

ISSUE 2 • 2008

ASH

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Applications, Science and Sustainability of Coal Ash

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ASH **at work**

Applications, Science and Sustainability of Coal Ash

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On the cover:

The American Coal Ash Association will celebrate its 40-year anniversary in Alexandria, Va., July 1 and 2, 2008. During this event the Coal Combustion Products Partnership (C²P²) will hold its awards ceremony. See full story on page 23.

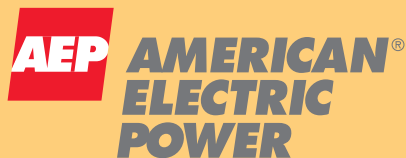




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IN WITH THE NEW

*By Al Christianson, ACAA Outgoing Chair, Great River Energy and
Mark Bryant, ACAA Incoming Chair, Ameren*

This month, we asked both Al Christianson, outgoing chair of the association and Mark Bryant, the new chair to offer some comments for this column. Al was in a reflective mood and we share with you some of those reflections looking back at both the industry and Al's career. He began with Great River in 1978 at a time when Coal Creek Station fly ash was being used only locally by a very select few. But in the late 1990s, Coal Creek Station started a concentrated effort with its ash marketing partner, Headwaters, to make infrastructure, transportation and customer service enhancements that would take Coal Creek fly ash sales to record levels. In the past ten years, GRE has continued to improve on infrastructure and customer service while maintaining the highest quality standards for its ash. Fly ash from Underwood, N.D. has a national reputation for quality and consistency, which enables its use in markets hundreds of miles farther than when first envisioned. As Al steps down, he says that his golf game (also started in the late 1970s) has not improved as much as the plant's CCP efforts. When asked about looking toward the future, he said, "What does the future hold? No more columns from Al, lots of golf for Al, and Al saying, 'Thank you to all the interesting and wonderful people I have met during this journey so far.'"

Thanks for your leadership these last two years and your unwavering support to the association and the industry!

We asked Mark to provide his views on what the future holds:

Associations like ours are great examples of how much can be accomplished when you have the right people in the right positions. Our executive director and the staff assembled in Denver have helped the association to another great year. Our affiliations continue to bring opportunity after opportunity for collaboration, research and regulatory reform. Our committee chairs are some of the most knowledgeable people in the industry who agree to take on an extra load in addition to their normal day jobs and their lives outside work. Without them, our work grinds to a halt. Our membership continues to grow as the words of effectiveness spread and we share news of the value and fun to be had at our meetings. True, sometimes our committee meetings could remind you of a church where everyone is afraid to sit in the front row and folks sit on their hands, but that usually doesn't last very long and the work gets divided and completed in good order. But mostly, we have the right people in the right places – namely our members – and we too should be proud

of what has been accomplished. Without the rank and file members, the association ceases to exist and everyone is left to fend for him or herself. Alone, our lives will get more complicated very quickly, but together ... well, that's where the real potential lies.

As the incoming chair, I am honored to have been selected to follow those before me: Al Christianson, Tom Jansen, Harry Roof, Ted Frady, Joel Pattishall, and the many others over these past forty years. All these people have been a part of the association for many years – much longer than I – and have seen the worst and now enjoy some of the best. Rest assured that I won't take this role lightly. I am also very happy that Mike Thomes will help navigate into the future, as vice chair; he is one of the most technically competent people I know in the industry. I have always been a student of history and truly believe that without knowledge of history, we are doomed to repeat the errors of the past. With the good counsel of these past and future chairs and others, I am confident we can continue to enjoy our successful association.

As we bid Al adieu and welcome Mark, we believe that ACAA's next 40 years will reflect the skills and attributes of both these gentlemen and the other chairs who will follow. ♦



COMFORT WITH CCPS PROVES FAR FROM UNIVERSAL

By Dave Goss, American Coal Ash Association

Despite our comfort with a subject, such as the non-hazardous nature of CCPs – especially fly ash – others may not share our sense of calm. The news media has recently covered CCP issues in Maryland and featured proposed regulations in Pennsylvania, Virginia, Connecticut, Florida, California and other states. We have discovered that just because we think we have the answers, many do not have access to the information we have or can provide.

In California, for example, the Collaborative for High Performance Schools (CHPS) has a materials subcommittee that reviews various building materials for inclusion (or exclusion) from a list of “low-emitting” materials considered safe for use in school buildings. Recently, there was an effort to ban concrete containing fly ash from CHPS’ materials listing because of a concern that mercury could potentially off-gas into the classroom, thus increasing the risk to students and staff.

Working with EPRI, the EERC, The Ohio State University, the University of

Nevada-Reno and a number of our member companies, we were able to postpone a vote to exclude concrete containing fly ash until further technical discussions could be arranged with the subcommittee. The data we have indicates that the likelihood of mercury in fly ash being released from the concrete is incredibly low. We are comfortable with that fact, but not everyone is. Several members of the subcommittee believe the risks are still great when measured in levels of parts per billion.

In another situation, the online version of Scientific American (Dec. 13, 2007) included an article titled “Coal Ash is More Radioactive Than Nuclear Waste.” Although the article proceeds to put this statement in context, we have found that members of the media have picked up on this and are using it in their messages, without regard to the details. It is clear our industry continues to enjoy that game of “javelin catching” – never certain when the next piece of misinformation will arrive or in what form the public will become concerned about CCP use.

ACAA is working with EPRI and others to address the mercury in concrete issue, as well as the health risks if any, of other heavy metals or trace elements in the products using CCPs. Alarming headlines in journals such as Scientific American do not make it easier for regulators to discern the real benefits or consequences of using and managing CCPs within their state. We have supplied a good deal of technical data to both Maryland and Connecticut to help provide them scientific information upon which to craft new regulations. We have met with the Pennsylvania DEP, as well, to discuss their proposed changes and have been pleased by the response from these state agencies. They have been genuinely pleased to have sound data to evaluate beneficial use or management guidance.

We ask that you keep the ACAA staff informed of any initiatives within your state or areas of expertise where technical, environmental or other data would help individuals reach sound decisions about the use of our products. We won’t be successful in every case, but if we don’t try, the industry will end up moving backward because of the lack of action. ♦



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USING FLY ASH AND NATURAL POZZOLANS IN LONG LIFE STRUCTURES

By Bruce Ramme and Julia Jacobsmeyer, *We Energies*

Historically, there have been numerous examples of fly ash and natural pozzolan use in long life structures, both by design and demonstrated performance. One of the earliest examples is a water storage tank used in Camiros, Greece from 600 B.C. to 300 B.C. The tank was built with concrete blocks and mortar consisting of lime, soil, sand, and siliceous aggregates. Generally, the mortar would have a composition (by volume) of six parts soil, two parts lime and one part sand. Tests showed that the tank had a compressive strength of 1,740 psi and after nearly 3,000 years, it still appears to be in “good condition.” A similar mortar was also used by the Romans in their aqueducts, as well as various marine structures. The Romans combined volcanic ash, lime, aggregate, and water to produce their mortar and concrete.¹ Volcanic erup-

tions, such as the ones in Santorin, Greece (1600 B.C. to 1500 B.C.) and Naples, Italy (A.D. 79) provided engineers of that time with the ash for various construction projects. Tests in 1961 proved that volcanic ash (crushed, then calcinated) met the requirements of ASTM C 618.¹

The use of natural pozzolans did not develop in the United States until the twentieth century. In the 1930s and '40s, the United States Bureau of Reclamation (USBR) promoted the use of natural pozzolans after testing proved that it assisted in the control of alkali-silica reactions in concrete and in lowering the heat of hydration. The California Division of Highways integrated the use of portland-pozzolan cement comprised of 25 percent crushed, calcined Monterey shale on several structures, including the Golden Gate Bridge in San Francisco, Calif. still

in service today. A 1912 boathouse built over water in Sausalito, Calif., was upgraded in 2005 using a 25 percent Class F fly ash concrete mixture. Because of the resilience of the fly ash, reinforcements of carbon steel were used in place of stainless steel and the specified strength of 4,060 psi was achieved in 28 days rather than the expected 56 days.²

Constructed in 1926, the two-level Wacker Drive in Chicago, Ill. maintained a service life of 75 years despite 20 years of salt and chemical usage for deicing. In 2002, a new viaduct structure, incorporating fly ash was designed with a life expectancy of at least 75 to 100 years.⁵ The concrete consisted of Type I cement, 10 percent Class F fly ash, 15 percent ground blast furnace slag, and 5 percent silica fume.³ To prevent cracking, a fogging process was used during placement, followed

Wacker Drive in Chicago



PHOTO BY KIM SCARBOROUGH



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**Iraivan Temple
built in Kauai,
Hawaii in 1999**

PHOTO BY DEREK FLENNIKEN



it.² By using HVFA concrete, the project saved approximately 882 tons of portland cement (the equivalent of 882 tons of carbon emissions) for the 3,921 cubic yards of concrete used.²

In Red Feather Lakes, Colo., the Great Stupa of Dharmakaya was built with a 1,000-year design life. The Stupa is a three-story Buddhist temple that houses relics, statues and a shrine to Buddha. The mix design of concrete consisted of 94 lb/yd³ of Class C fly ash, as well as 76 lb/yd³ of 9 percent silica fume.¹⁵ The base of the Stupa used 250 tons of concrete and sits upon a 31-column foundation¹⁶.

immediately by a seven-day wet cure using cotton mats and soaker hoses, as specified by the Illinois Department of Transportation. Test results showed that the concrete mixture had an average compressive strength between 6,500 psi and 9,000 psi. A strength limit of 9,500 psi was placed on the concrete because higher compressive strengths can lead to cracking during temperature changes.⁴ A latex-modified concrete overlay of 2.75 inches was installed to prevent deicing chemicals from penetrating the structural concrete.⁴ The overlay can easily be replaced if necessary every 20 to 25 years.

Class C fly ash (<1 percent carbon by mass), gravel, and siliceous sand.² A polycarboxylate high-range water-reducing admixture 0.01 gal/ft³ was also added to the concrete to reduce the water content. The HVFA concrete met strength requirements by using up to 65 percent fly ash (by mass). It was also found that thermal cracking was reduced when the portland cement content was lowered to 6.5 pcf. The compressive strength at 56 days was 3988 psi – the same average strength as portland cement concrete at 56 days. Compressive strength tests showed that cold weather slows the strength gain of HVFA concrete, while hot weather quickens

The Cathedral of Our Lady of the Angels in Los Angeles, Calif., also integrated the use of fly ash in order to obtain a service life of at least 500 years.¹⁰ The concrete used in this project consisted of ready-mixed concrete containing white cement with a low C₃A content and 15 percent fly ash substitution. Testing showed that the fly ash mixtures used five gallons of water less than metakaolin mixtures that were more susceptible to thermal cracking.⁸ Various control procedures were used because of the inconsistency in the color of the fly ash. More than 800 corners were designed into the building, which demonstrated the fine architectural detailing

More recently, the Iraivan Temple built in Kauai, Hawaii in 1999, was constructed with a foundation composed of Class F high volume fly ash (HVFA) concrete. Like many other Hindu temples, the Iraivan Temple is estimated to have an extensive service life of 1,000 years.² The HVFA foundation was adopted by two additional temples in the United States – one in Houston, Texas and one in Chicago, Ill. High volume fly ash concrete was used in the piers that support the foundation slabs and walls because of difficult soil conditions at both locations.

The Chicago Bochasanwasi Shri Akshar Purushottam Swaminarayan Sanstha (BAPS) temple and the BAPS temple in Texas were designed with a service life of 1,000 years. The Hindu temple in Chicago uses 250 piers – 30 feet by 3 feet – which are composed of Type 1 portland cement,

**The Great Stupa of
Dharmakaya**



San Francisco-Oakland Bay Bridge



PHOTO BY DAN BLUESTEIN

possible with fly ash concrete. Preventive measures, such as the use of elastomeric base isolators and a 28-inch moat, were taken into account for seismic activity. In the event of an earthquake, the isolators will allow the building to move up to 27 inches in any direction.¹⁰

Fly ash was incorporated into the construction of a building in Richland, Wash. that stores 2,316 tons of spent nuclear fuel. This concrete mixture consisted of 390 pounds Type II cement, 150 pounds Class F fly ash and 60 pounds silica fume per cubic yard, as well as 150 ounces high-range water reducer and 84 ounces mid-range water reducer.⁶ The concrete was placed amid high temperatures, so 900 pounds to 1,000 pounds of ice were added to each 10-yard load (the moisture from the ice left only 10 gallons to 20 gallons of water to be added). This mixture had a 7,500 psi compressive strength at 90 days. This building is designed for a service life of 75 years.

