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Compressive Strength of Cement Containing Ash from Municipal Refuse or Sewage Sludge Incinerators

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There is presently strong public opposition to the establishment of new landfills for disposal of municipal solid waste because of unsightliness, the threat of groundwater pollution and thus diminished adjacent property values. Many communities are therefore considering recycling programs and incineration as alternatives. The resulting ash from such incinerators may, however, typically contain high concentrations of toxic metals (Greenberg et al. 1978; Furr et al. 1979) as well as toxicologically significant levels of a wide range of organics including polychlorinated dibenzodioxins and dibenzofurans (Eiceman et al. 1979). Safe disposal of such ash materials is therefore of concern.

Ash derived from coal burning has long been used as an additive to cement for specific applications such as dam construction (Lea 1971). It was of interest to investigate the feasibility of incorporation of municipal refuse or sewage sludge ashes in hydraulic cement mortars and to test their resultant compressive strength as an alternative to disposal of such ashes in landfills or other sites.

MATERIALS AND METHODS

Two sewage sludge ashes and six refuse ashes from municipal incinerators in eight cities were used in the study. The type of ash and its pH and carbon content are given in Table 1. Some of the refuse incinerator ashes were mixtures of fly ash and bottom ash. Many incinerator plants purposely mix the fly ash which contains higher levels of toxicants with bottom ash therefore diluting their concentration and permitting their legal disposal in landfills. Whereas the refuse fly ashes were dried, mixed and used directly, each of the ashes containing bottom ash was air-dried and ground to a fine powdery consistency in a hammer mill (sieve opening, 1.5 mm i.d.) and mixed by tumbling.

The American Society of Testing Material Method C-109 (ASTM 1987) was used for compressive strength tests. Control samples

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Table 1. Origin of municipal ashes used and their pH and carbon content.

City code	Type of ash	pH	Carbon (wt,%)
I	Sewage sludge BA[a]	8.2	0.6
II	Sewage sludge BA	6.9	2.2
III	Refuse incinerator BA	7.9	3.6
IV	Refuse incinerator BA-FA[b]	10.2	1.6
V	Refuse incinerator BA-FA	7.3	1.7
VI	Refuse incinerator BA-FA	12.5	2.1
VII	Refuse incinerator FA[c]	10.6	2.1
VIII	Refuse incinerator FA	4.2	7.4

[a]Bottom ash
[b]Bottom ash-fly ash mixture
[c]Fly ash

consisted of Rochester Portland type I cement (250 grams), graded standard sand (687.5 grams) and 145 ml of distilled water. Ten, 20 and 30 percent ash, by weight, was substituted for the cement. The weight of sand remained the same (687.5 grams) for all batches. The volume of water used was adjusted as required to maintain the flow at 110 ± 5. Three, replicate 50 mm cube specimens of the control and each ash mixture were cast. The preparation of the mortar, determination of flow, storage of the test cubes for 28 days and measurement of compressive strength were in strict accordance with the ASTM method (1987).

RESULTS AND DISCUSSION

The compressive strengths of the test cubes of mortar cement containing increasing percentages of the ashes are given in Table 2. The specification requirements for compressive strength (kg/cm^2) of the following types of masonry cements after 28 days of curing are as follows: 175 (type M), 126 (type S), 52.5 (type N) and 24.5 (type O) (ASTM 1984). Therefore ashes I, II and IV would meet the specifications for type N masonry cement, ashes III and V would meet those of type S and VI, VII and VIII those of type M. Types M, S or N mortar cements are suitable for construction of exterior load-bearing walls above or below grade or for such interior walls. These types are also suitable for use in construction of pavements, walks, patios, sewers or manholes (ASTM 1984).

Twenty-eight days was chosen as the curing time before testing but compressive strength is known to increase if curing is extended to one year. Whereas the strength of the cubes generally decreased with increasing percentage of any of the ashes containing bottom ash, cubes VII and VIII containing refuse fly ash most consistently maintained compressive strengths comparable to that of the corresponding control containing no ash. The particle size range of fly ash particles would expectedly be much finer than

Table 2. Compressive strength of 5 cm cubes of mortar cement containing increasing percentages of ashes from municipal sewage sludge and refuse incinerators.

City code	Compressive strength (kg/cm^2)			
	Control	10% ash[a]	20% ash	30% ash
I	327 ± 9[b]	233 ± 4	188 ± 1	120 ± 2
II	351 ± 5	273 ± 5	136 ± 4	64 ± 2
III	338 ± 11	279 ± 8	214 ± 7	132 ± 8
IV	300 ± 11	156 ± 12	167 ± 8	78 ± 2
V	331 ± 7	162 ± 4	147 ± 14	127 ± 6
VI	345 ± 7	290 ± 10	152 ± 8	175 ± 3
VII	267 ± 3	252 ± 13	239 ± 3	250 ± 13
VIII	299 ± 5	344 ± 7	333 ± 7	334 ± 8

[a]Weight %
[b]Mean ± standard error of triplicate measurements.

those of the milled bottom ashes. The fly ash would therefore become more intimately mixed with the cement particles which would enhance their entering into the reactions of cement formation. Coal fly ash is a normal constituent of Portland Cement deriving from the burning of coal during cement manufacture and is believed to enter into the ultimate cement reactions. Importantly, this latter fly ash which immediately mixes with the cement in a hot dry condition would expectedly participate in the cement formation reactions much more vigorously than fly ash added later (as in this study) which has acquired moisture from contact with air or from having been deliberately wetted to hold down dust during its collection.

Whether bottom ashes, if ground to the fineness of fly ash, would no longer diminish the compressive strength when added to cement is unknown but the cost of subdividing it further would be a factor. Probably of most importance, municipal refuse bottom ashes are far more heterogeneous in composition than fly ash. They may typically contain fragments of glass, ceramics, ferrous and non ferrous metals and other materials that may not participate in reactions of cement formation and may weaken the final product. If organic matter is too high in a cement mixture the resulting product will be weakened. Although the organic matter content of some refuse ashes may be extremely high due to incomplete refuse incineration, the percent carbon in the ashes used in this study probably did not contribute to decreasing compressive strength.

As well as the presence of toxic metals in fly ashes and bottom ashes, improperly incinerated refuse may produce fly ashes containing elevated levels of toxic organics such as polychlorinated dibenzodioxins and dibenzofurans (Steisel et al. 1987). Thus incorporation of the ash in cement may contribute to immobilization of such compounds in a material suitable for construction purposes or disposal. Finally, the reserve alkalinity of most refuse ashes has been estimated to be sufficient to neutralize the effects of acid rain leaching for many years (Cundari and Lauria 1986) which could improve the durability of cement used for exterior construction.

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