ASH CHARACTERIZATION AT CALIFORNIA MSW INCINERATORS

BENJAMIN LEVIE, DEAN SEVY, AND MARK TORMEY
R. W. Beck
Denver, Colorado

BOB BOUGHTON
CIWMB
Sacramento, California

ABSTRACT

Sampling and analysis of ash at the three MSW incinerators was performed to determine if beneficial use could be made of this material. Potential uses are as aggregate for road subbases, bases, asphalt, and concrete. The tests were California Department of Transportation (CALTRANS) methods whose results can be compared to California standards. Results revealed potential for use of the ash for road applications with certain caveats and treatment recommendations.

INTRODUCTION

The beneficial use of MSW incinerator ash in road applications has been the subject of many studies, both in the United States and abroad. Studies have shown that the bottom ash is a reasonable substitute for aggregate which has been mined. The studies performed have generally been focussed on a specific application for the ash in which field demonstrations are performed, such as a short length of road or a parking lot [1]–[6]. Results of these demonstrations have generally been positive, although commercial use of the ash aggregate in the United States is still unproven.

The California Integrated Waste Management Board commissioned a study to look at the beneficial use of various incinerator ashes, including MSW, biomass, and medical waste. The approach of this project was to take a broad brush look at ash uses based on sampling and laboratory testing of ash from many facilities. This paper will present and discuss results from this study on MSW incinerator ash from the three California MSW incinerators: Commerce, Southeast Resource Recovery Facility (SERRF) and Stanislaus. All three facilities are mass burn, stoker-fired incinerators with acid gas treatment consisting of dry scrubbers. The fly and bottom ash are mixed together in the facilities.

ASH SAMPLING

Ash sampling protocol was developed to take representative ash samples at each facility. The protocol for each facility depended on the facility ash operation, all of which were significantly different.

The Commerce facility ash treatment system separated the ash into an under 1″ bottom and fly ash and an over 1″. The under 1″ was mixed with 10 to 12 percent of ready mix cement in a cement mixer. This was discharged after 120 revolutions into a 40 cubic yard roll-off lined with plastic. The roll-offs are allowed to cure for at least a day before being transported to the landfill for temporary road use there.

Samples were taken by shovel from the roll-offs as they were being filled. The cement mix was put into 4′ by 8′ by 1′ forms where they were allowed to cure for 24 hours. They were then broken up with a 10 lb hammer until the pieces could pass through a 2″ screen.

At SERRF the ash is also treated with cement, although in lesser amounts and using a proprietary process. The entire ash sample of bottom and fly ash was sampled at the ash discharge chute using a front end loader. The ash does not contain enough cement to cause it to harden.

At Stanislaus, there is an ash treatment system which takes the mixed ash through a trommel screen to remove fines and then uses a ferrous metal recovery system to take out larger ferrous metal objects. Samples (not including ash removed by the trommel) were taken following this system.

For each facility a sample consisted of 500 to 1,000 pounds of ash which was screened with the 2″ screen and weighed. Overs were separated into organic, ferrous and inert/slag fractions and weighed. The overs were not included in the sample analysis. Three samples per day were taken at each facility over the course of three days. The day's samples were composited and coned and quartered to yield a daily composite sample of 500 lbs. Another 500 lb sample was left for the last day when a random composite sample would be selected from the three extra daily composite samples. Thus a total of four samples were sent to the lab for each facility visit. Stanlislaus was visited twice during the project to evaluate seasonality variance in the ash.

The Commerce facility's ash did not contain significant amounts of over 2″ material due to its pre-screening ash system. At Stanislaus and SERRF the ash overs were similar in proportion and breakdown. Nearly 20 percent of the ash was over 2″. Of this 1 to 2 percent were organics, consisting of unburned paper, plastics, food and yard waste, 5 to 10 percent were ferrous consisting of cans, nails and pots and pans, and 8 to 12 percent were slags and inerts such as rock, brick, asphalt, concrete and glass.

