STRENGTH ENHANCEMENT OF CONCRETE CONTAINING MSW INCINERATOR ASH

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ABSTRACT

In previous work [1] pretreatment of fresh municipal solid waste (MSW) incinerator ash with a novel type of additive, which was not identified chemically in that paper, was shown to markedly increase the compressive strength of portland cement concrete using the MSW ash as fine aggregate. A recent study has shown that, at lower levels of additive, aged MSW ash does not demonstrate the same enhancement. This presentation will provide additional information concerning the previous study, give the results of the current one and discuss the implications of both.

INTRODUCTION

Much work is being conducted to find beneficial uses for the solid residues from energy-conversion process, such as coal-fired electric power plants and combustors of municipal solid waste (MSW). Landfill caps and liners, grouts, structural fills, artificial aggregate for road bases, concretes of various types, and additives for cement have all been examined as outlets for these energy-related wastes. For all of the uses just listed, solidification is the principal goal, while stabilization of the eight RCRA metals (arsenic, barium, cadmium, chromium, lead, mercury, selenium and silver) is an important secondary consideration.

Two residues obtained from the most thorough of the MSW combustors - the O'Conner rotary burner - fail to meet the following specifications for Class C Fly Ash - moisture content, ignition loss, pozzolanic activity index and fineness. [1] In addition they fail the EP toxicity test for cadmium and lead [1], as shown in Table 1. Thus, they cannot be used as cement additives and they must be stabilized when included in any of the other beneficial uses listed in the last paragraph.

An earlier paper [1] described a study in which a combined MSW ash from the O'Conner combustor was used as fine aggregate in portland cement concrete. In that paper it was pointed out that using MSW ash for this purpose substantially degrades the strength of the concrete so produced, but it reported that a novel additive had been discovered which gives early indications of economically restoring concretes containing MSW ash to their normal strengths.

However, the authors of that earlier paper did not reveal the chemical composition of the novel additive. At that time they were exploring the possibility of obtaining a patent on the use of the additive. Since then, they have decided that, such a patent being essentially be unenforceable if awarded, the nature of the additive should be disclosed.

One purpose of this paper, then, is that disclosure, along with some additional information obtained during the last few months of the Westinghouse-sponsored project, which came to its conclusion shortly after that paper was written. [2] Subsequently, another graduate student conducted a brief examination of this topic and found some interesting differences between the behavior of fresh and aged MSW ash. [3] The second purpose of this paper, then, is to report his findings.

SOLIDIFICATION ENHANCEMENT USING NOVEL ADDITIVES

The novel additive is a common acid. Two different acids have been tested - hydrochloric acid and acetic acid. The method of introduction of the acid may best be shown by giving the procedure (based upon ASTM C192-88) for mixing a batch of concrete in which it is included. The specific batch described is Batch 32:

- Add 17.0 pounds of coarse aggregate and 25.8 pounds of MSW ash to a small cement mixer and commence rotation.

- Add 500 ml of 12 normal hydrochloric acid and mix for several minutes.

- Add 33.5 pounds of cement and 12.0 pounds of water (enough to provide a slump of 1.5 to 2.5 inches) to the mixer in equal proportions, one after the other, in three or four different intervals.

- When the mix is ready for molding, fill twenty three inch by six inch cylindrical cardboard molds and place them in a curing room.

- After each period of three, seven, fourteen, twenty-eight and ninety days, test four cylinders for compressive strength, reporting the average strength of the strongest three cylinders.

Figure 1 provides a record of the 28-day average compressive strengths for twelve concretes prepared with MSW ash as fine aggregate and with varying amounts of either hydrochloric acid or acetic acid. The abscissa is structured in units of **gram** moles/pounds MSW ash. For comparison, the 28-day strength of a concrete made with no additive (Batch 5) is shown. Nearly a 300% increase in compressive strength (1400 psi to 5500 psi) is achieved by Batch 30, made with 0.25 gram moles of hydrochloric acid per pound of MSW ash.

The results of the 90-day compressive strengths are confused. These batches were made near the end of the project and 90-day strengths were not obtained for Batches 44 through 49. In addition, the cylinders for Batches 27, 35, 36 and 37 deteriorated such that no strength could be measured. The 90-day compressive strengths for Batches 30, 31, 32 and 42 are 4940, 4380, 6200 and 1618 respectively. [It should be noted that no 28-day strength for batch 42 was measured. The value in Figure 1 is the 90-day strength.] Thus, the compressive strength of Batch 30 decreased somewhat after Day 28, that for Batch 31 rose very slightly and that for Batch 32 increased dramatically. The addition of these two acids may be affecting the crystallography of the cementitious portion of the concretes. Intermediate amounts of acid appear to increase strength without degradation, while larger amounts cause deterioration. Much work needs to be conducted to understand the causes and effects of strength enhancement by acid addition.