Several recent bridge designs with long service lives have also integrated the use of fly ash. For example, the 6th Street Viaduct in Milwaukee has a 75-year design life. The bridge used 40,000 yd³ of structural concrete to width spans totaling nearly one mile.¹² The concrete mix included 30 percent Class C fly ash.¹⁴ The structure contains fully automated, movable bridges for boat traffic. Although the high performance concrete that was used increased the resistance to water and salt, the surface will still need to be replaced every 25 years.¹³

In Canada, the Confederation Bridge (1997) has a life expectancy of 100 years. Concrete components used in the bridge were precast⁷ and the design incorporated the use of between 10 percent to 29 percent Class F fly ash.¹⁴ Fly ash has been used in the re-construction of the San Francisco-Oakland Bay Bridge, particularly in footings and large mass pours.

Researchers at Penn State and the University of Utah have designed concrete mixtures with a service life of 75 to 100 years for bridges. The concrete shows a lower permeability and a lower cracking

potential than the standard mixes currently used. The mixtures used 154 combinations of cement and materials such as fly ash, silica fume and slag.¹¹

In the original construction of the Hoover Dam, some fly ash was used to control heat of hydration when sections of the dam were being placed. Had fly ash not been used, it was estimated that because of the large volume of concrete being placed it would have taken the face of the dam nearly 150 years to cool to ambient temperatures. Portions of the Hoover Dam bypass project are currently being constructed using a 20 percent fly ash mixture with an expected design life of 75 years.¹⁴ The signature bridge spans nearly 2,000 feet (610 meters) with three phases: the Arizona approach, the Nevada approach and the Colorado River Bridge.¹⁷ Construction of the Hungry Horse Dam in Montana used approximately 132,360 tons of fly ash.¹⁸ This dam was completed

in 1952 and contractors opted to replace 35 percent of the portland cement with fly ash.¹⁹

HVFA concrete pavements produced with up to 70 percent Class C fly ash and 60 percent Class F fly ash as the cementitious material have been in service at We Energies' facilities in Wisconsin since 1984 with excellent in-service strength and durability. Forty to 50 percent Class C fly ash concrete has also been used in numerous other utility structures during this same period with excellent performance.^{21, 22}

Although this is not an exhaustive treatment of the historical or recent uses of fly ash in concrete structures, it is illustrative of the tremendous benefits of incorporating fly ash into mix designs where longevity, high performance and durability are required. High volume fly ash use is increasing and many newer, long lasting structures will be built. ♦

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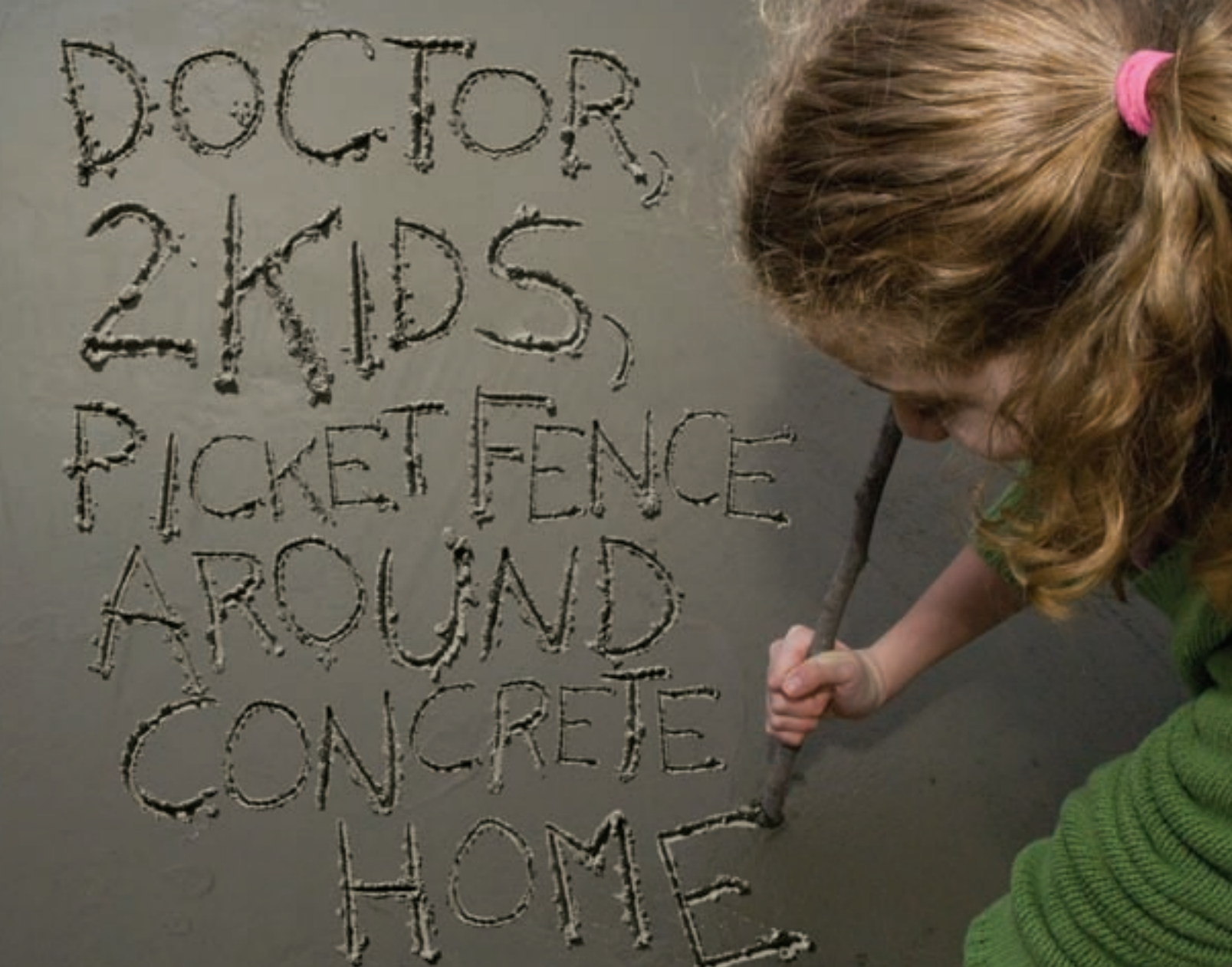
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REGULATIONS FOR BENEFICIAL USE CHANGING NATIONWIDE

By Dave Goss, American Coal Ash Association

One of the most significant barriers to increasing the use of CCPs, especially in non-traditional areas, is inconsistency in or lack of regulatory guidance by state and local agencies. Not all states have regulations that pertain explicitly to CCPs and instead may have regulations that address solid waste, or recycling or perhaps nothing at all. In the Report to Congress: "Barriers to the Increased Utilization of Coal Combustion/Desulfurization Byproducts by Governmental and Commercial Sectors" (July 1994), Recommendation No. 5 states it is necessary for industry, federal, state and local agencies to review and revise, as necessary, existing specifications and regulations relating to coal combustion byproduct use and to develop specifications and regulations where needed. Since the issuance of that report, terminology has changed and in January 2003, the EPA introduced the Coal Combustion Products Partnership (C²P²). The success of this program can be measured, in part, by the number of partners nearing 200, the detailed case studies available (www.epa.gov/epaoswer/osw/conservation/c2p2/index.htm), and by the acknowledgment by several states that C²P² is, in fact, a program to consider when developing beneficial use regulations.

Recently, ACAA has become aware of some states that have proposed new regulations or are in the process of revising beneficial use guidance pertaining to CCPs. Connecticut announced in January 2008, its intent to issue a "General Permit for Beneficial Use of Coal Combustion Products (CCPs)." As part of the announcement, a fact sheet about

beneficial use was included, which made direct reference to the C²P² Web site as a key information source. ACAA worked with the Connecticut Construction Industries Association, and several of our members who market or produce CCPs in the New England area, to provide information to the Connecticut DEP applicable to several uses described in the proposed rulemaking.

ACAA was invited to attend a meeting in Harrisburg to discuss Pennsylvania's planned changes to beneficial use regulations in that state. Assisted by Reliant Energy and other members, I met with PA DEP staff to discuss and provide information about a number of CCP applications under consideration. Similarly, members from Mirant Mid-Atlantic, Constellation Energy, Charah, Lehigh Cement and I had the opportunity to participate in a public hearing on House Bill 388 in front of the Maryland Environmental Matters Committee on Feb. 13, 2008 and at a work group meeting at the Maryland Department of the Environment (MDAE) on Feb. 26, 2008. The House Bill proposed some stringent and inflexible requirements pertaining to CCP use in the state. The bill, however, was subsequently withdrawn and MDE is gathering information about potential beneficial uses of CCPs that will be implemented by the Department of the Environment later this year. ACAA, USWAG and others have supplied a number of documents to the MDE staff on topics ranging from structural fills and FGD gypsum to beneficial use regulations in other states and applicable CCP standards and specifications. We provided the staff with a copy of ACAA's

extensive listing of regulations, technical documents and Web sites with information about CCPs and other industrial materials.

In 2005, ACAA created an extensive listing of documents and Web sites that can be used as resources about CCP utilization. The document contains more than 340 entries and is continually being updated as staff identifies new sources of information. ACAA members can download a PDF copy of this document on the ACAA Web site by going to Standards & Specifications on the left of the home page and clicking on the file "Compilation of Regulations, Standards, Specifications, Web sites and Other Resources that Pertain to CCPs." Members are encouraged to provide the staff with leads to new or revised information on CCPs that can be added to this compilation.

In some states, beneficial use of CCPs contributes directly to state goals for recycling or reuse of industrial materials. Michigan, for example, has set a goal of increasing recycling within the state to 50 percent or greater in the coming years. While this includes recycling of all materials generated or used within the state, CCPs and other materials – like foundry sands, scrap tires and construction and demolition debris – can make a significant impact on this goal. ACAA is discussing with Michigan's Department of Environmental Quality, the Industrial Resources Council and EPA Region 5, the idea of a workshop or set of meetings to provide information to DEQ staff on the practical issues related to recycling and beneficial use of CCPs and other industrial materials.

ACAA and its members have recently been active in providing CCP information to the North Dakota Department of Health Division of Water Quality, to Mississippi Department of Transportation, Virginia's Department of Environmental Quality and Maryland's State Highway Administration. We have also worked with other members and colleagues in California to help provide technical information about mercury in concrete containing fly ash to the state's Collaborative for High Performance Schools (CHPS) Materials Subcommittee. In this situation, there has been an effort

to ban any concrete containing fly ash in CHPS verified school buildings because of a concern about mercury. Technical information provided by EPRI, the Ohio State University, the EERC, Headwaters Resources, and the University of Nevada-Reno, has been given to committee members to help them make an informed decision about mercury in concrete, whether it contains fly ash or not.

