Florida Department of Transportation Research

Evaluating the Use of Waste-To-Energy Bottom Ash as Road Construction Materials

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Municipal solid waste incineration (MSWI) generates millions of tons of ash each year. In European and Asian countries, this ash has been recycled into road beds, asphalt paving, and concrete products — encouraged and enforced by standards, management practices, and legal requirements — thus preventing vast amounts of ash from going to landfills. Many studies have shown both benefits and minimal environmental impact of using MSWI ash. However, persistent uncertainty about engineering properties and inconsistency in federal and state regulations in the U.S. have hindered MSWI ash recycling, and most ash ends up in landfills. In this project, University of Central Florida researchers reviewed current management practices, existing regulations, and environmental consequences of MSWI ash use around the U.S. and the world.

MSWI generates several kinds of ash, predominantly fly ash (FA) in smoke stacks and bottom ash (BA) in incinerator residues; they differ in many ways. Basic properties of FA and BA were studied in physical, microstructural, and chemical tests. Petrographic exams, such as scanning electron microscopy, energy dispersive X-ray, and X-ray diffraction revealed chemical composition and general content of the ash. The creation of bubbles due to aluminum — the main side effect of ash used in concrete — was evaluated by submerging ash and aluminum powder in a highly alkaline solution and measuring evolved hydrogen.

The researchers characterized the influence of ash on engineering properties of cement paste and concrete specimens by partially replacing Portland cement and fine aggregate with ground and sieved MSWI ash. Cement paste and concrete cylinders were cast with various amounts of mineral and fine aggregate additions, respectively; strength and durability were tested. For specimens incorporating BA, mechanical and durability characteristics were inferior to controls.

Fly ash (left) is more uniform in shape, while bottom ash (right) is more irregular. They differ in many other properties. Shown at the same size for comparison, bottom ash particles, averaging about a micron and ranging up to 50 mm, tend to be much larger than fly ash particles.

Reduction in overall performance of cementitious materials with ash replacement was attributed to (1) hydrogen gas evolution and (2) segregation of paste and aggregate due to lower homogeneity as bottom ash content increases.

BA was used in hot-mix asphalt (HMA) by replacing portions of fine aggregate in total aggregate. BA replaced aggregate smaller than 4.75 mm at 0 to 40% for evaluation of the optimum proportion of BA in HMA. HMA specimens were prepared following Marshall mix design and tested with the Marshall stability test, flow test, and moisture susceptibility. Results showed that 20% BA exhibited the highest stability and moisture resistance. At 20% BA, optimum binder content was then evaluated. Results showed that the optimum binder content for specimens containing 0% (control mixture) and 20% BA were 5.7% and 6.8%, respectively. BA was found to be a lightweight aggregate with higher porosity requiring higher amounts of asphalt binder.

By advancing knowledge of the properties and behavior of MSWI ash, this project explores the beneficial use of ash as a low-cost substitute in Portland cement, Portland cement concrete, and hot mix asphalt, diverting of ash from landfills, satisfying both economic and environmental goals.

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