METAL STABILIZATION IN MSW ASH-CONTAINING CONCRETE

Samples of the first nine concretes containing MSW ash, made in this project, were extracted by the project team according to the EP toxicity method and the concentrations of the eight RCRA metals in the extracts were measured by Geochemical Testing of Somerset, Pennsylvania. The results of these tests are given in Table 1. The two metals, cadmium and lead, which caused the MSW ash to fail the EP toxicity test, have been well stabilized in all nine concretes.

COMPARISON OF BEHAVIOR OF FRESH AND AGED ASH

This portion of the study was conducted two years after the earlier portion. Aged ash was drawn from the fourth (and final) batch of ash that had been collected several years previously. Fresh ash was obtained from the Dutchess County MSW Incinerator. It was drawn from the ash conveyor prior to lime addition.

This portion of the study utilized mortar, rather than full concrete containing coarse aggregate. The method of mortar production, based upon ASTM C109, was as follows:

- Place the ash into a mixing bowl.

- Add hydrochloric acid (if it is to be used) and mix.

- Add water and mix.

- Add cement (to a water/cement ratio of 0.81) and mix.

- Fill six plastic two-inch molds with mortar, place them in a curing room for 24 hours, break them from the molds, and continue curing for six more days.

- Measure the compressive strength of each of the six cubes, using a universal testing machine; calculate the average strength of the four strongest cubes.

Figure 2 provides a record of the compressive strengths for eight aged ash-containing mortars, six prepared with varying amounts of hydrochloric acid and two with no acid. Figure

3 provides a record of the compressive strengths for three fresh ash-containing mortars, two prepared with varying amounts of hydrochloric acid and one with no acid. For comparison of Figures 2 and 3 with Figure 1, it may be noted that 100 mmol of acid in Figures 2 and 3 corresponds to 0.032 gram moles acid/pound of ash in Figure 1.

First, it may be observed that all of the mortars were prepared with relatively low amounts of acid. The largest amount of acid, about 0.05 gram moles acid/pound of ash, was used in Batch 6. This corresponds to the amount used in Batches 31 and 37 of the earlier portion of the study. Thus, the increases in compressive strength with increasing amounts of acid, observed in Figures 2 and 3 to be under 100%, are as expected, based upon the experience recorded in Figure 1.

From a comparison of Figures 2 and 3 it is clear that the compressive strength of mortar made from fresh ash is over six times that of mortar made from aged ash. Fresh ash has a certain amount of pozzolanic character which is lost as it ages. It is also clear from this comparison that acid addition is much more effective in increasing the compressive strength of mortar containing fresh ash than for that containing aged ash. Mortar with fresh ash doubles in strength with the addition of about 60 mmols of acid, while mortar with aged ash may require 120 mmols or more of acid for the same effect. Thus, there may be a phenomenological linkage between the strength enhancement caused by acid addition and the pozzolanic nature of the ash.

CONCLUSIONS

The addition of common acids, such as hydrochloric and acetic acids, to mortars and concretes containing MSW incinerator ash, increases the compressive strength of the final product. The increase is more pronounced when the ash is fresh. Aging of ash degrades the final strength of the mortar and also reduces the effect to be expected by acid addition.

It should be noted that the results of this study are quite preliminary in nature. Much more work needs to be done to verify and quantify the trends and to ascertain their causative mechanism.

REFERENCES

[1] Cobb, J. T., Jr., et al., Clean Energy from Waste& Coal, M. R. Khan, ed., ACS Symposium Series, 515, 1993, p. 264.

[2] Reed, D. J., MS Thesis, University of Pittsburgh, 1992.

[3] Lewis, J. T., III, MS Thesis, University of Pittsburgh, 1994.

Constituent	EP-toxicity Maximum Allowable Limit	Primary Drinking Water Standards	Plain Concrete Control A/B	Avg Concrete Samples 1 to 9	Max. Concrete Samples 1 to 9	Avg Ash Samples 1 and 2	Max. Ash Samples 1 and 2
Arsenic	5.00	0.050	0.006	0.0192	0.05	0.011	0.018
Barium	100.00	1.000	1.09	0.7600	1.36	0.195	0.240
Cadmium	1.00	0.010	0.01	0.1067	0.47	1.375	1.770
Chromium	5.00	0.050	0.09	0.0333	0.09	0.04	0.050
Lead	5.00	0.050	0.01	0.1522	0.78	6.08	7.480
Mercury	0.20	0.002	0.0002	0.0007	0.004	0.001	0.001
Selenium	1.00	0.010	0.002	0.0042	0.02	0.002	0.002
Silver	50.00	0.050	0.01	0.0167	0.03	0.025	0.030