Although ACAA is primarily focused on beneficial use, we are available as a resource to members and non-members

who have a need for any type of CCP information. If there are local, state or federal issues that could affect production, management, utilization or disposal anywhere in the United States, ACAA may be a helpful resource to provide insight, technical assistance or other information to whomever might need that assistance. We have also provided information to persons in Singapore, Canada, Romania, China, India, Turkey, Saudi Arabia, Israel, and many other nations. We are an internationally recognized source of information on CCPs. ♦



IRC

Industrial Resources Council

ACAA is a member of the Industrial Resources Council (IRC) – a council under the National Recycling Coalition. The IRC's goal is to increase market opportunities for materials produced by the industries that the council's six members represent: ACAA, the Construction Materials Recycling Association (CMRA), Foundry Industry Recycling Starts Today (FIRST), National

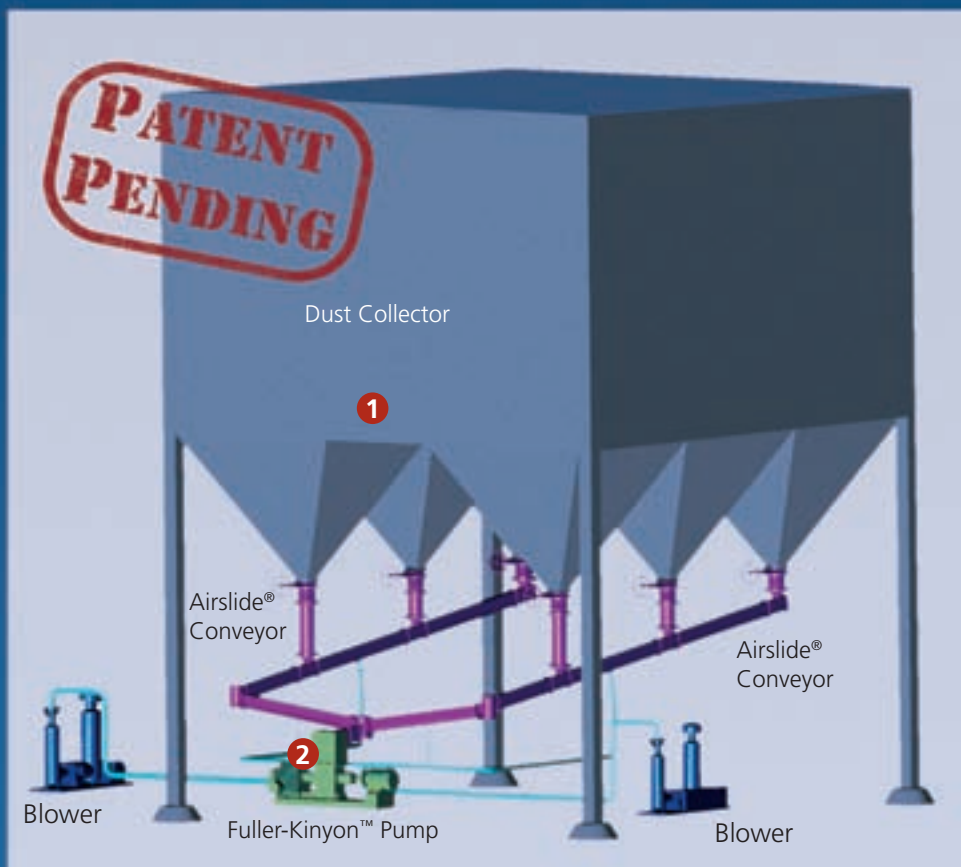
Council for Air and Stream Improvement (NCASI), National Slag Association (NSA), and the Rubber Manufacturers Association (RMA). Since the regulatory and beneficial use issues facing our industry and others are very similar, the IRC serves as a focal point of discussion, connecting the information dots about material use. The IRC is currently in partnership or in dialogue with the Association of State and Territorial Solid Waste Management Officials (ASTSWMO), the EPA's Industrial Materials Recycling initiative, the American Public Works Association (APWA), the American Association of State Highway Transportation Officials (AASHTO), the Recycled Materials Resource Center (RMRC) and state agencies.

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"Since the installation of the system in 1995, we have replaced one 4-foot long section of the Airslide fabric. Other than that, the system is nearly maintenance free."
- Glenn Outland, Plant Engineer, Roanoke Valley Energy Facility

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ISO-Veyor 'King of the Islands'

InBulk Technologies Ltd, UK

InBulk Technologies, part of the international bulk logistics group, InterBulk Group Plc, is making new ground in supply of its patented non-tipping ISO-Container for cementitious materials in areas where there is difficult access to intercoastal areas and islands.

The ISO-Veyor is an intermodal tank container developed by InBulk Technologies, facilitating easy transition between road and rail and sea.

It consists of a cylindrical vessel constructed within the frame dimensions of a 20 ft or 30 ft ISO unit. It can be handled exactly as a standard ISO container, utilising currently available trailer chassis and rail car rolling stock and is compatible with container shipping as it shares the same ISO dimensions of standard shipping containers. The ISO-Veyor can be handled efficiently and easily by standard container infrastructure.

The ISO-Veyor can be filled at source and remain sealed until the point of delivery thus removing the need for intermediate handling or storage of the contents.

The clever part is that the ISO-Veyors fluidisation membrane is designed to follow the curvature of the tank barrel, avoiding the need for space consuming cones, thus allowing superior payloads and discharge performance in terms of both time and residue remaining. With the simple addition of an air supply (and without tipping, so reduced opportunity for accidents or need for a costly tipping chassis) the ISO-Veyor discharges its contents, 30 tons in 30 minutes and leaves very little material behind following every discharge.

The major advantage that the ISO-Veyor system offers is transportation flexibility.

Cement, coal ash and lime are being loaded at terminals by gravity through standard manholes, while mounted on a trailer or railcar, and then transported to a rail or barge shipping terminal for trans-shipment, without double handling of the material, to markets or destinations hundreds of miles away.

One area where InBulk has witnessed a surge of activity is for customers operating to projects located on Islands. Some scenarios include construction projects, where the ISO-Veyor provides an ideal system for intermodal deliveries without the requirement to make investments in silos or large volume storage facilities.

Previously, handling situations required Pressure Differential Tankers on ferries or RORO ships. Costs due to trailer damage, driver hours, longer distances and fuel surcharges are avoided. ISO-Veyors are more environmentally friendly as they allow owners to make choices between the most efficient methods for transport.

The ability for the material to be stored horizontally, up to four units high, also offers on-site storage options that in the past were hampered by economics or space limitations or lack of trailers or railcars.

The products which can be transported in ISO-Veyors have extended market access for powders like cement, fly ash, ground granulated blast furnace slag, white cement, aluminates and by-products. Future developments will see this range extended to chemicals and food grade versions, which would be fully cleanable in line with current systems for liquid ISO-Tanks.

Jim MacLean, Business Development Manager for the US & Canada explains:

"Through our parent group's global network, InBulk now has the ability to offer a managed dry bulk logistics service almost anywhere in the world.

New enquiries from areas such as mining, construction, offshore oil, and industries seeking new supply sources have increased dramatically since our first start of operations, especially from island locations.

The enquiries have included ISO-Veyors travelling between locations in the Caribbean, Central and South America to North America. Asia, Indonesia and Malaysia are also interesting markets with a lot of scope for development."



The ISO-Veyor has also made some notable strides in key overseas markets such as the US. In December 2006 Lafarge North America became the first American owners and operators of the ISO-Veyor.

Lafarge North America's Montreal office has ordered more of the 20 ft PH type ISO-Veyor for a marine shipment of cement powders to Newfoundland customers from the Port of Montreal.

Stephane Caron, Distribution Operation Manager for Eastern Canada comments:

"We are delighted to be placing another order for ISO-Veyors as the flexibility of this solution minimized logistical risks, while reducing costs to a minimum and maximizing supply chain efficiencies. Empty containers are offloaded, transported to our terminal for reloading and returned to the ship for the return leg same day. Lafarge also recognizes the ISO-Veyor technology supports our corporate goals for sustainability."

To arrange a trial of the ISO-Veyor contact Jim MacLean

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RE-IMAGING COAL:

Novel Process Removes Mercury While Retaining Ash Sales

By Al Bland, Western Research Institute

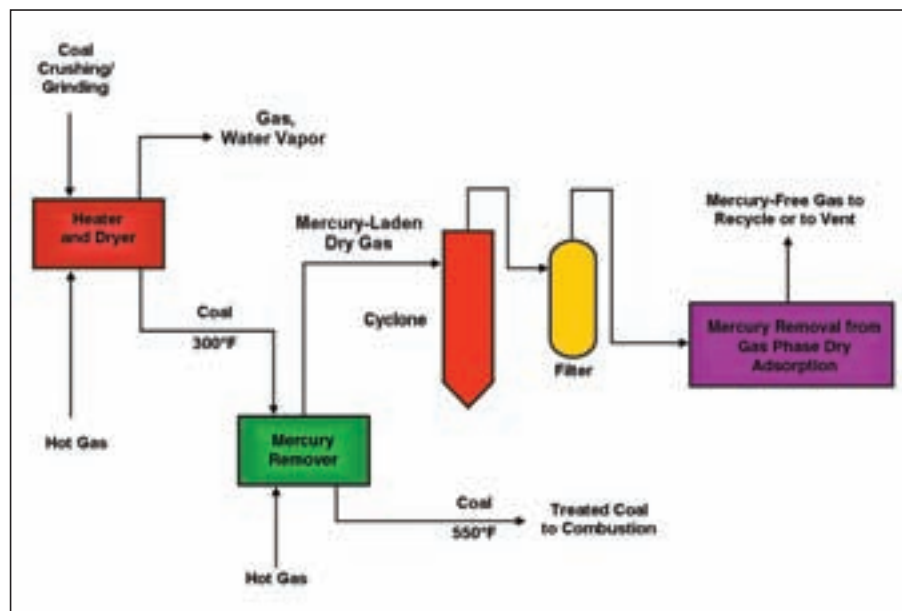
Coal-fueled power generation will continue to play an integral role in the electricity generation in the United States for decades to come. Over 320GW of power in the United States is from coal and additional coal-fueled power plants are projected to come online in the next decade (EIA). Currently, about 50 percent of that coal-fueled generation in the U.S. is from subbituminous coals, such as those from the Powder River Basin of Wyoming.

Emissions from coal-fueled units are being scrutinized and regulations are being considered at the federal and state levels. Mercury and CO₂ are currently targets of public debate, resulting in industry's need to strive for a near-zero emissions clean coal industry. In contrast with processes that remove mercury from utility flue gas, a DOE-funded process has been patented by Western Research Institute (WRI) that removes mercury from the coal prior to combustion, thereby maintaining ash quality/sales. This process is also compatible with clean coal processes such as advanced gasification/integrated gasification combined cycle (IGCC) plants.

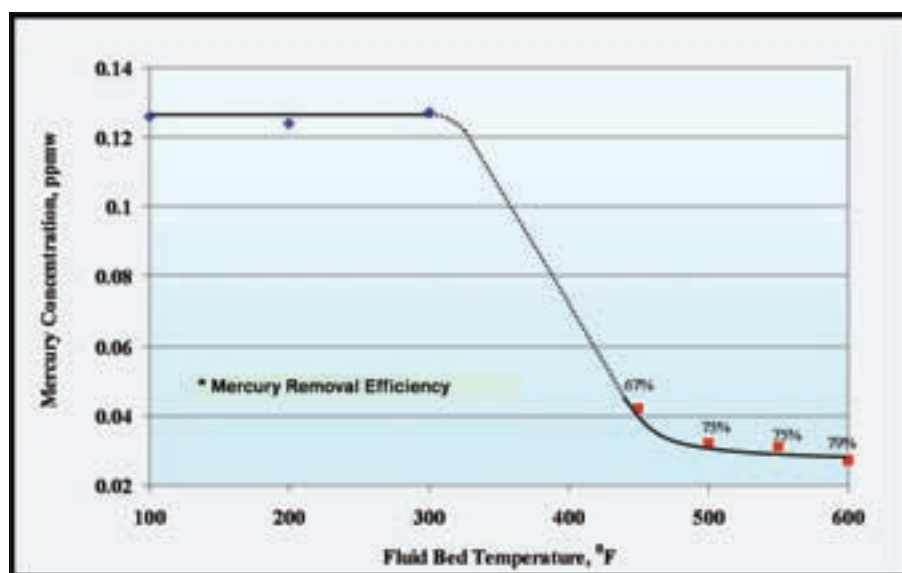
PROCESS

This novel process is based on a two-stage thermal pretreatment of the raw coal to remove both moisture and mercury. In this process, the coal is heated to remove the moisture and then heated to a higher temperature in a separate zone to evolve the mercury.