TESTS

CALTRANS worked with the CIWMB and R.W. Beck to develop a battery of tests which would give an indication of the beneficial uses possible for the ashes tested. Some of the test methods are derived from similar ASTM tests while others are unique. One ASTM test was selected which does not have a CALTRANS counterpart. The battery of tests performed on the samples are listed and described:

California Department of Transportation Standard Test Methods [7]

CT 201 Method of Soil and Aggregate Sample Preparation

CT 202 Method of Tests for Sieve Analysis of Fine and Coarse Aggregates — This test determines the relative particle distribution for the ash. Results are reported by a graph which shows the percent of the material which passes through different sized screens.

CT 206 Method of Test for Specific Gravity and Absorption of Coarse Aggregate — This test measures the bulk specific gravity and absorption of moisture or water of the larger sized aggregate material in the ash.

CT 207 Method of Test for Specific Gravity and Absorption of Fine Aggregate — This test measures the bulk specific gravity and absorption of moisture or water of the smaller sized aggregate material in the ash.

CT 208 Method of Test for Apparent Specific Gravity of Fine Aggregates — This test measures the apparent specific density of the fine aggregates proposed for use in bituminous (asphalt) mixes, cement treated bases (for road support), and aggregate bases. The difference between this test and CT 207 is that this test does not account for the porosity of the aggregate, and therefore yields a lower value for fine aggregates.

CT 211 Method of Test for Abrasion of Coarse Aggregate by Use of the Los Angeles Rattler Machine — This test determines the amount of material which is lost due to attrition in a rotating chamber, and is an indication of the durability of the material for various applications.

CT 212 Method of Test for Unit Weight of Aggregate — This test measures the weight of aggregate in a cubic foot container.

CT 213 Method of Test for Organic Impurities in Concrete Sand — This test determines the amount of organic impurities in the sand portion of the ash.

CT 217 Method of Test for Sand Equivalent — This test indicates the amount of sand versus clay and silt in the ash. The greater the number, the more sand and less clay there is.

CT 226 Method of Determination of Moisture Content by Oven Drying — This test determines the percent moisture in the ash as received by the laboratory.

CT 229 Method of Test for Durability Index — This test measures the relative resistance of the ash in producing clay sized particles. The test generates forces between the ash particles in the presence of water to simulate wear and tear on the aggregate. A higher number indicates more durability.

CT 301 Method of Test for Determination of the Resistance "R" Value of Treated and Untreated Bases, Subbases, and Basement Soils by the Stabilimeter — The R value is

TABLE 1 CAL TRANS SPECIFICATIONS FOR VARIOUS APPLICATIONS

Material	Specification Requirement for California D.O.T. Test									
	CT 211 500r Max.	CT 213	CT 217 Min.	CT 229 Min.	CT 301 Min.	CT 303 Kc Max.	CT 303 Kf Max.	CT 312 Min.	CT 515 Min	CT 548 Min.
Commerce Refuse										
Aggregate Subbase, Class 3			18		40					
Aggregate Base			22	35	78					
Asphalt Treated Permeable Base	45%									
Asphalt Concrete and Asphalt Concrete Base Aggregate, Type 3	50%		42			1.7	1.7			
Lean Concrete Base Aggregate			18							700 psi
Cement Treated Base Aggregate, Class A			18					750 psi		
Portland Cement Concrete Aggregate — Coarse	45%			60						
Portland Cement Concrete Aggregate — Fine		Satis.	71	60					95%	
Slurry Seal Aggregate			45	55						
Bituminous Seal Aggregate	40%									

an indicator of how stable a base or subbase material will be. The higher the value, the better the stability.

CT 303 Standard Method of Test for Centrifuge Kerosene Equivalent and Approximate Bitumen Ratio (ABR) — The K number for fines and coarse aggregate are determined and, in turn, used to calculate the approximate bitumen ratio which gives the asphalt needed for asphalt road applications. The lower the K_c and K_f number, the better for asphalt uses.

CT 312 Design and Testing of Classes "A and B" Cement Treated Bases — This method yields the appropriate cement and moisture contents to be combined with available aggregates for cement treated bases.

