Unclassified

CANADA

DEPARTMENT OF ENERGY, MINES AND RESOURCES

OTTAWA

Mines Branch Investigation Report

IR 73-15 March 1973

# EVALUATION OF FINELY DIVIDED INDUSTRIAL WASTES FOR USE AS POZZOLANS IN CONCRETE

by

G.G. Carette

Mineral Processing Division

NOTE: This report relates essentially to the samples as received.

Unclassified

Mines Branch Investigation Report IR 73-15

# EVALUATION OF FINELY DIVIDED INDUSTRIAL WASTES FOR USE AS POZZOLANS IN CONCRETE

by

G. G. Carette*

---

## SUMMARY OF RESULTS

Six industrial waste materials were investigated to evaluate their potential for use as pozzolanic materials in concrete. The pozzolanic properties of these materials were determined using the test methods provided in ASTM Standard C618-72.

Three of these six materials were found to meet most of the essential requirements of pozzolans. Their index values for activity with portland cement were between 96 and 122 per cent and, for activity with lime, these values were between 813 and 1022 psi. The three other materials investigated showed no significant pozzolanic activity either with portland cement or with lime.

---

*Engineer, Mineral Processing Division, Mines Branch, Department of Energy, Mines and Resources, Ottawa, Canada.

## INTRODUCTION

It is recognized that the use of pozzolans in concrete, either as admixtures or as partial replacement of cement, may result in significant economic benefits and may also improve quality of concrete. The recent growing interest in pozzolanic materials , their increased acceptance for use in concrete, combined with the concern of the industry for the utilization of waste, have brought about search for possible use of such materials.

## SCOPE OF TESTS

The test methods specified in ASTM Standard C618-72 - "Fly Ash and Raw or Calcined Natural Pozzolans for Use in Portland Cement Concrete" were used to evaluate the materials under investigation. The above standard provides also the chemical and physical requirements for the use of these materials.

## MATERIALS INVESTIGATED

The following waste materials (CM)* were investigated:

1. (CM467) - a fly ash from a power plant in Saskatchewan;
2. (CM491) - a fly ash from a thermal power generating station at Mississauga, Ontario;
3. (CM493) - a calcined shale dust from a lightweight aggregate plant at Mississauga, Ontario;
4. (CM496) - a slag cooling-pond residue from a steel plant at Hamilton, Ontario; Sample CM496A is the material

---

*This is the indentification number for material submitted to the Construction Materials Section for investigation.

dredged from the pond and CM496B, the same material, but washed;

5. (CM497) - a precipitated silica dust from a ferro-silicon plant at Montreal, Quebec; and

6. (CM500) - a silica flour from an autoclaved concrete block plant at Hamilton, Ontario.

In the ASTM C618 specification, pozzolans are divided into three classes, depending on their type and their compliance with certain specific requirements. According to the nature of the materials listed above, the two fly ashes are identified with class "F" of this specification and their performance will be compared with the requirements for this class. The four other materials come under class "S" of the same specification and the requirements corresponding to this class will be used in the evaluation of these materials.

## TESTS

The following tests were carried out on each sample according to the procedures outlined in ASTM Standard C618-72::

1. chemical analyses; and
2. physical tests:
   a) fineness,
   b) pozzolanic activity with portland cement,
   c) pozzolanic activity with lime,
   d) water requirement.

The above constitute the main tests required for evaluating the pozzolanic potential of a material. ASTM specifications include some additional physical tests, however, these are not within the scope of the present investigations.

TEST RESULTS

1. Chemical Analyses

The chemical analyses are given in Table 1 together with the corresponding ASTM requirements.

The results show that all materials tested meet the ASTM chemical requirements of their respective class, except for the samples CM496 (A and B) which have a relatively low silica-alumina content and a considerable amount of calcium oxide. The magnesia content of these latter samples is also well over the specification limits.

2. Physical Tests

The physical test results are shown in Table 2 with the corresponding ASTM physical requirements for the two relevant classes of pozzolans.

1) Fineness

The ASTM standard C618-72 specifies the determination of two properties characterizing the fineness of a pozzolan, the surface area and the amount retained on the 325-mesh sieve (wet sieving). In these investigations, the fineness tests were done on the materials as received and were confined to the determination of the percentage amount retained on 325-mesh sieve after wet sieving.