Run of mine coal, crushed to a suitable size, enters the moisture removal zone



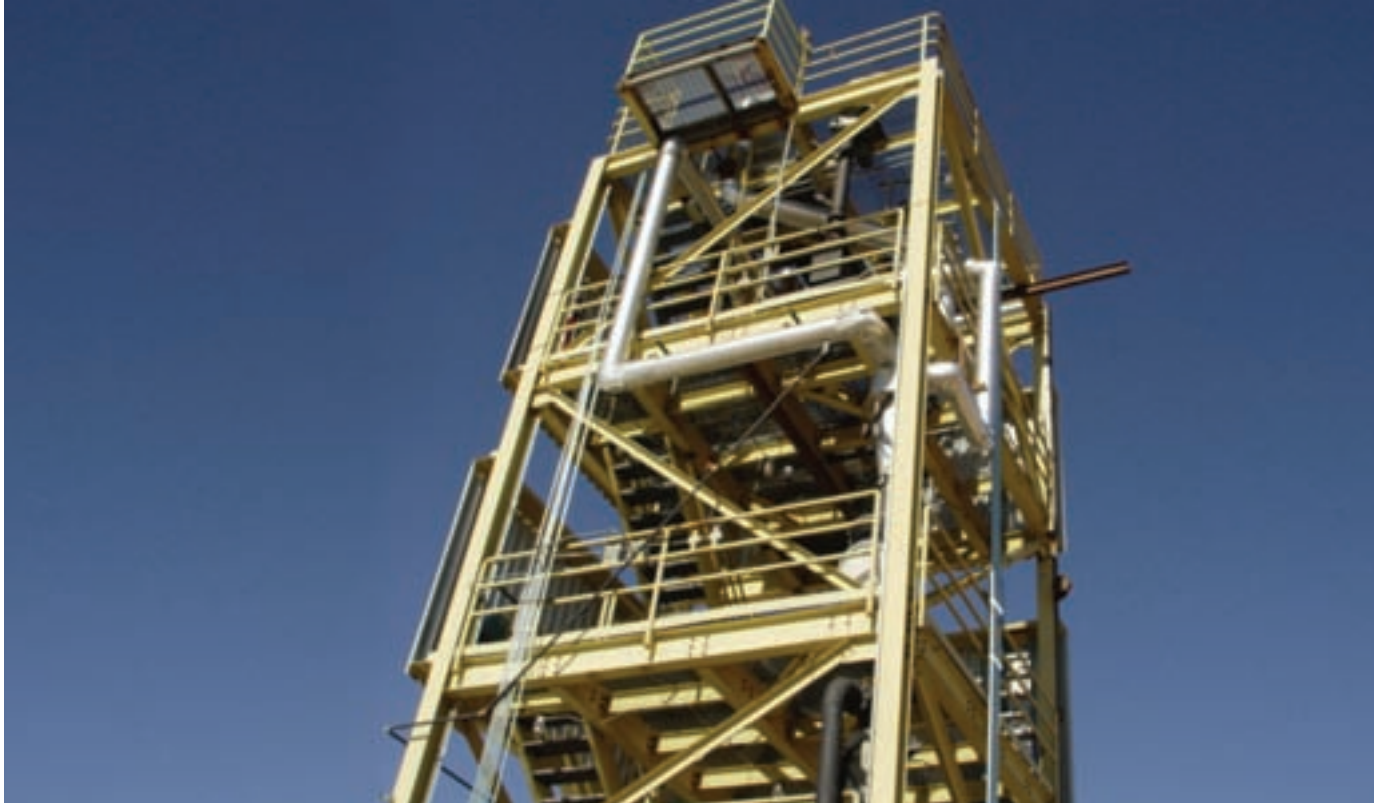
Process Flow Diagram for WRI's Mercury Removal Technology



Typical Mercury Release as a Function of Temperature for PRB Coal.

where it is heated to a temperature not exceeding 300°F. In this zone the free water and some of the more tightly bound water is volatilized and removed from the zone by the heating medium. The coal is then further heated in the mercury removal zone to approximately 550°F, where 70 percent to 80 percent of the mercury in PRB and lignite coal is volatilized and re-

moved from the zone by an inert sweep gas. Mercury is released and captured in the temperature window of 400°F to 550°F. The treated coal is then cooled and directly fed into the power plant pulverizers. The sweep gas stream, containing the evolved mercury, passes into the mercury removal equipment and the mercury is captured.



Process Pilot Plant at the WRI ATC

DEVELOPMENT STATUS

Process development for PRB subbituminous, as well as North Dakota and Gulf Coast lignite coals, continues under the DOE Cooperative Agreement DE-FC26-07NT42785 with WRI, entitled "Pilot Testing of WRI's Novel Mercury Control Technology by Pre-Combustion Thermal Treatment of Coal." Project partners include the Energy and Environmental Research Center (EERC), ETAA Energy, Foster Wheeler North America, GCEE and Washington Group International (WGI). Industry-affiliated co-sponsors include Basin Electric Power Cooperative,

Detroit Edison, Electric Power Research Institute (EPRI), Montana-Dakota Utilities, North Dakota Industrial Commission, SaskPower and Southern Company. DOE project goals are to provide greater than 50 percent mercury removal at costs less than \$30,000/lb of mercury removed.

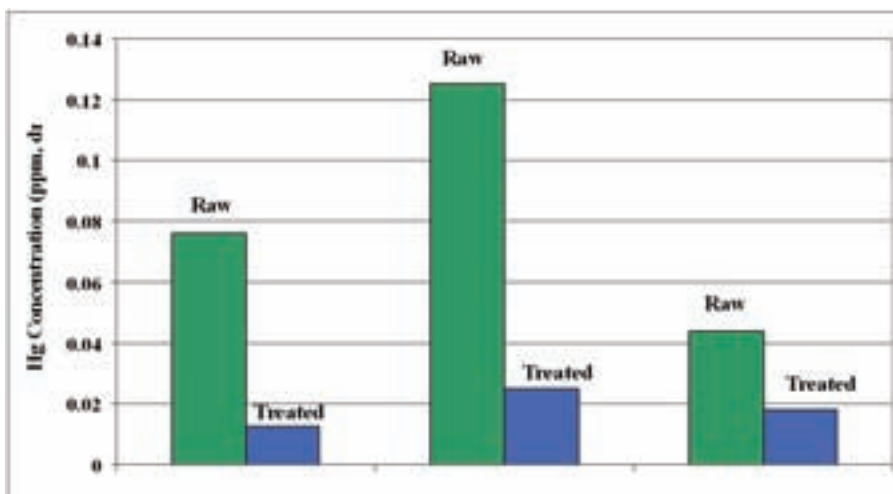
Both bench-scale testing and larger-scale pilot testing are proceeding at WRI's Advanced Technology Center. Results from the testing indicate that the removal goal of 50 percent is achievable for the range of subbituminous and lignite coals and that the mercury removal ranges from 50 percent to 87 percent removal.

In addition, pilot pc combustion tests have demonstrated the viability of the technology in producing a product with excellent combustion characteristics that demonstrates a reduction in NO_x compared to the untreated coals.

PROCESS BENEFITS

Low-rank coals present special problems when it comes to mercury control. These include:

- Higher fraction of elemental mercury in subbituminous and lignite-fired installations.
- Recent findings that cite the potential for triggering of New Source Review (NSR) with ACI and the negative impact of SO₃ on activated carbon injection (ACI) performance.



Mercury Removal from PRB Subbituminous Coals by the Thermal Coal Upgrading Process.

The WRI process is to be integrated into the power plant and employs waste heat for the process energy. By integrating the process at the utility, a lower moisture removal is possible without the issues associated with spontaneous combustion in the stockpile and excess dust generation commonly associated with past coal drying processes. In addition, the coal upgrading process has numerous benefits for the utility and could potentially represent a positive benefit to the bottom line of the plant, unlike most of the activated carbon technologies proposed for post-combustion mercury control.

Emission Reductions:

This treatment process reduces emissions of SO_x and CO₂ due to increased efficiency gains by 3.5 percent to 4 percent, removes and captures mercury (and also lesser amounts of arsenic and selenium), and reduces NO_x emissions from the plant by up to 30 percent. Most importantly, the WRI mercury control technology does not have the potential to trigger New Source Review in 2009 and beyond and is not impacted by SO₃ and other species in the flue gas, as are post-combustion technologies such as activated carbon injection.

Plant Efficiency:

The energy conversion efficiency for PRB coal-fueled units is lower because the fuel contains about 28 percent to 30 percent moisture. The high moisture of raw PRB and lignite coal reduces energy conversion efficiency in coal-fueled power plants. Moisture reduction is one way to improve the efficiency.

Water Savings:

Power plants have high freshwater needs. In the west and in the southeast where the PRB coal is shipped and consumed, water shortages are common and efforts to reduce water

needs at the plant are paramount. This unique process can produce enough clean water to meet the plants freshwater consumption needs for boiler feed water make-up.

Ash Sales:

The removal of mercury prior to combustion obviously allows for continued sales of the ash, since no sorbents end up in the ash from the combustion of the treated coal. The financial impact of lost ash sales is a major factor in the cost of mercury control technologies.

Cost:

The Washington Group (WGI), for EPRI in 2004, concluded that the WRI process cost was 16 percent to 27 percent less for mercury control than the TOXECON process. Based on the value of the above co-benefits and WGI's estimates of capital and operating costs, the estimated payback of capital is in the range of four years and the cost of mercury removal could be in the range of 20 percent of the DOE goal – providing an attractive opportunity for the U.S. power industry.

In summary, WRI's treatment offers a unique approach in that it controls mercury

emissions (while maintaining ash sales), increases plant efficiency, and offsets power plant fresh water consumption. Most importantly, this new mercury control technology does not have the potential to trigger New Source Review in 2009 and beyond and reduces other emissions such as NO_x and CO₂. This technology is not impacted by SO₃ and other species in the flue gas and does not deploy sorbents imported from overseas as is the case with much of the activated carbon proposed for post-combustion mercury control strategies. ♦

Acknowledgements

The author acknowledges the support of the project by the U.S. Department of Energy National Energy Technology Laboratory under Cooperative Agreement DE-FC26-07NT42785. The author also acknowledges the support of ACAA members and other project partners and the utility-affiliated co-sponsors noted within the article.

For more information, contact: Dr. Alan E. Bland, vice president, Western Research Institute, 365 North Ninth St., Laramie, WY 82072. Phone: 307-721-2386
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ACAA CELEBRATES ITS 40TH ANNIVERSARY

By Dave Goss, American Coal Ash Association

The ACAAA's 40th Anniversary was celebrated in Alexandria, Va. on July 1 and 2, 2008. The association invited several well-respected industry experts as speakers, including Oscar Manz, who offered historical insights as a tenured professional. Among the event's highlights was the 2008 Coal Combustion Products Partnership or "C²P" Awards Ceremony held July 2. Please see this year's winners on page 30.

The fall ACAAA meeting will be held in Denver, Oct. 21 and 22, 2008 at the Warwick Hotel. The venue is within minutes of the State Capitol, 16th Street Mall, the Denver Convention Center, Pepsi Center,

the Cherry Creek shopping district and other Denver tourism destinations.

In 2009, ACAAA's annual meeting will be held at the Embassy Suites in Scottsdale, Jan. 20 and 21. It's a beautiful time of year in Arizona, so plan to bring your family to enjoy the warmth and the related activities in the Valley of the Sun.

It's not too early to plan to attend WOCA 2009 in Lexington, Ky., May 4 to 7. The Call for Papers is open until mid-October as described on the official WOCA Web site (<http://www.worldofcoalash.org/presenters/callforpapers.html>). There will be an emphasis on sustainability, CO₂ and CCPs, green building and other timely topics. ❖



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PARTNERING FOR SUCCESS

*By Thomas J. Feeley III, Charles E. Miller, and Andrew P. Jones,
Department of Energy/National Energy Technology Laboratory*

BACKGROUND

Mercury (Hg) emissions were first identified for potential regulation in the 1990 Clean Air Act Amendments. Since then, concerns have been raised about whether control technologies could be cost effective, especially given mercury's low concentration and subsequent reactivity during coal combustion. Those concerns are giving way to action due, in large part, to the leadership role of the U.S. Department of Energy's National Energy Technology Laboratory (DOE/NETL) in improving both the cost and performance of Hg control technologies through a successful public-private partnership.

DOE/NETL, under the Office of Fossil Energy's Innovations for Existing Plants (IEP) Program, has managed the premiere Hg research and development (R&D) program for coal-fueled power generation facilities. Working collaboratively with the U.S. Environmental Protection Agency, Electric Power Research Institute, University of North Dakota Energy and Environmental Research Center, power plant operators, state and local agencies, and a host of research organizations and academic institutions, the IEP Program has fostered the development of reliable measurement techniques for the different chemical forms of Hg. Sampling and data analysis have identified the primary factors that affect Hg speciation and capture in coal combustion flue gas, ultimately leading to the development of cost-effective Hg control technologies.