CT 515 Method of Test for Relative Mortar Strength of Portland Cement Concrete Sand — This test indirectly measures the concrete-making properties of the sand portion of the ash.

CT 548 Method of Test for Evaluation of Aggregate for Lean Concrete Base (LCB) — This test serves to determine the strength producing properties of the aggregate for this application, and the amount of cement needed for adequate compressive strength.

ASTM C-289 Standard Test Method for Potential Reactivity of Aggregate (chemical method) — This test gives an indication of whether the ash may react with cement over time and cause a network of fine cracks in the surface [8].

CALTRANS issues a standards book [9] from which one can determine the minimum standards necessary for each beneficial use to be explored. Table 1 shows these uses and standards respectively.

RESULTS

CT 202 which gives the particle size distribution of the ash samples is remarkably similar for all the samples, in spite of their different treatments. This is remarkable in light of the fact that the three facilities have very different ash screening processes, and two facilities add cement in

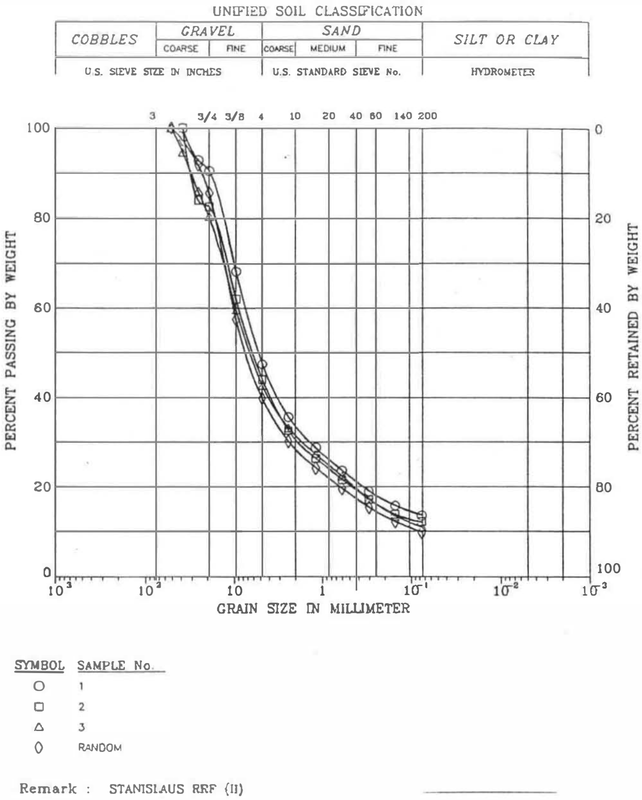

FIG. 1 CT-202 SIEVE ANALYSIS OF COARSE AND FINE AGGREGATE

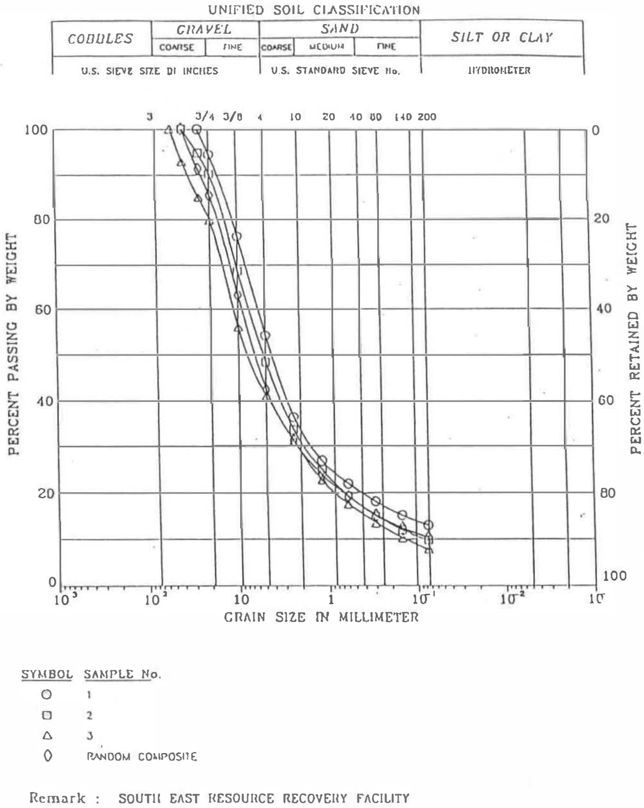

FIG. 2 CT-202 SIEVE ANALYSIS OF COARSE AGGREGATE

various amounts to treat the ash. Figure 1 shows a distribution for the samples taken at SERRF. According to this distribution, 10 percent of the ash is coarse gravel, 40 percent is fine gravel, and 40 percent is sand sized. Only 10 percent is the size of silt or clay. For comparison, Figure 2 shows a distribution for the samples taken on the second visit to Stanislaus.

Table 2 gives the test results for aggregate and sand characteristics which are useful in determining which applications may be better suited for the ash. The Stanislaus samples were shown to have a higher bulk density than the other facilities. CT208 tests were roughly similar for all the facilities. This means that the Stanislaus ash mainly differed from the other facilities' ash in that they were less porous. The composition of the ash is apparently similar. This is corroborated by the relatively low moisture absorption of the Stanislaus samples. CT 207 could not be run for the Commerce and SERRF samples due to organics in the ash.

The moisture in the ash (CT 226) was also significantly lower for the Stanislaus ash. A lower moisture content is desirable for asphalt paving applications as higher throughputs can be achieved in the asphalt mixing operation.