Table 1. EP Toxicity Tests on Nine Concretes Containing MSW Ash

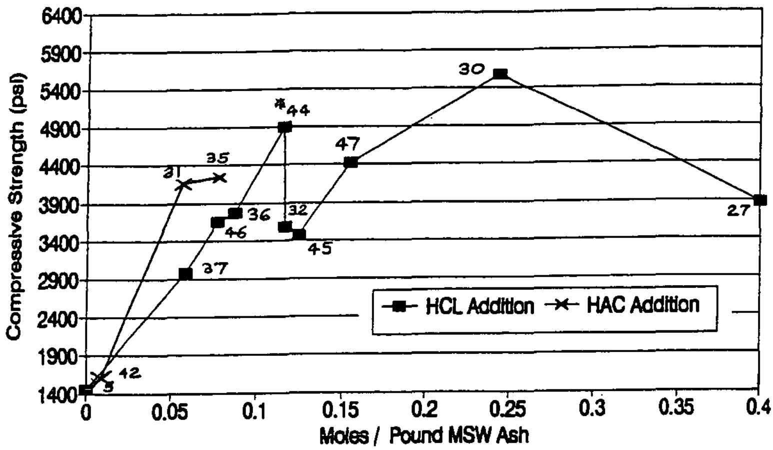

Figure 1. Effect of Acid Concentration on Compressive Strength of Concrete Containing MSW Ash

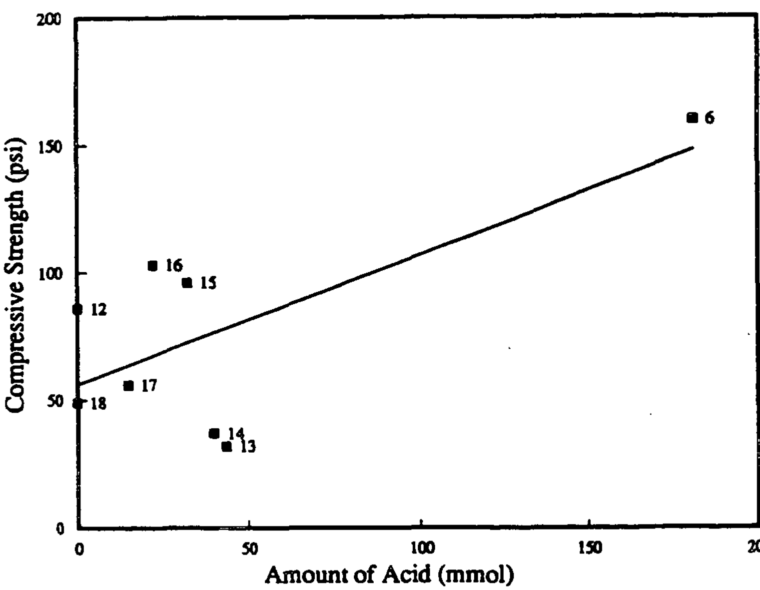

Figure 2. Effect of Acid Concentration on Compressive Strength of Mortar Containing Aged MSW Ash

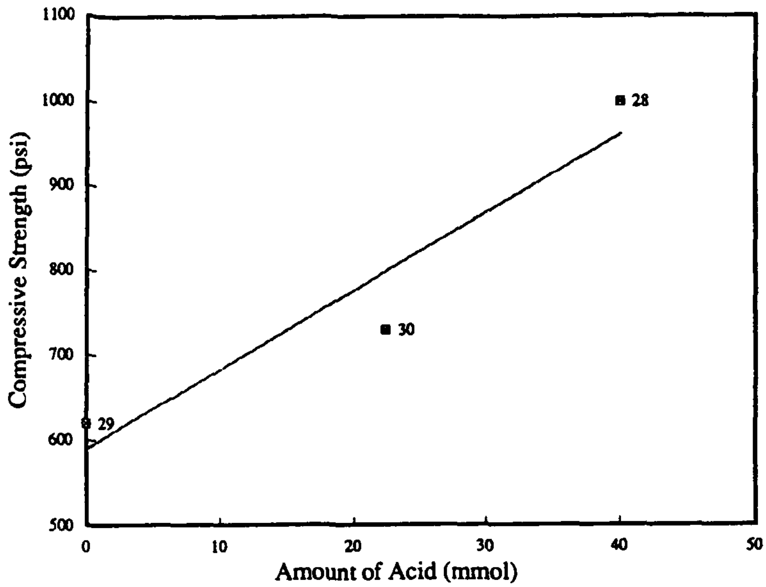

Figure 3. Effect of Acid Concentration on Compressive Strength of Mortar Containing Fresh MSW Ash