The trace amount of Hg present in coal is volatilized during combustion and converted to gaseous elemental mercury

(Hg⁰). Subsequent cooling of the coal combustion flue gas and interaction of the gaseous Hg⁰ with other flue gas constituents – such as chlorine and unburned carbon – result in a portion of the Hg⁰ being converted to gaseous oxidized forms of mercury (Hg²⁺) and particulate-bound mercury (Hg_p). As a result, coal combustion flue gas contains varying percentages of Hg_p, Hg²⁺, and Hg⁰, and the exact speciation has a profound effect on the Hg capture efficiency of existing air pollution control device (APCD) configurations, which has been found to range from zero to more than 90 percent.¹ The Hg_p fraction is typically removed by a particulate control device such as an electrostatic precipitator (ESP) or fabric filter (FF). The Hg²⁺ portion is water-soluble and, therefore, a relatively high percent can be captured in wet flue gas desulfurization (FGD) systems, while the Hg⁰ fraction is generally not captured by existing APCD.

TECHNOLOGY DEVELOPMENT

This knowledge was subsequently funneled into the development of a suite of Hg-specific control technologies for the diverse fleet of U.S. coal-fueled power plants. DOE/NETL initiated an R&D program in the mid-1990s directed at two general approaches for controlling Hg: (1) Hg-specific control technology such as sorbent injection, and (2) Hg⁰ oxidation concepts. In 2000, following laboratory through pilot-scale development of these technology approaches, DOE/NETL launched a three-phase field-testing program. The program called for the installation and full-scale and slip-stream testing of the most promising Hg control technologies at operating coal-fueled

power plants. The initial field testing (Phase I) focused on untreated activated carbon injection (ACI) and improving the capture of Hg across wet FGD systems, while Phase II, which began in 2003, was expanded to include testing of chemically treated ACI, sorbent (i.e., activated carbon) enhancement additives, and oxidation catalysts. The goal of Phases I and II was to develop Hg control technologies (available for commercial demonstration by year-end 2007, for all coal ranks) that could achieve 50 percent to 70 percent Hg capture at costs 25 percent to 50 percent less than the baseline (1999) estimate of about \$60,000 per pound of Hg removed (\$/lb Hg removed). Phase III of the field-testing program was initiated in 2006, and directed at continued field testing of advanced Hg control technologies that could achieve 90 percent or greater capture at a 50 percent to 70 percent cost reduction and that would be available for commercial demonstration by 2010. In addition, the Phase III field testing emphasized the assessment of potential balance-of-plant impacts associated with continuously operating a Hg-specific control technology.

Over the past seven years, the IEP Program has managed full-scale field tests of Hg control technologies at nearly 50 U.S. coal-fueled power generation facilities. The flexibility of the IEP Program allowed DOE/NETL to quickly incorporate insights and lessons learned from its partners into the development of advanced Hg control technologies tailored to specific areas of need. For instance, a determination that chlorine released during coal combustion promotes Hg oxidation in flue gas led to field

testing of technologies designed to provide a halogen “boost” for coals – such as subbituminous and lignite – that tend to contain low levels of chlorine. DOE/NETL has observed a step-change improvement in both the cost and performance of Hg control during full-scale field tests of chemically-treated (or brominated) ACI upstream of a particulate control device and coal treatment with an aqueous calcium bromide (CaBr₂) solution at power plants equipped with a wet FGD system.

The development, and subsequent field testing, of chemically-treated ACI represents a concerted effort to enhance Hg capture at units firing low-rank coal after Phase I results at We Energies’ Powder River Basin (PRB) subbituminous coal-fueled Pleasant Prairie Unit 2 showed total Hg removal via untreated ACI was limited to about 65 percent.² Figure 1 provides a comparison of untreated and chemically-treated ACI performance at three of DOE/NETL’s Phase II field testing sites: (1) Great River Energy’s Stanton Station Unit 10 (Lignite/FF), (2) Basin Electric’s Leland Olds Station Unit 1 (Lignite/ESP), and (3) Stanton Station Unit 1 (PRB/ESP). These parametric data curves illustrate the improved Hg capture efficiency of chemically-treated sorbents

at power plants burning lower-rank coals as high levels of Hg capture are attainable at relatively low injection rates. In fact, the treated sorbents achieved at least 90 percent total Hg capture at an injection rate of 3 pounds per million actual cubic feet (lb/MMacf) of flue gas or less at these Phase II field testing sites.

A DOE/NETL economic analysis³ released in May 2007, indicates that the high Hg capture efficiency of chemically-treated sorbents has drastically reduced the estimated cost of Hg control because of a reduction in the injection rate required to achieve a given level of control, which offsets the higher cost of these

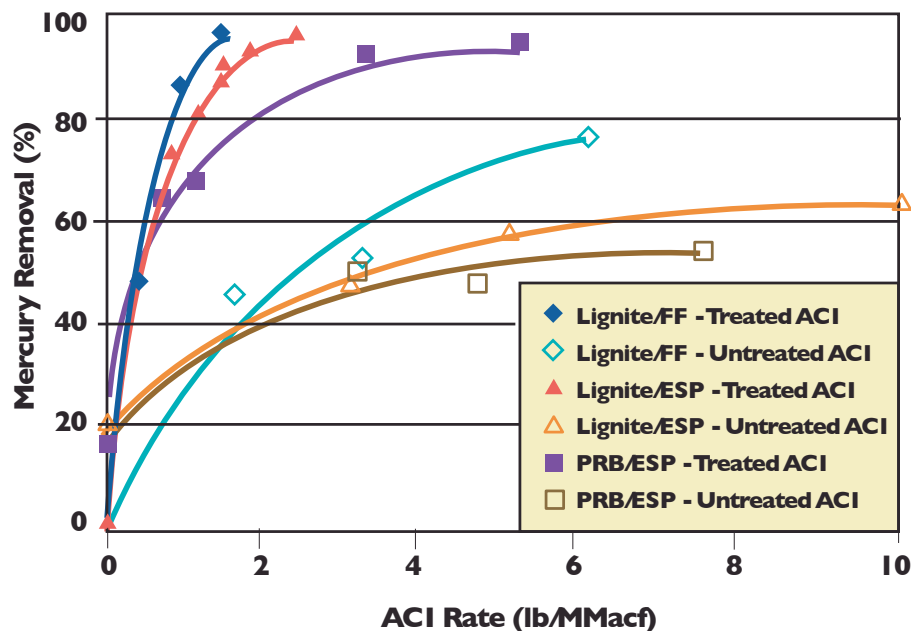


Figure 1 – Comparison of Untreated and Chemically-treated ACI Performance at Facilities Burning Lower-Rank Coals

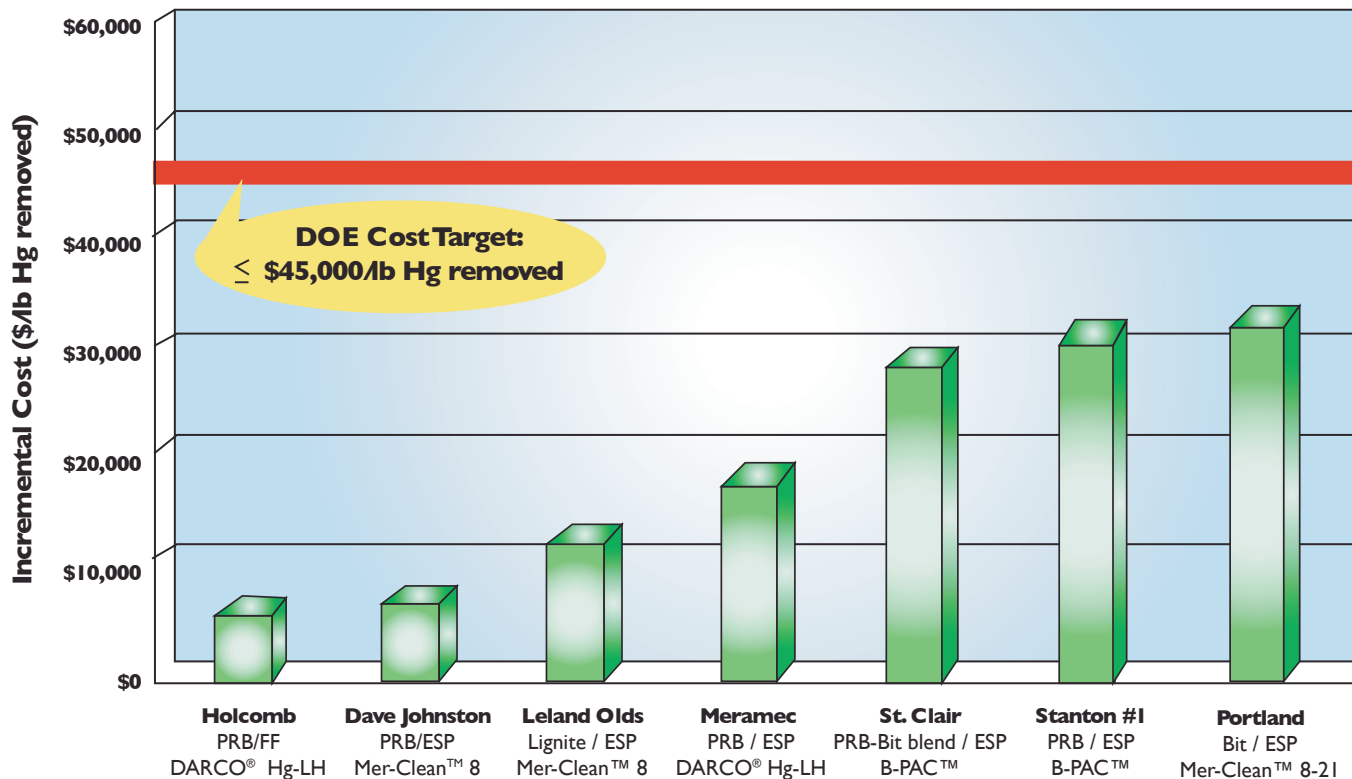


Figure 2 – 20-Year Levelized Incremental Cost of 90 percent Hg Control with Chemically-treated ACI

treated sorbents. As shown in Figure 2, the 20-year levelized incremental cost of 90 percent ACI Hg control ranges from about \$30,000 to less than \$10,000/lb Hg removed for seven of DOE/NETL's Phase II field-testing sites where chemically-treated ACI was evaluated. These results point to the fact that DOE/NETL has surpassed the Hg control cost goal set forth by the IEP Program.

In addition, DOE/NETL has evaluated technologies – such as chemical additives and oxidation catalysts – designed to enhance FGD Hg capture, because oxidation of flue gas Hg⁰ followed by absorption of Hg²⁺ across a wet FGD system has the potential to be a reliable and cost-effective Hg control strategy for coal-fueled power plants. During a two-week trial conducted at Luminant Power's Monticello Station, which burns a blend of PRB subbituminous and Texas lignite coals, total Hg capture averaged 86 percent with a CaBr₂ injection rate of 113 parts per million (ppm) Br in the coal.⁴ Greater than 90 percent total Hg capture was observed during a short-term test with a CaBr₂ injection rate of 330 ppm Br in the coal.

TECHNOLOGY COMMERCIALIZATION

Although the federal regulatory structure for Hg emissions from coal-based power generation facilities is once again uncertain following the U.S. DC Circuit Court of Appeals decision to vacate EPA's Clean Air Mercury Rule Feb. 8, 2008,⁵ DOE/NETL's field testing program has successfully brought Hg control technologies to the point of commercial-deployment readiness. As of February 2008, over 80 full-scale ACI systems, a signature technology of the IEP Program, have been ordered by U.S. coal-fueled power generators, according to the Institute of Clean Air Companies.⁶ These contracts include both new and retrofit installations and represent over 41 GW of coal-based electric generating capacity. Approximately 30 GW of existing electric generating capacity (~9 percent of total U.S. coal-based capacity) will be retrofit with ACI systems to control Hg emissions. The ACI systems have the potential to remove more than 90 percent of the Hg in most applications, at a cost that can dip below \$10,000 per pound of Hg removed. ♦

ACKNOWLEDGEMENTS

This report would not have been possible without the efforts of the DOE/NETL project managers and researchers who provided valuable technical input. The authors would like to acknowledge the contributions of Lynn Brickett, Andrew O'Palko, Bruce Lani, Sara Pletcher, Pierina Noceti, Barbara Carney, William Aljoe, Evan Granite, Henry Pennline, and James Murphy. The authors also acknowledge the efforts of EPA, EPRI, coal-fueled power generators that participated in the program and the research organizations and academic institutions that were active participants.