Table 3 gives the physical test results which are directly applicable to the CALTRANS standards. From reviewing the standards of Table 1, it is apparent that the Commerce and SERRF ash satisfy the specifications for subbase aggregate. Base material specifications were not attained, nor were other application specifications met. It is also noted that the samples showed high enough levels of organic contamination to cause many of the tests to be impossible to run or to cause results to be unreportable or indeterminate.

Tests on samples from Stanislaus were successfully performed for the most part. The second visit's samples were particularly low in contaminants. The three numbers from CT 549 represent values of compressive strength in psi as the percent of cement in the mix of ash is increased from 8.5 to 11.5 percent. The material tested met specifications for aggregate subbase and possibly asphalt-treated permeable base, asphalt concrete, and asphalt concrete base aggregate. The first visit's samples were significantly different than the second visit. In fact, the relative mortar compressive strength from the first visit was three times higher, and the durability (CT229) was greater. This points to the variability of the ash over time due possibly to differences in MSW, operation, or boiler conditions.

TABLE 2 CHARACTERIZATION OF MSW ASH

MSW Waste Source	Residue Sample	California D.O.T. Test							
		CT 206 SG	CT 206 ABS %	CT 207 SSD	CT 207 ABS %	CT 208	CT 212	CT 226 %	ASTM C-289
Commerce Refuse									
Sample 1 Fine/Coarse	Mixed	1.55	22.6	*	*	2.25	64.4	29.8	Innocuous
Sample 2 Fine/Coarse	Mixed	1.32	30.2	*	*	2.50	65.7	29.3	Innocuous
Sample 3 Fine/Coarse	Mixed	1.37	29.1	*	*	2.56	69.3	27.7	Innocuous
Random Sample Fine/Coarse	Mixed	1.46	27.4	*	*	2.42	***	27.5	Innocuous
SERRF									
Sample 1 Fine/Coarse	Mixed	1.23	17.8	*	*	2.48	62.5	23.3	*
Sample 2 Fine/Coarse	Mixed	1.47	10.3	*	*	2.54	65.4	29.8	Innocuous
Sample 3 Fine/Coarse	Mixed	1.5	9.3	*	*	2.57	82.7	23.7	*
Random Sample Fine/Coarse	Mixed	1.33	13.9	*	*	2.56	78.9	27.4	*
Stanislaus RRF - 1st Visit									
Sample 1 Fine/Coarse	Mixed	2.06	6.4	2.83	9.2	2.45	91.5	20.4	Innocuous
Sample 2 Fine/Coarse	Mixed	2.06	6.1	2.82	8.7	2.55	81.6	14.6	Innocuous
Sample 3 Fine/Coarse	Mixed	2.09	7.7	2.81	8.8	2.52	77.0	18.4	Innocuous
Random Sample Fine/Coarse	Mixed	1.99	7.9	**	**	2.55	**	16.5	**
Stanislaus RRF - 2nd Visit									
Sample 1 Fine/Coarse	Mixed	2.15	8.6	2.25	15.2	2.58	85.5	17.4	Innocuous
Sample 2 Fine/Coarse	Mixed	2.09	8.4	2.24	9.0	2.56	93.0	17.4	Innocuous
Sample 3 Fine/Coarse	Mixed	2.19	7.4	2.15	13.7	2.58	93.8	16.0	Innocuous
Random Sample Fine/Coarse	Mixed	1.96	11.1	**	**	2.57	**	16.4	**

