

HIGH CARBON FLY ASH FINDS USES IN HIGHWAY CONSTRUCTION

Haifang Wen

Recycled Materials Resource Center
University of Wisconsin at Madison

&

Robert Patton

National Energy Technology Laboratory
Department of Energy

What is happening to fly ash?

Many power plants in the United States are eagerly looking for ways of utilizing their fly ash to avoid landfilling. Each year, over 900 million tons of coal is used for electricity generation in the United States. The combustion of coal, however, produces large volume of byproducts, including fly ash, flue gas desulfurization (FGD), and bottom ash, etc. According to American Coal Ash Association surveys, in 2006, about 72 million tons of fly ash were produced. Due to the increasingly stringent environmental policy stipulated by the Environmental Protection Agency (EPA) and/or local authority, the power generation industry must take measures to reduce the emission of nitrogen oxides (NO_x), sulfur oxides (SO_x), and Mercury (Hg). Low-NO_x burners reduce emissions by changing the combustion characteristic of coal boilers, but they increase the amount of residual unburned carbon in ash. Additionally, activated carbon is injected to reduce mercury emission, which also increases the carbon level in fly ash. In 2006, 40 million tons of that was placed in landfills, resulting in significant land purchase and energy costs, and potential environmental issues. Increased carbon levels make air-entrained concrete production more difficult. These issues transform ash from a revenue generating commodity to the third-greatest operating cost (behind fuel and labor) at coal-based power plants. It would also take commercial products away from ash marketers, concrete producers, cement manufacturers, construction contractors, plastics manufacturers and others who depend on using coal combustion products. Consumption of fly ash, especially off-spec fly ash (e.g. high carbon fly ash), will greatly relieve the pressure on the power industry by beneficially utilizing the fly ash.

Solution to high-volume high carbon fly ash utilization

In general, within-spec fly ash is referred to as Class C and Class F fly ash. Combustion of bituminous or anthracite coal produces Class F (low calcium) fly ash and combustion of lignite or sub-bituminous coal produces Class C (high calcium) fly ash. Class F fly ash is pozzolanic while Class C fly ash is both self-cementitious and pozzolanic. The top limit of loss on ignition (LOI) for both Class C and F fly ash, mostly due to carbon, is 6% and 5% for ASTM C-618 and AASHTO M295 standard, respectively.

“Currently, most specification fly ash can be used as a supplementary cementitious materials (SCM) in concrete to improve durability and economy as well as to meet

environmental goals. Cementitious high-calcium, high-carbon fly ashes can have self-hardening properties in the presence of moisture, like some Class C fly ashes. However, the high carbon content often eliminates it from being used, because the carbon in fly ash absorbs air-entraining admixture in freshly-mixed concrete, making it very difficult to control entrained air. We need to find ways to use these non-specification fly ashes, such as high carbon fly ash, for highway construction. Fly ash is an already heat-treated cementitious material that needs to be used in a beneficial way -- environmentally and economically.”” says Richard Meininger, a research highway engineer of Federal Highway Administration.

Unlike concrete which needs air-entrainment (generally 6%), extra voids are not desired in a base course under an asphalt pavement. A base course with maximum density and minimal void content will last longer than a loose base course. Therefore, the high carbon content in CHCFA presumably will not affect the performance of a base course. At the same time, the cementitious property of CHCFA will produce a strong base course to support the loads, compared to untreated base course. Stabilization of pulverized cold in-place recycled asphalt pavement materials with CHCFA will create a strong base course, which improves the long term performance of asphalt pavement and beneficially utilizes the high carbon fly ash, which would otherwise be landfilled.

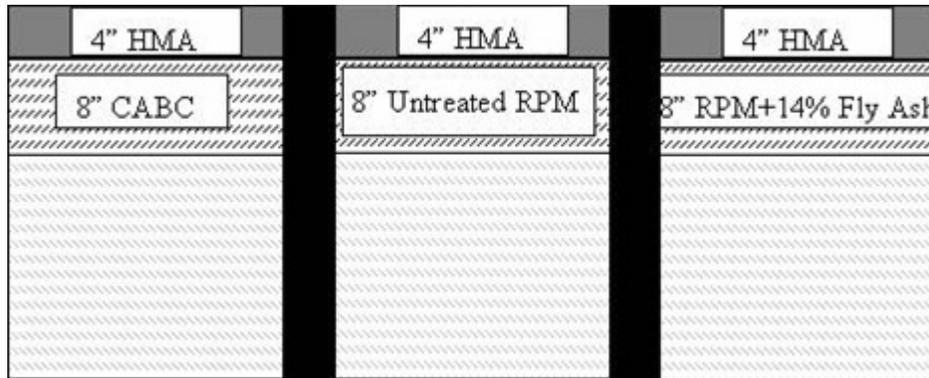
Construction Demonstration

“While there are many potential benefits of using fly ash stabilization, some questions still remain. The most important question is whether or not the fly ash used in the base course has any harmful effects on the environment,” says Tim Clyne, a Minnesota Department of Transportation Engineer, “Another question that pavement designers are trying to answer is what is the actual stiffness or strength of the stabilized layer. They will then be able to use more accurate values in future pavement designs and compare it to that of more traditional base materials.”