For additional information on DOE/NETL's Hg R&D program, including work focused on characterizing the fate of Hg in coal utilization byproducts, refer to this white paper posted on the NETL's public Web site.

DISCLAIMER

References in this article to any specific commercial product or service are to facilitate understanding and do not imply endorsement by the U.S. Department of Energy.

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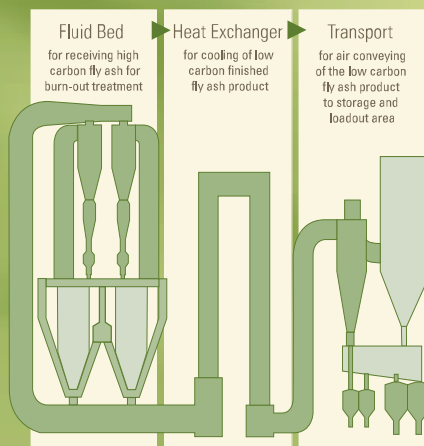


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PMI

C²P² ANNOUNCES 2008 AWARD WINNERS

By Dave Goss, American Coal Ash Association



n July 2, the third awards ceremony for the Coal Combustion Products Partnership (C²P²) was held in Arlington, Va., following the summer ACAA meeting.

As at the two previous events, representatives of the U.S. EPA and other C²P² sponsors presented awards, this year to 14 nominees. Each year, companies and individuals are recognized for innovation, enhanced CCP utilization, communications and outreach, partnership, environmental achievement, research, and overall achievement. Special recognition is also accorded select individuals based on their lifetime involvement in the industry.



**COAL COMBUSTION
PRODUCTS PARTNERSHIP**

OVERALL ACHIEVEMENT

Headwaters Resources

Headwaters Resources was recognized as an industry leader driving higher CCP utilization in concrete and other applications. The company has aggressive professional outreach programs reaching architects and engineers who specify concrete mix designs. Headwaters actively lobbies, resulting in legislation or government regulations requiring CCP use. The company also develops new technologies that utilize CCPs in high volumes, particularly those CCPs that may not be acceptable for traditional applications because of quality issues. They have pioneered expanding markets in alternative building products, such as blocks, bricks, tiles, pavers, manufactured stone and stone veneers, and packaged mortars and stuccos. Headwaters manages more than 20 million tons of CCPs annually and has contracts with more than 90 utilities. The company operates 110 locations and 43 rail terminals.

INNOVATION

Henry Liu, Freight Pipeline Company

The fly ash brick, also known as “Greenest Brick” is the result of research and development carried out by Dr. Henry Liu and his Freight Pipeline Company through Small Business Innovation Research grants from the National Science Foundation. The energy used in making fly ash bricks is only about 10 percent of that used in making the same quantity of clay bricks; the process burns no fossil fuel and emits no greenhouse gases. This technology invented by Dr. Liu, is innovative because it has solved a problem that plagued previous researchers working with 100 percent fly ash brick: the freeze-thaw problem. Previously, fly ash bricks could not pass even 10 cycles of freeze-thaw in a special test mandated by ASTM (American Society of Testing and Materials). Dr. Liu was able to enhance the freeze-thaw resistance of the fly ash brick to more than 50 cycles, making the bricks pass the same standard (ASTM C 62) as ordinary fired clay bricks used for buildings.

INNOVATION: SPECIAL RECOGNITION

Wal-Mart

Wal-Mart recently issued company-wide specifications requiring fly ash and other supplementary cementitious materials (SCMs) in all construction. Wal-Mart now has specifications for the use of fly ash for non-troweled exterior sitework, structural concrete, grout, concrete masonry units, and troweled concrete floors in amounts ranging from 12 percent to 25 percent. These innovative requirements placed the company in the forefront of large retail corporations. Wal-Mart has long supported using fly ash, but its past experience caused some challenges. Many of its consultants, contractors, and construction managers remembered past problems – such as delayed set times and poor finishes – largely caused by inexperience with fly ash. Wal-Mart did not allow hearsay to sour them on fly ash. Continued research and expert knowledge demonstrated that fly ash use can result in lower costs (or no cost increase), improved environmental performance, and material benefits. Tests of its concrete placements allowed Wal-Mart to see the benefits and mitigate the concerns. Wal-Mart’s dedication and innovative approach has now led to its leadership role among retailers in fly ash use.

ENHANCED UTILIZATION

PPL Generation

PPL Generation cut in half the amount of soil or other till material needed for various projects around its power plants, by mixing it with equal portions of bottom ash. The mixture saved the corporation more than \$2 million in disposal and procurement costs last year. Prior to use, PPL tested how well grass would grow in the mixture of soil and bottom ash. Although PPL’s Coal Combustion Products group began using bottom ash as a soil additive in 2002, last year was the first time 100 percent of the coal ash produced from the Montour and Brunner Island plants in Pennsylvania, was used for beneficial purposes. The group has been able to use or sell more than 95 percent of its CCPs for beneficial uses over the past several years, with the exception of the silt-like portion of bottom ash. Being able to use the 40,000 tons of the finest particles of bottom ash generated every year at the two plants brings that percentage up to 100.

COMMUNICATION AND OUTREACH

University of Kentucky CAER

The University of Kentucky Center for Applied Energy Research has created a new CCP education Web site (<http://www.caer.uky.edu/kyasheducation/index.html>). This interactive Web site provides clear explanations of the issues surrounding CCPs, including their potential for beneficial use, environmental benefits, and what UKY is doing to study them. The story is told in non-technical terms and organized and scripted with the help of communications-savvy professionals. The information is usable at the high-school level, but also useful for communicating with the general public, legislators, and non-specialists in the field of energy production. Specific topics discussed on the Web site include the origins of CCPs, what CCPs can be used for now and in the near future, and what the future might bring.

COMMUNICATIONS AND OUTREACH: SPECIAL RECOGNITION

Association of Canadian Industries Recycling Coal Ash (CIRCA) and the University of New Brunswick

The mission of CIRCA is to bring together Canadian producers and marketers of CCPs to increase technically sound, environmentally responsible and commercially competitive uses of CCPs as mineral resources. As part of that mission, CIRCA engaged Dr. Theodore Bremner and Dr. Michael Thomas of the University of New Brunswick to prepare a Web-based educational unit to introduce civil engineering students to CCPs (<http://www.unb.ca/civil/bremner/CIRCA/WebPages/index.htm>). Students first use the Web-based format and then download the accompanying text or PowerPoint presentation for more detailed study. Students then complete the test module and the assigned essay, available through the designated faculty member teaching Engineering Materials. Please see more on page 50.

SPECIAL RECOGNITION: CEMEX/ MINERAL RESOURCE TECHNOLOGIES

Mineral Resource Technologies, Inc. (MRT)

Mineral Resource Technologies, Inc. (MRT) is a subsidiary of CEMEX, Mineral Resource Technologies, which is currently the largest user of CCPs in the United States. CEMEX markets to its customers and uses internally over 3.5 million tons of fly ash annually. CEMEX USA utilized over 2.1 million tons of CCPs in its ready mix, concrete pipe, and cement manufacturing facilities in 2007. In the same year, CEMEX had 32 concrete plants that had a seasonal average fly ash use rate of at least 25 percent and 13 plants with at least 30 percent during the peak season months of April through September 2007. Through focus on specialized mix designs CEMEX/MRT have set a high standard for fly ash utilization and are further expanding the potential applications where CCPs can add value to the construction materials industry.

CONTINUED ON PAGE 34

PARTNERSHIP

City and County of Denver and University of Colorado at Denver

In 2007, Denver partnered with the University of Colorado at Denver's Sustainable Urban Infrastructure Program to develop a first-of-its-kind greenhouse gas inventory at the city scale that included the embodied energy of key urban materials, including concrete. The inventory showed that cement in concrete contributed more than 2 percent of the city's greenhouse gas footprint. The UCD team investigated alternative concrete mixes containing fly ash and found them to be more durable than ordinary concrete. In May 2007, Greenprint Denver announced Denver's Green Concrete Policy as a part of the city's Climate Action Plan. In October that year, Mayor John Hickenlooper signed an executive order outlining the city's sustainability policy, including a requirement that construction projects use concrete with at least 20 percent fly ash. This requirement is the first of its kind in a U.S. city (<http://greenprintdenver.org>).

RESEARCH: SPECIAL RECOGNITION

AmerenUE and Charah

In September 2006, AmerenUE's Labadie Power Plant opened the AmerenUE/Charah, Inc. Concrete Packaging Facility, which recycles approximately 10,000 tons of fly ash and 60,000 tons of bottom ash annually into about two million bags of high-quality concrete mix. In addition to the ash being used to make concrete mix, approximately 240,000 tons of Labadie's bottom ash was used as structural fill in the construction of the state-of-the-art facility. Through a collaborative effort among AmerenUE, Charah®, Inc., The Home Depot® and QUIKRETE®, this unique facility presented recent representatives of the Asia-Pacific Partnership on Clean Development and Climate (AP6) an opportunity to see firsthand what can be accomplished when industry works together to solve problems creatively. AmerenUE believes that those who visit the AmerenUE/Charah, Inc. Concrete Packaging Facility will be inspired to seek similar partnerships that offer market-based solutions to the significant environmental issues facing the electric utility industry worldwide.

ENVIRONMENTAL ACHIEVEMENT

University of North Dakota Energy & Environmental Research Center

The Energy & Environmental Research Center (EERC) at the University of North Dakota has been researching beneficial uses of CCPs for more than 30 years. In 1977, EERC initiated a project to determine the effects of *Fly Ash and Flue Gas Desulfurization Material on Groundwater Quality in a Reclaimed Lignite Strip Mine* under a U.S. EPA funded project. Work under that project raised questions about the engineering and environmental performance of CCPs and especially about moderate- to high-calcium content fly ash. The EERC has since worked to answer those and many other questions. EERC's work has been instrumental in solving various questions and problems related to CCP use and, thereby, leading to wider acceptance of CCPs for beneficial use. The beneficial use of CCPs has enormous environmental benefits, including the reduction of greenhouse gas emissions and energy use, reduced mining of virgin materials, and reduced need for landfill space.

ENVIRONMENTAL ACHIEVEMENT: SPECIAL RECOGNITION

PMI and Dominion

In Massachusetts, PMI Ash Technologies, LLC and Dominion teamed to install a carbon burn out (CBO) facility to address both carbon (LOI) and mercury CCP challenges. CBO has allowed the Brayton Point Power Station to increase fly ash use by greater than 50 percent in the CBO's first year of commercial operation, while utilizing carbon injection to control mercury emissions. In Virginia, Dominion and PMI teamed to install a second CBO facility. In the CBO's first commercial year of operation, Chesapeake Energy Center increased beneficiated fly ash usage by 80 percent, while allowing the facility to reduce NO_x and SO₂ and implement, at a later date, mercury controls without sacrificing ash sales. The two projects have also allowed for increased CO₂ reductions of approximately 200,000 tons in their first year of commercial operation. The CO₂ reductions from both projects are expected to increase to approximately 400,000 tons annually within the first five years of operation.

RESEARCH

The Ohio State University

The Ohio State University has been active in CCP research since 1990, led by Dr. William Wolfe and Dr. Tarunjit Butalia of the Department of Civil and Environmental Engineering, and Dr. Warren Dick of the Ohio Agricultural Research and Development Center. Their work has included ongoing research on the agricultural use of FGD gypsum, and on the civil engineering use of CCPs, particularly in pavement structures and the process of full-depth reclamation of asphalt pavement. A recent project in Delaware and Warren Counties in Ohio demonstrated full-scale test sections of roadway using full-depth reclamation technology in combination with fly ash. These road sections will be monitored for a minimum of two years to compare their performance with that of standard pavements. Other research in FGD gypsum use has helped make The Ohio State University a premiere CCP research institution.

RESEARCH: SPECIAL RECOGNITION

Texas A&M University Department of Civil Engineering

Dr. Don Saylak of Texas A&M University's Civil Engineering Department has been spearheading a multi-faceted, on-going effort of the By-Product Utilization and Recycling Research Group to develop beneficial uses for CCPs currently being generated at the 18 coal- and lignite-burning electric power plants in Texas. The group introduced a new CCP utilization concept designed to upgrade the load-bearing characteristics of bottom ash and increase its use in asphaltic concrete surface courses. In this concept, bottom ash is coated with liquid sulfur, which upon cooling fills the internal and external voids of the cellular-like particles. The result is an increase in the crushing resistance of the bottom ash without requiring prohibitively large quantities of asphalt to satisfy mix design specifications. As a result of this research, an "All CCP Roadway" was constructed in 1999. This was an experimental field project designed to demonstrate that CCPs can be used in all layers of a road, i.e. subgrade, base and surface courses. After nearly 10 years of post-construction evaluation this unique roadway is still performing very well.