NOTES

*Unable to determine
**Unable to test

CONCLUSIONS AND RECOMMENDATIONS

This study was intended to be only a first look at the potential for beneficial use of the ash in road applications. As such, we can formulate a few preliminary conclusions on the ash characteristics, and perhaps more definitively recommend future strategies for a path towards commercial utilization of this material. The results in California should also be applicable in other states.

First, it appears that this study corroborates many others whose finding is that the bottom ash of the incinerator is more useful as an aggregate material than a mixture. While all three facilities studied had a mixture of ash, the Stanislaus ash had been screened to remove fines, which presumably include much of the fly ash. This portion of the ash stream, seems to adversely affect many of the tests which are required to be performed for various road uses.

The addition of cement to the ashes is detrimental to the ash aggregate characteristics important for road applications. The SERRF and Commerce ashes tested were low in durability and stability compared with Stanislaus, untreated ash. While this could be a function of other factors besides cement addition, the cement is certainly a factor. It should be noted that these facilities are using cement to keep metals bound in the ash so that they are less leachable. Their strategy for ash treatment was selected to minimize landfill costs, not to maximize potential for beneficial commercial use. The Commerce ash is actually being used beneficially for temporary landfill roads, and as such, is not required to pay a tipping fee at the landfill.

The organics in the ash can be a problem in many of the tests. It is unclear, however whether this translates directly to poor properties for road applications. It may thus be unfair for a new material such as ash to be subjected to tests which were devised for other materials. It is interesting that in spite of the differences, the Stanislaus ash exceeded the specifications for many of the tests. This suggests that

TABLE 3 PHYSICAL TESTING RESULTS OF MSW ASH

MSW Waste Source	Residue Sample	California D.O.T. Test									
		CT 211 500r	CT 213	CT 217	CT 229	CT 301	CT 303 Kc	CT 303 Kf	CT 312	CT 515	CT 548
Commerce Refuse											
Sample 1 Fine/Coarse	Mixed	*	Unsatis.	62	14/*	85	*	*	*	*	*
Sample 2 Fine/Coarse	Mixed	*	Unsatis.	62	14/*	89	*	*	*	*	*
Sample 3 Fine/Coarse	Mixed	*	Unsatis.	68	13/*	84	*	*	*	*	*
Random Sample Fine/Coarse	Mixed	*	Unsatis.	63	14/*	81	*	*	*	*	*
SERRF											
Sample 1 Fine/Coarse	Mixed	48.6	Unsatis.	34	*/*	84	*	*	*	*	*
Sample 2 Fine/Coarse	Mixed	43.8	Unsatis.	48	*/*	81	*	*	*	*	*
Sample 3 Fine/Coarse	Mixed	*	Unsatis.	54	30/*	81	*	*	*	*	*
Random Sample Fine/Coarse	Mixed	50.2	Unsatis.	42	16/*	83	*	*	*	*	*
Stanislaus RRF - 1st Visit											
Sample 1 Fine/Coarse	Mixed	48	Unsatis.	60	44/67	73	2.6	1.5	*	105	*
Sample 2 Fine/Coarse	Mixed	48	Unsatis.	53	24/63	82	2.2	2.1	*	105	*
Sample 3 Fine/Coarse	Mixed	49	Unsatis.	55	28/62	75	2.3	2.5	*	105	*
Random Sample Fine/Coarse	Mixed	**	**	49.5	**	**	**	**	**	*	**
Stanislaus RRF - 2nd Visit											
Sample 1 Fine/Coarse	Mixed	42	Satis.	51	22/10	74	2.1	2.1	*	35	340/375/400
Sample 2 Fine/Coarse	Mixed	33	Satis.	54	23/17	79	2.0	>3	*	35	185/270/320
Sample 3 Fine/Coarse	Mixed	29	Satis.	57	25/23	81	1.8	1.0	*	40	300/540/570
Random Sample Fine/Coarse	Mixed	**	Satis.	54	**	**	**	**	**	**	**