For the two samples of fly ash tested, CM491, with a fineness value of 19.7 per cent, meets the ASTM 20 per cent maximum requirement, whereas CM467, with a corresponding value of 24.6 per cent, slightly exceeds this specified maximum. For the other samples, the results cannot be compared directly with the ASTM requirements; for Class S

TABLE 1

Chemical Analyses of Industrial Waste Materials

| Chemical Constituents | Sample Composition by per cent | | | | | | | ASTM C618-72 Specifications | |
|---|---|---|---|---|---|---|---|---|---|
| | CM-467 | CM-491 | CM-493 | CM-496 A | CM-496 B | CM-497 | CM-500 | Class F | Class S |
| Silicon dioxide ($SiO_2$) | 42.79 | 42.71 | 60.55 | 33.78 | 34.35 | 95.00 | 96.9 | | |
| Aluminum oxide ($Al_2O_3$), plus iron oxide ($Fe_2O_3$) | 31.13 | 44.72 | 25.02 | 12.75 | 11.69 | 0.20 | | | |
| Silicon oxide ($SiO_2$), plus aluminum oxide ($Al_2O_3$), plus iron oxide ($Fe_2O_3$) | 73.92 | 87.43 | 85.57 | 46.53 | 46.04 | 95.20 | | min 70.0 | min 70.0 |
| Magnesium oxide (MgO) | 4.79 | 0.87 | 3.46 | 13.34 | 13.77 | 0.32 | | | max 5.0 |
| Sulphur trioxide ($SO_3$) | 0.63 | 1.08 | 0.49 | 1.70 | 1.90 | 0.32 | | max 5.0 | max 4.0 |
| Calcium oxide (CaO) | 13.59 | 4.47 | 3.06 | 34.55 | 34.59 | 0.70 | | | |
| Alkalies - $Na_2O$ | 6.29 | 0.44 | 0.94 | 0.35 | 0.33 | 0.08 | | | |
| $K_2O$ | 0.56 | 1.80 | 4.50 | 0.59 | 0.53 | 0.23 | | | |
| Loss on ignition (LOI) | 0.50 | 4.66 | 2.52 | 3.47 | 3.58 | 3.22 | | max 12.0 | max 10.0 |
| Moisture content | 0.12 | 0.36 | 0.22 | 0.47 | 0.53 | 0.31 | | max 3.0 | max 3.0 |

material, the ASTM standard specifies only surface area for fineness. However, by comparison with the results obtained for the two fly ashes, it can be observed that Sample CM497, with a value of 2.8 per cent for the amount retained on 325-mesh sieve, is a very fine material whereas Sample CM500 is about as fine as the fly ashes. Samples CM493 and CM496 (A and B), on the other hand, contained much more plus 325-mesh material because they contained large particles and hard lumps. This portion of a material does not generally contribute to its pozzolanic activity, so the fraction coarser than 200 mesh was removed from the two samples before making pozzolanic activity tests. As a result, the amount of plus 325-mesh material was reduced to about 15 per cent in both cases.

2) Pozzolanic activity with portland cement

The pozzolanic activity index with portland cement was determined for each material with a normal portland cement obtained from a local plant. This index is expressed as the ratio between the 28-day compressive strength of specimens made with and without pozzolanic material replacing cement.

Three of the six materials (Samples CM467, CM491, and CM497) showed good activity with portland cement. The values obtained for their portland cement indices were 96.6, 113.7, and 122.4 per cent, respectively, against the 85 per cent ASTM minimum requirement. Sample CM497, although showing good activity,had poor mortar-making characteristics. A high water content was required due to the sticky nature of the mortar produced, and the molding of specimens, in accordance with ASTM procedures, was very difficult with this mortar.