LIFETIME

Oscar Manz

Oscar Manz has spent his career researching CCPs and enabling their use; his dedication has served as a model for many in the CCP industry. He began teaching at the University of North Dakota in 1952. In the late 1960s, the U.S. Bureau of Mines and the mining industry opened up the lignite coal fields of North Dakota, and Mr. Manz became interested in the resulting fly ash because of its similarities to ceramic materials. He started teaching material and concrete testing to civil engineering students and recognized the potential for fly ash as a beneficial material rather than a waste. In 1963, he gave his first fly ash paper in which he noted that North Dakota lignite fly ash did not meet ASTM C 618 for use in concrete. Other lignite power plants in Canada and Texas had reported the use of their fly ash in concrete, so he initiated an effort to evaluate North Dakota lignite fly ash. As his research continued, he developed the Combustion Byproduct Utilization Institute at the University of North Dakota Civil Engineering Department to further investigations into fly ash. Eventually, his work led to the inclusion of high-lime Class C fly ash in ASTM C 618 specifications.

In 1967, Mr. Manz became part of the international "Group of Experts" working on problems related to the utilization of coal ash, as a representative of the National Ash Association (ACAA's predecessor). Thenceforth, Mr. Manz worked with NAA staff and members to continue participation in the global CCP network of producers and researchers. He attended international meetings and symposia and built many long-term relationships with groups and individuals working with CCPs. As a result, he published numerous reports on the worldwide production and use of CCPs from 1970 to 1997 with input from his global network of colleagues. Oscar retired from the university in 1989, but he has continued to be active in CCP work as a consultant and serves as an advisor to the Energy & Environmental Research Center CCP research group.

LIFETIME

E. Cheri Miller

For more than 26 years Cheri Miller was employed by the Tennessee Valley Authority managing all aspects of coal combustion byproduct production and use. During this time she developed particular expertise with FGD systems including design, siting and permitting of gypsum disposal facilities; complex environmental reviews; and negotiation of marketing and disposal contracts. One of her most significant accomplishments was negotiating a unique three-party arrangement among TVA, Synthetic Materials and Temple Inland Forest Products. Her work resulted in construction of one of the nation's largest FGD gypsum wallboard plants at TVA's Cumberland Fossil Plant in northwest Tennessee. In 2003, this project was recognized by the TVA Board of Directors as one of the "TVA Top Ten Ideas of the 21st Century." She also expanded TVA's CCP marketing and utilization program by almost 400 percent in annual tonnage and over 600 percent in gross revenues since 1994, making this program one of the most successful CCP utilization and marketing programs in the United States. Throughout the time she served as TVA's representative to ACAA, Cheri was a driving force in promoting CCPs and addressing regulatory and beneficial use issues. Her dedication and vision helped the association maintain its role in representing a balanced view of the diverse aspects of the industry. Cheri retired from TVA in 2007 and formed her consulting business, Gypsum Parameters, which specializes in advising industry on strategic development of FGD gypsum resources. ♦



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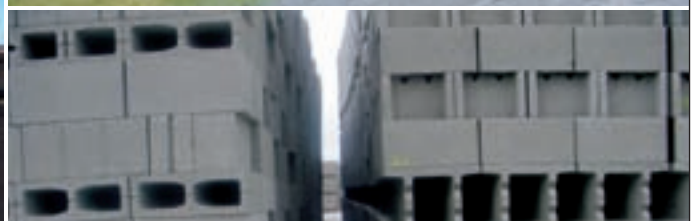
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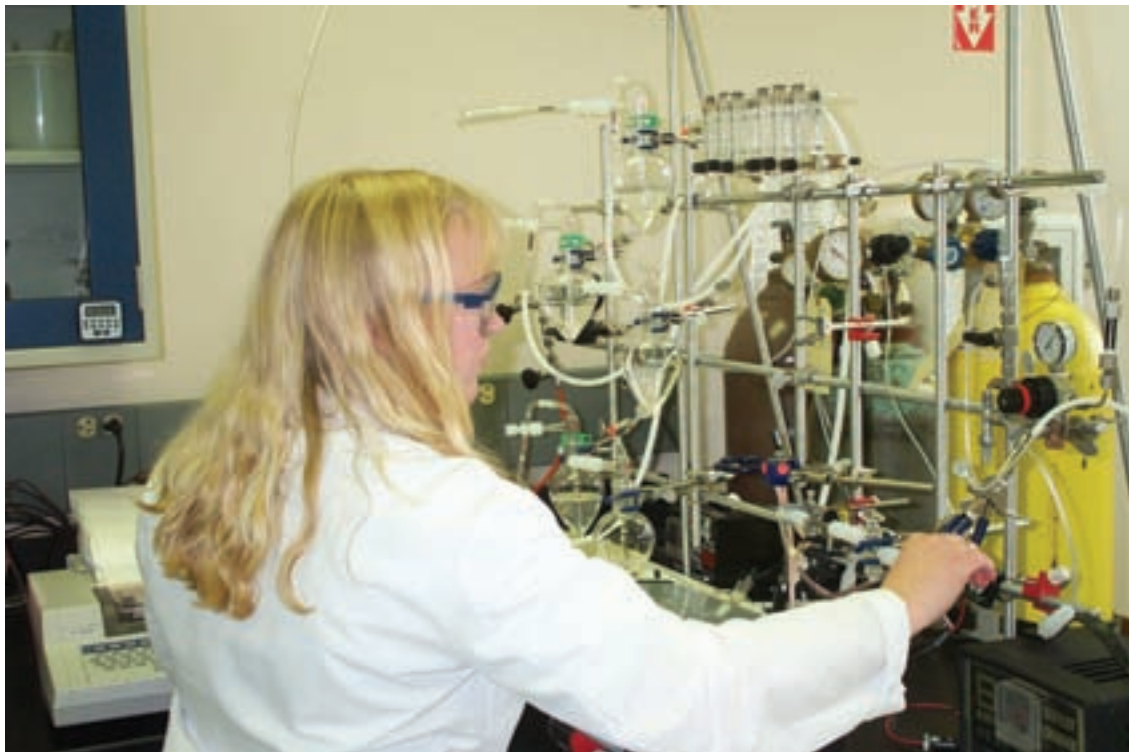
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HOW CARBON-BASED SORBENTS WILL **IMPACT** FLY ASH UTILIZATION AND DISPOSAL



Measurement of long-term mercury vapor release by atomic fluorescence

By Debra F. Pflughoeft-Hassett,
David J. Hassett,
Tera D. Buckley,
Loreal V. Heebink, and
John H. Pavlish,
Energy and Environmental Research Center

INTRODUCTION

On March 15, 2005, the U.S. Environmental Protection Agency (EPA) issued the Clean Air Mercury Rule (CAMR) to permanently cap and reduce mercury emissions from coal-fueled power plants. This rule made the United States the first country in the world to regulate mercury emissions from electric generating utilities. If fully implemented, CAMR and EPA's Clean Air Interstate Rule (CAIR) would have reduced United States utility emissions of mercury from 48 tons a year to 15 tons – a reduction of nearly 70 percent. However, on Feb. 8, 2008, the United States Court of Appeals in the District of Columbia vacated the CAMR regulations for both new and existing electric generating units. What will happen next is not

well defined, but the EPA must again consider mercury rulemaking in light of this decision.

For many existing coal-fueled power plants, the lowest cost, leading technology to comply with CAMR emission regulations would be activated carbon injection (ACI) into the flue gas where the gas-phase mercury can be sorbed on the activated carbon (AC). If the AC is injected upstream of the primary particulate control device (PCD), it will be mixed and collected with the fly ash in the downstream PCDs. In some instances, the AC may be injected after the primary PCD and collected in a separate or secondary downstream PCD. Both of these ACI strategies will result in a fly ash+AC mixture different from CCPs currently generated.

Editor's note: *The text of this article was condensed due to space constraints. The full text is available on the ACAA Web site at www.acaa-usa.org*



Laboratory evaluation of vapor-phase mercury release potential for soil-ash mixtures.

The EERC has performed numerous projects related to the utilization and disposal of coal combustion byproducts (CCPs) since the 1970s including an industry-DOE funded effort to evaluate fly ash+AC (activated carbon) for potential to re-release sorbed mercury and other air toxic elements under various environmental conditions. Using results of laboratory studies of mercury release from fly ash+AC and an understanding of CCP management, an analysis of the impact of carbon-based sorbents on CCP management was performed.

PROPERTIES AND PERFORMANCE OF FLY ASH + AC

Properties of fly ash+AC were evaluated under multiple EERC research efforts. The ranges of pH, loss on ignition, and total mercury content of the samples evaluated are shown in Table 1. Fly ash samples without AC present were also evaluated, and comparative data for those samples are also shown in Table 1. In some cases, samples acquired included baseline samples (no AC) and test samples (fly ash+AC) from the same facility.

LABORATORY METHODS

Laboratory methods were used to evaluate the potential for mercury release from fly ash+AC samples. The release mechanisms that were evaluated in laboratory studies included:

- Leaching.
- Vapor-phase transport at ambient and elevated temperatures.
- Microbiologically mediated vapor-phase transport.

Details of the methods used and developed for this purpose are described elsewhere.¹

POTENTIAL IMPACT OF ACI ON CCP DISPOSAL

Based on the experiments performed at the EERC and an assessment of information published on EERC and other large-scale mercury emission control projects, the following issues may need to be addressed relative to the collection and disposal of fly ash+AC at utility disposal sites:

- ACI (pre- and post-PCD) may alter the physical behavior of the fly ash (+AC) and may impact PCD performance and may also exhibit different handling performance such as the level of dusting for dry handling and transport.
- Only a slight increase in material volume is expected if the AC is injected upstream of a primary PCD, however, if AC is injected downstream of the primary PCD and upstream of a secondary PCD, the combined fly ash+AC material will have a significantly higher level of AC.
- Mercury is not expected to be readily mobilized by leaching from CCPs in disposal settings, however, there is

Table 1. Fly Ash and Fly Ash+AC (pre-PCD) Samples Evaluated by the EERC

Coal Type	No. of Samples	Sample Type with Hg Control Description	24-hour pH Range	LOI ¹ Range, %	Total Hg Concentration Range, µg/g
Bituminous	21	Fly ash	5.52–12.65	0.47–21.2	<0.01–0.685
	6	Fly ash + AC (post-primary PCD)	3.99–9.20	12.6–24.4	0.742–120
Subbituminous	3	Fly ash	12.27–12.56	0.32–1.08	0.261–1.22
	4	Fly ash + AC (pre-primary PCD)	10.95–11.90	2.28–4.14	1.09–5.81
Lignite	13	Fly ash	10.50–12.74	0.22–7.48	<0.01–0.878
	6	Fly ash + AC (pre-primary PCD)	11.86–12.61	0.96–4.21	0.225–12.7

¹ Loss on ignition.

² Not tested.

higher potential for formation and release of mercury and especially organomercury compounds from wet disposal systems. The amount of mercury release would be expected to be very low.

- Vapor-phase releases of mercury are expected to be extremely low, and the incorporation of AC with fly ash may influence the flux of mercury at fly ash+AC disposal sites to be even more likely to be sorption.
- Formation and release of elemental and organomercury was facilitated by the presence of microbial activity and fungus under near-neutral pH conditions, and further evaluation of this phenomenon is required to better understand the impact at CCP disposal sites.

