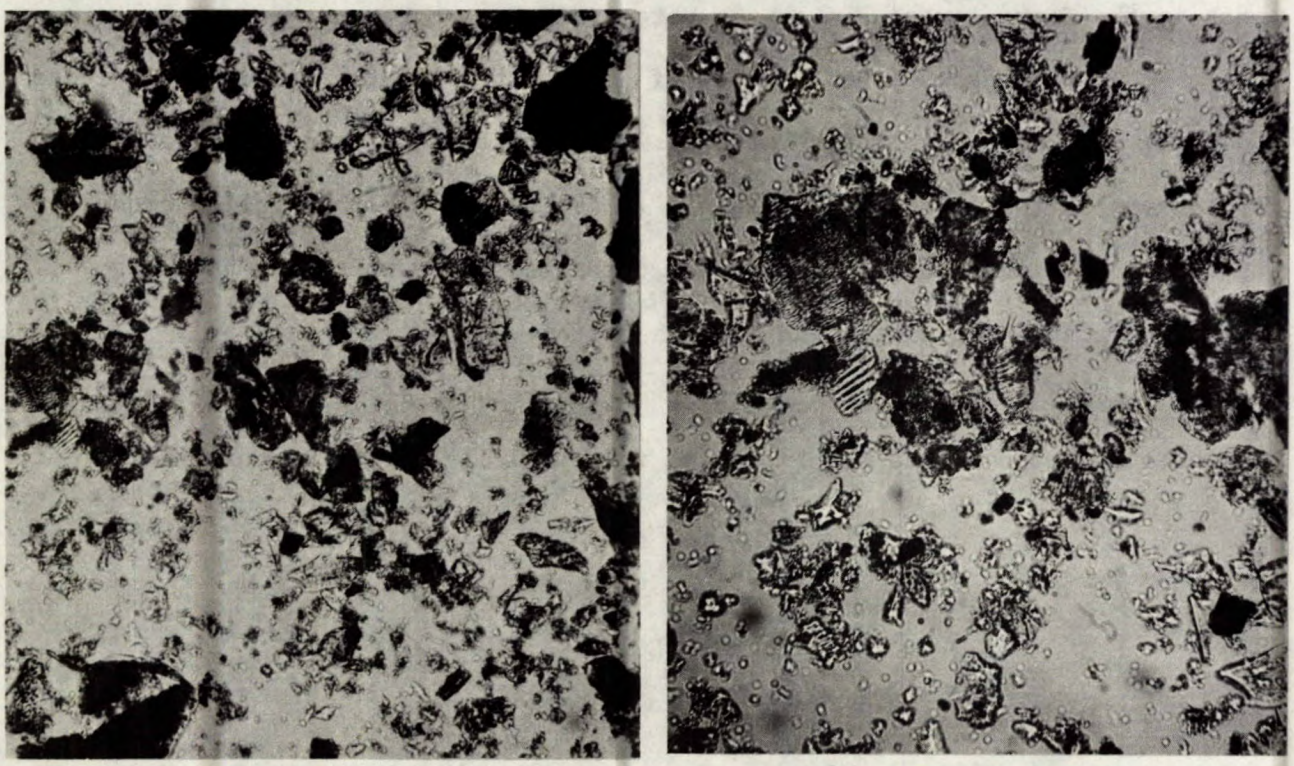

Figure 1. Photomicrographs of washed and dried air-cooled slag.

Left: Irregular, light-colored fragments of gehlenite-akermanite and monticellite, small black particles of carbon, and larger dark, sub-conchoidal fragments of glass charged with impurities. Magnification 125X.

Right: Enlargement of an area to show rippling in glass particles due to partial crystallization of silicates. Magnification 250X.

per cent. Glass is common, but incipient crystallization of the silicates has occurred. Particles of carbon are also common. The equilibrium system for slags of this general composition has been studied by Osborn and Schairer (2) and others (3).

2. Pozzolanic Properties

a) Chemical analyses

Results of chemical analyses are shown in Table 1 together with the corresponding ASTM chemical requirements.

The composition is very similar for both the dredged and the re-washed sludges. The material does not conform to the chemical requirements for pozzolans prescribed by ASTM. The analyses show that the samples have a relatively low silica-alumina content and a considerable amount of calcium oxide. The magnesia content is well over the specification limits. The presence of fluorine was also detected in both samples.

b) Physical tests

Tests were made on the two sludge samples to determine the following properties: (1) specific gravity, (2) fineness, (3) pozzolanic activity index with portland cement, (4) pozzolanic activity index with lime, and (5) water requirement.