NOTES

*Unable to determine
**Unable to test

an ash screening system and ferrous removal system such as used at Stanislaus can be effective for cleaning the ash to remove contaminants.

We recommend future testing to judge the effectiveness of various ash screening systems in other MSW incinerators. Studies can be done to show the effect of changes in operating parameters, and feedstock changes. RDF facilities could also sampled to compare with the mass burn facilities tested in this study.

In order to remove barriers to beneficial use of the ash, it will be important to continue a dialogue with CALTRANS concerning their standards and test requirements. Field demonstrations could be performed to verify the ability of a material which does not meet standards to perform adequately under real conditions. This would point toward lowering standards for ash aggregates, using different test methods, or devising new ones.

In the long run, economics and environmental impact need to be examined for a given application of the ash. Many studies have shown the bottom ash to have negligible environmental impacts in field demonstrations [10]–[12]. Public acceptance is difficult to obtain and liability or perception of liability may keep ashes use to lower profile sites such as landfills or private areas.

The economics of ash use usually constrains its end market to within 25 miles of the incinerator. Also important is its life expectancy. If a road's life is shortened due to using an inferior, although less expensive material, the life cycle costs of the road may be increased. In addition, overall air pollution could be increased due to putting in a new road and diverting the traffic for this construction work. Therefore, one must consider the interdependency of costs and impacts when evaluating the use of a new material such as ash for road applications.

REFERENCES

[1] Musselman, C., et. al., "New Hampshire Bottom Ash Roadway," Ash VI Conference Proceedings, Arlington, Virginia, 1993.

[2] Recchia, C., "Connecticut Bottom Ash Roadway," Ash VI Conference Proceedings, Arlington, Virginia, 1993.

[3] Hartlen, J., "Incinerator Ash Utilization in Some Countries in Europe," Ash I Conference Proceedings, Philadelphia, Pennsylvania, 1988.

[4] Ormsby, W.C., "Paving with Municiap Incinerator Residue," Ash I Conference Proceedings, Philadelphia, Pennsylvania, 1988.

[5] Gress, D., et. al., "Bottom Ash in Hot Asphalt Concrete," Ash IV Conference Proceedings, Arlington, Virginia, 1991.

[6] Hooper, W., "Processed Ash in Road Construction," Ash IV Conference Proceedings, Arlington, Virginia, 1991.

[7] State of California Department of Transportation, *Standard Test Methods*, Volumes I–III, 1991.

[8] "American Society for Testing and Materials," *Cement and Aggregates*, Volume 4.02, 1993.

[9] State of California Department of Transportation, *Standard Specifications*, July, 1992.

[10] Hartlen, J., Fallman, A., "Sorted Bottom Ash from Incineration in Road Embankments," Ash III Proceedings, Arlington, California, 1990.

[11] Jackman, T.M. Cambotti, R.K., Roffman, H.K., "Health Risk Assessment of Minnesota MWC Ash Utilization Demonstration Project — Utilization of MWC Ash an Alternative to Landfilling," Ash IV Conference Proceedings, Arlington, Virginia, 1991.

[12] Chesner, W., "New Jersey Ash Stockpile and Pavement," Ash VI Conference Proceedings, Arlington, Virginia, 1993.