The U.S. Department of Energy sponsored this study to build test sections at MnROAD accelerated testing facility, with the cooperation of the Minnesota Department of Transportation. To expedite the performance evaluation, three test sections were built at MnROAD test road. MnROAD provides a very good opportunity to evaluate this new material and technology in the real world in a timely fashion. MnROAD is 3.5 miles long and is divided into different test sections, which represent varying combinations of road-building materials and designs. Each section is about 500 feet long. These three sections will consist of the same asphalt layers, subbase, and subgrade, but three different base courses materials: conventional crushed aggregates, full depth reclaimed pavement materials (RPM), and CHCFA stabilized RPM materials. A single heavily loaded truck continuously drives on the sections and this could provide direct comparison of the performance between the sections. MnROAD is equipped with a great number of sensors in the pavement to detect traffic volume, stress and strain under loading, moisture, and temperature. The real-time data are collected by a computer and stored in the server for subsequent analysis.



Aerial Photo of MnROAD Site (Courtesy of MnDOT)



Pavement Structures of Test Sections at MnROAD

Fly ash obtained from unit 8 of the Riverside Power Station in St. Paul, MN was used to stabilize the RPM. This fly ash has a calcium oxide (CaO) content of 22.37% and a carbon content of 16.35%. Riverside unit 8 fly ash is a cementitious high carbon fly ash. It is considered a non-compliant material by the Minnesota Pollution Control Agency and a special permit was applied for this construction demonstration project.

“Xcel Energy is excited about this demonstration project. We have plenty of anecdotal information indicating that, when responsibly used in soil stabilization applications, these relatively high carbon fly ashes will provide good geotechnical and environmental performance. But this project provides an excellent opportunity to express that performance in rigorous engineering terms -- which should expand confidence and value in this use of fly ash.” says Mike Thomes, the Combustion Products Coordinator of Xcel Energy.

As of Oct. 30, 2007, the construction of experimental road is complete. The fall of 2007 has seen tremendous rainfalls. The precipitation infiltrated into the base courses. The untreated RPM and crushed aggregate sections were too wet for the construction equipments and trucks to drive on them for asphalt paving. However, the fly ash treated RPM bases was not affected by the precipitation and was paved with asphalt successfully. For the other two sections, the wet base materials were never dried up and eventually had to be removed. Wet subgrade soils were also removed. The new subgrade and bases were re-placed and paved with asphalt. The asphalt layers were compacted using intelligent compactor which can tell the driver of compactor if the compaction is sufficient from the screen of the compactor. The instrumentation devices in these two bases were re-installed. During construction, researchers from University of Wisconsin – Madison, MnDOT, and Bloom Consultants, LLC conducted significant field tests on subgrade soils, base course, and asphalt.

“The construction process itself went quite smoothly” says Tim Clyne, “A vibratory padfoot roller is necessary for compaction, and the motor grader needs to be on top of things to get the material bladed quickly. MnROAD experienced an extraordinary amount of rain over the summer, and the fly ash stabilized section was able to support the hot mix trucks during paving operations while the non-stabilized sections were not.”



Recycled Pavement Materials on Site



Fly Ash Stabilization: before mixing with RPM (right) and after mixing (left)

Environmental monitoring

Leachate has been collected on a monthly basis. Laboratory characterization is underway. The leaching water in the storage tanks are sampled and amount of leaching water are recorded. In the meantime, laboratory characterization of materials sampled during the construction is underway. These lab results are being compared to the field tests results.



Installation of Lysimeter to Collect Leachates from Base Materials



The Recycled Materials Resource Center (RMRC) is sponsored by Federal Highway Administration (FHWA) to increase the wise use of recycled materials in roadway construction and maintenance. The RMRC is being hosted by the University of Wisconsin – Madison and the University of New Hampshire.



The National Energy Technology Laboratory (NETL), part of DOE's national laboratory system, is owned and operated by the U.S. Department of Energy (DOE). NETL supports DOE's mission to advance the national, economic, and energy security of the United States.