Test results are shown in Table 2 with the corresponding ASTM physical requirements.

(1) Specific gravity

Both samples were found to have a specific gravity of 2.84.

(2) Fineness

The two samples contained significant amounts of coarse and lumpy material and were not suitable for use in pozzolanic activity tests. Most of the lumps could be easily broken down but more than 15 per cent remained on the 200 mesh sieve. The amount retained on the 325-mesh sieve, as determined by wet sieving was 28.3 and 36.0 per cent for the dredged and the re-washed samples, respectively, which is about two to three times the ASTM maximum limit.

TABLE 1

Chemical Analysis of Dredged and Re-Washed Sludges

Chemical Constituents (in per cent)	Dredged Sludge Sample A	Re-Washed Sludge Sample B	ASTM C 618 Specifications
Silicon dioxide (SiO_2)	33.78	34.35	-
Aluminum oxide (Al_2O_3), plus iron oxide (Fe_2O_3)	12.75	11.69	-
Silicon dioxide (SiO_2), plus aluminum oxide (Al_2O_3), plus iron oxide (Fe_2O_3)	46.53	46.04	min 70.0
Magnesium oxide (MgO)	13.34	13.77	max 5.0
Sulphur trioxide (SO_3)	1.70	1.90	max 3.0
Calcium oxide (CaO)	34.55	34.59	-
Alkalies - Na_2O	0.35	0.33	-
- K_2O	0.59	0.53	-
Loss on ignition (LOI)	3.47	3.58	max 10.0
Moisture content	0.47	0.53	max 3.0

TABLE 2

Physical Tests for Pozzolanic Activity Determination on Dredged and Re-Washed Sludges

	Tests Performed	Dredged Sludge Sample A	Re-Washed Sludge Sample B	ASTM C 618 Specifications
1	Specific gravity	2.84	2.84	-
2	Amount retained when wet-sieved on No. 325-mesh sieve, per cent	28.3	36.0	max 12.0
3	Pozzolanic activity index with portland cement at 28 days, per cent	57.2	64.8	min 85
4	Pozzolanic activity index with lime at 7 days, psi	nil	nil	min 800
5	Water requirement, per cent of control	108	108	max 115

(3) Pozzolanic activity with portland cement

The pozzolanic activity tests were made only on the minus 200-mesh portion. The pozzolanic activity index with portland cement was determined in accordance with ASTM Method C 618, using the same Type I portland cement in both control and test mixes; the index is expressed as the ratio between the 28-day compressive strength of specimens made with and without pozzolanic material replacing cement. For the dredged and the re-washed sludge investigated, the index values obtained were 57.2 and 64.8 per cent respectively, which compare unfavorably with the minimum of 85 per cent prescribed by ASTM requirements.

(4) Pozzolanic activity with lime

Tests for determining the pozzolanic activity with lime were performed in accordance with Section 7.16.5 of ASTM Specification C 595 for Blended Hydraulic Cement. The activity index in this case is expressed as the 7-day compressive strength of test specimens made according to the above specification; however, no index is given for the two sludges tested because the test specimens showed no significant strength after the required 7 days of curing. The minimum index value as prescribed by ASTM is 800 psi.

(5) Water requirement

The water requirement is calculated from the amount of water used in tests for obtaining the pozzolanic activity index with portland cement, and is expressed as the ratio between the water contents of control and test mixes. The water requirement values obtained were 108 per cent for both samples, which are within the ASTM requirement of 115 per cent maximum.

DISCUSSION AND CONCLUSIONS

The dredged and the re-washed sludges investigated are similar in composition and properties. The results of physical and chemical tests show that the material does not conform to the ASTM specification requirements for pozzolans. In particular, the low pozzolanic activity indices obtained for the samples indicate that the material is not suitable for use as an admixture for partial replacement of portland cement in concrete.

The unsatisfactory pozzolanic activity of the sludge can be explained from the phase composition. Most of the samples consist of stable, silica-poor

calcium silicates which would be chemically inert under the curing conditions used. The low proportion of glass, even if totally reactive, would not contribute greatly to the mass pozzolanic activity of the sludge. Possibly fine comminution would improve its activity (4).

REFERENCES

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