TABLE 2

Physical Tests for Pozzolanic Activity Determination
on Industrial Waste Materials

| Test Performed | Sample Designation | | | | | | | ASTM C618-72 Specifications | |
|---|---|---|---|---|---|---|---|---|---|
| | CM-467 | CM-491 | CM-493 | CM-496 A | CM-496 B | CM-497 | CM-500 | Class F | Class S |
| Specific gravity | 2.41 | 2.46 | 2.59 | 2.84 | 2.84 | 2.08 | 2.60 | | |
| Amount retained when wet-sieved on No. 325-mesh sieve, per cent | 24.6 | 19.7 | 64.0 | 28.3 | 36.0 | 2.8 | 18.6 | max 20.0 | |
| Pozzolanic activity index with portland cement at 28 days, per cent | 96.6 | 113.7 | 76.0* | 57.2* | 64.8* | 122.4 | 66.6 | min 85.0 | min 85.0 |
| Pozzolanic activity index with lime at 7 days, psi | 1022 | 813 | 297* | nil | nil | 941 | nil | min 800 | min 800 |
| Water requirement, per cent of control | 94 | 98 | 102 | 108 | 108 | 140 | 100 | max 105 | max 105 |

* Only material passing 200-mesh sieve was used.

Samples CM493, CM496 (A and B), and CM500 did not meet the ASTM requirements for activity with portland cement, their index values ranging from 57.2 to 76.0 per cent. For Samples CM493 and CM496 (A and B), these values correspond to those obtained on the minus 200-mesh material. Finer fractions of these same two materials were tested. For Sample CM 493, the minus 325-mesh was used in these tests, whereas, for the two samples CM496 (A and B), the material was reduced until less than 10 per cent was retained on the 325-mesh sieve. The results, however, did not show any significant improvement in pozzolanic activity with portland cement.

3) Pozzolanic activity with lime

The method for determing the pozzolanic activity with lime is described in ASTM Standard C595 for Blended Hydraulic Cement. This index is expressed as the 7-day compressive strength of test specimens made according to the above standard.

Only three samples - CM467, CM491, and CM 497 - showed good pozzolanic activity with lime; the respective lime index values were 1022, 813, and 941 psi against the ASTM minimum requirement of 800 psi. As expected, the same three materials showed favorable reaction with portland cement; in this case, however, Sample CM467 has the highest activity index value. For Sample CM497, a relatively high water content had to be used for a given flow due to the sticky characteristic of the pozzolan-lime mortar; this sticky characteristic also made the material more difficult to compact.

For the other samples, the results of activity tests with lime were poor in that Sample CM493 showed insignificant activity and Samples CM496 (A and B) and CM500 no activity. Increase in fineness of these materials again did not have any particular effect on their activity.

4) Water requirement

The water requirement was calculated from the amount of water used in tests for determining the pozzolanic activity index with portland cement and is expressed as the ratio water in control mix:water in test mix.

With the exception of CM496 (A and B) and CM497, all the samples met the ASTM specification of 105 per cent maximum for this ratio. For Samples CM496 (A and B), the water requirement (108%) was slightly over the specification limit. The water requirement for Sample CM497, as previously mentioned, was ecessively high due to the sticky nature of the mortar produced. This latter, even when over-wetted, would not show the expected flow characteristics because the value obtained with the flow table did not reflect is actual consistency. However, a relative water content of 140 per cent was used to determine its pozzolanic activity with portland cement although the corresponding flow value was only 90 per cent against the 100 to 115 per cent specified by ASTM.

## DISCUSSION AND CONCLUDING REMARKS

The results of chemical and physical tests indicate that only one of the six materials investigated, the fly ash sample CM491, fully conforms to the ASTM specification requirement for pozzolans in regard to the tests performed. This material therefore can be regarded as having good potential for use as a pozzolan in concrete. Two of the other materials investigated, the fly ash CM467 and the precipitated silica dust CM497, although not strictly adhering to these requirements, also demonstrate some potential. The fly ash sample CM467 meets all the main ASTM specified requirements for pozzolans with the exception of fineness which should not constitute a major problem in its utilization. The precipitated silica dust CM497 shows satisfactory performance as a pozzolan for use in concrete, except for its high water requirement. The effect of high water requirement would, however, have to be investigated in detail, particularly on concrete, before making any conclusions about the pozzolanic value of this material.

The three other materials investigated, the calcined shale dust CM493, the slag cooling-pond residue CM496 (A and B), and the silica flour CM500 do not meet the ASTM specifications for activity either with portland cement or with lime. Because such activity constitutes the basic property of pozzolans, it is unlikely that these three materials, as received, could have practical application as pozzolans for use in concrete.

GGC/ln