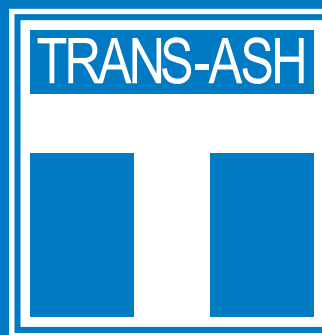
POTENTIAL IMPACT OF ACI ON CCP UTILIZATION

Fly Ash Utilization in Concrete

Most specifications for fly ash to be used as a mineral admixture in concrete prescribe a limit for the LOI exhibited by the fly ash. LOI is considered by industry to be one of the key quality measures for fly ash, but is not necessarily a direct indicator of fly ash performance or carbon content. When significant unburned carbon is present in, or AC is added to the fly ash, LOI can provide a comparative indicator of the carbon present. Typical LOI limits are 5 percent or 6 percent. The high unburned carbon fly ash may perform well as a mineral admixture in concrete even though it does not meet the existing specification, however, it has also been shown that unburned carbon can be detrimental to the concrete performance when air entraining is required. Air entraining is accomplished by addition of an air-entraining agent (AEA). AEAs can be sorbed onto unburned carbon and AC, making them unavailable to facilitate the incorporation of air bubbles into the concrete mix. AC, even in very small percentages, can have a drastic effect on the amount of AEA required to produce sustainable foam in cement-fly ash mixtures. Full-scale implementation of ACI for mercury control would likely increase the quantity of fly ash that is unsuitable for use as a mineral admixture in concrete. The potential for mercury to be released from the fly ash and fly ash+AC in concrete mixing, placement and use, is very low. Since the leachability of mercury from fly ash is low, fly ash typically comprises only a small percentage of the entire concrete mix, and the leachability of constituents from concrete is also low; the potential for mercury associated with fly ash to be leached from concrete is very low. The potential for vapor-phase release of mercury is also very low, based on ambient-temperature mercury release experimental results. Further, the alkaline nature of a concrete mix is not expected to allow for the growth of microbes, so the potential for microbiologically mediated formation and/or release of mercury is low.

Geotechnical Applications

For the purposes of this paper, structural fills, embankments, mining applications, and soil stabilization applications have been categorized together as geotechnical applications. For fly ash+AC (pre-PCD), the physical and engineering performance of the material is expected to be similar to that of the associated baseline fly ash, with some potential for handling issues such as increased dusting. The presence of AC is not expected to impact the pozzolanic/cementitious



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performance of the fly ash. Conditions will frequently be specific to a site, but can be expected to potentially include exposure to moisture or water, ambient temperatures, and contact with soils (either mixing or on a boundary between fly ash and soil). Again, laboratory results indicate that release of mercury through leaching and exposure to ambient temperatures will be very low and should not preclude the use of fly ash +AC in these applications.

Cement Manufacture

Fly ash is used as a raw feed for cement clinker production, primarily to contribute specific required elements such as aluminum in the final cement composition. When used in this application, the fly ash is exposed to elevated temperatures in the cement kiln. Laboratory experiments used to measure the release of mercury from fly ash when exposed to elevated temperatures, indicated that for almost all fly ash and fly ash +AC samples, 100 percent of the mercury was released from the sample by the time the sample reached 750°C (1,382°F). Because cement kilns reach temperatures significantly higher than the experimental maximum, it is expected that the mercury associated with fly

ash+AC would be released during the clinker formation process.

On Dec. 8, 2006, EPA issued final amendments to National Emission Standards for Air Toxics (NESHAP): Portland Cement Manufacturing Industry, that banned the “use of fly ash from utility boilers if the mercury content of that fly ash has increased as a result of certain utility emission controls (such as activated carbon injection), unless a facility can demonstrate that fly ash use will not increase its mercury emissions.”

Waste Stabilization and Solidification

A significant quantity of fly ash (more than 2.5 million tons in 2006) was used to stabilize and/or solidify wastes.⁴ Typically a large amount of the wastes being stabilized with fly ash are wet FGD materials. Wet FGD material (nonoxidized) typically has a high water content and is thixotropic, making it difficult to handle and transport. Fly ash is frequently added in these situations to produce a more easily managed solid. Fly ash+AC should exhibit similar physical performance in this stabilization process, and mercury releases

from direct leaching from exposure to water and direct vapor-phase transport from exposure to ambient air should be small. The use of fly ash+AC to stabilize wet FGD material may provide conditions to promote the microbiologically mediated releases (vapor-phase and leaching) of mercury both from the fly ash+AC and from the wet FGD material, which may also contain mercury.

It is possible that in some waste stabilization applications the AC may offer some co-benefit because the sorptive capacity of the AC is not expected to be exhausted and could capture waste constituents, enhancing the stabilization effect. This proposed co-benefit would be expected to be small since the amount of AC in fly ash+AC will typically be low.

CONCLUSIONS

Based on results of the laboratory experiments conducted at the EERC and elsewhere, the EERC draws the following conclusions regarding the impact ACI will have on fly ash management:

- ACI will increase carbon and mercury content in fly ash.
- Mercury was not readily leachable from fly ash or fly ash+AC. It is not expected that regulatory changes will occur for the management of CCPs based on the potential for mercury to leach from CCPs.
- Ambient-temperature release of mercury was low for all fly ash and fly ash+AC materials evaluated in laboratory experiments and is not expected to impact current management practices.
- Mercury was readily released from fly ash and fly ash+AC samples when exposed to elevated temperatures of 750°C and greater.
- The microbiologically mediated release of mercury from fly ash+AC was generally low in laboratory experiments, but organomercury was formed and released at extremely low levels under conditions conducive to microbial growth and when fungus was present.
- The physical and engineering performance of fly ash+AC is expected to be similar to the baseline fly ash, with the exception that the AC, even at low levels, may preclude the use of fly ash+AC in concrete where air entrainment is specified. ♦

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HIGH CARBON FLY ASH FINDS USES IN HIGHWAY CONSTRUCTION

By 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 to utilize fly ash to avoid land filling. Each year, more than 900 million tons of coal are used for electricity generation in the United States. The combustion of coal, however, produces a large volume of byproducts, including fly ash, flue gas desulfurization (FGD), and bottom ash, etc. According to the American Coal Ash Association, in 2006, about 72 million tons of fly ash were produced, while 40 million tons were placed in landfills. This disposal results in significant land purchase and energy costs, as well as potential environmental issues.

Increasingly stringent environmental policy stipulated by regulators means that 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. Increased carbon levels make air-entrained concrete production more difficult. These issues will transform ash from a revenue-generating commodity to the third greatest operating cost (behind fuel and labor) at

coal-fueled 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 subbituminous 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 Class F fly ash, mostly due to carbon, is 6 percent and 5 percent for ASTM C-618 and AASHTO M295 standard, respectively.

“Currently, most specification (spec) fly ash can be used as supplementary cementitious materials (SCMs) 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. The high carbon content, however, often eliminates its use, 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 the Federal Highway Administration.

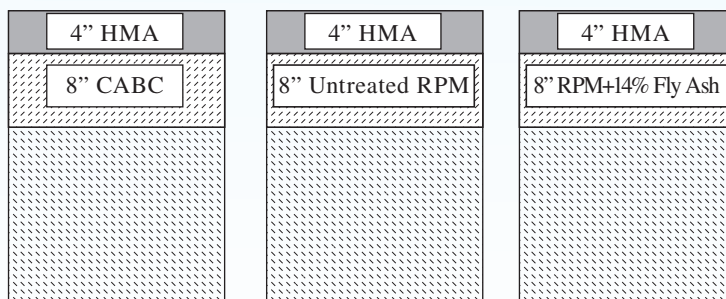
Unlike concrete, which needs air-entrainment (generally 6 percent), extra voids are not desired in a base course under an asphalt pavement. A base course with maximum density and minimal void content will last longer than a loose base course. Therefore, the high carbon content in CHCFA presumably will 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 that otherwise would be landfilled.



Aerial photo of MnROAD site

(Courtesy of MnDOT)

Pavement structures of test sections at MnROAD



CONSTRUCTION DEMONSTRATION

"While there are many potential benefits of using fly ash stabilization, some questions still remain," says Tim Clyne, a Minnesota Department of Transportation engineer. "The most important question is whether or not the fly ash used in the base course has any harmful effects on the environment. 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, sub-base, and subgrade, but three different base course 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 for subsequent analysis.

Fly ash obtained from Unit 8 of the (Xcel Energy) Riverside Power Station in Minneapolis, Minn., was used to stabilize the RPM. This fly ash has a calcium oxide (CaO) content of 22.37 percent and a carbon content of 16.35 percent. Riverside Unit 8 fly ash is a cementitious high carbon fly ash. The Minnesota Pollution Control Agency considers it a noncompliant material and a special permit was applied for this construction demonstration project.

"Xcel Energy is excited about this demonstration project," says Mike Thomes, the combustion products coordinator of Xcel Energy. "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."

As of Oct. 30, 2007, the construction of the 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. The fly ash treated RPM bases, however, were not affected by the precipitation and were paved with asphalt successfully. For the other two sections, the wet base materials were never dried up and, eventually, were 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 an intelligent compactor that can tell the driver via the screen of the compactor, if the compaction is sufficient. 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 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 (above) and after mixing (below).



Installation of lysimeter to collect leachates from base materials

ENVIRONMENTAL MONITORING

The fly ash used for construction has relatively high mercury and some other heavy metals. These heavy metals could be tied in the base by the reaction of fly ash. Lysimeters were constructed to collect and monitor leachate generated by water percolating through the pavement under the supervision of professor Tuncer B. Edil from the Recycled Materials Resource Center (RMRC) at the University of Wisconsin-Madison. Leachate has been collected on a monthly basis. Laboratory characterization is underway. The leaching water in the storage tanks is sampled and the amount of leaching water is 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. ❖

The Recycled Materials Resource Center (RMRC) is sponsored by the 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.



Ecological Advantages:

- Significant reduction in water usage
- Pipeline transportation is safe, reliable, silent and dust free
- Water run off is limited, thus reducing water reclaim systems
- Thickened ash is not subject to run out
- Seepage into groundwater is virtually eliminated
- Ground can be easily covered for restoration of natural environment

Operational Advantages:

- Minimal or non mechanical spreading at disposal site
- Minimizes the number of people required for system operation
- High availability of pipeline transportation system
- Low maintenance pumps greatly reduce annual operating costs

Economical Advantages:

- Significantly higher pump efficiency vs. centrifugal systems
- Transportation of smaller volumes reduces overall costs
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- Extends effective life of disposal sites



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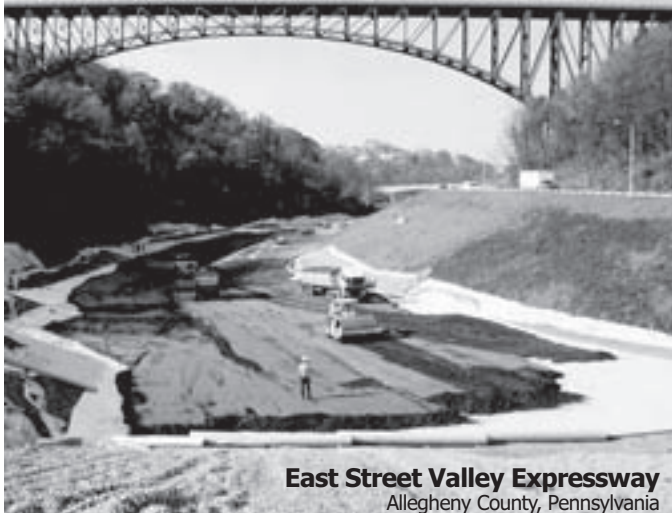
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RICE HUSK ASH

Untapped potential as a global cement replacement

By Helena Meryman, SBC Global

GLOBAL WARMING, CO₂ AND CEMENT

There is increasing awareness that between 5 percent to 8 percent of global CO₂ emissions are attributed to portland cement production. It is less well known that cement-related CO₂ emissions are increasing. The growth in the demand for concrete is accelerating. This demand produces an annual increase in cement production emissions, which exceeds the reductions in emissions the cement industry has achieved through manufacturing improvements and cleaner fuels. To meaningfully reduce the carbon footprint of concrete construction, the portland cement portion of the concrete must be reduced. This can be achieved in a variety of ways – the most effective and readily available means is to replace a large amount of the portland cement with carbon neutral alternatives. Complementary cementing materials (CCM) such as coal fly ash, rice husk ash, slag and mineral ultrafines are considered carbon neutral because they are diverted from the waste stream. With proper proportioning using carbon neutral substitutes, the global warming potential of the concrete binder can be reduced to less than 50 percent of current output. Coal fly ash and slag are well known CCMs. In the United States, rice husk ash (RHA) is a largely unrecognized material that deserves an introduction. This article provides a brief overview of the material and a summary of a recent research project conducted by the author.

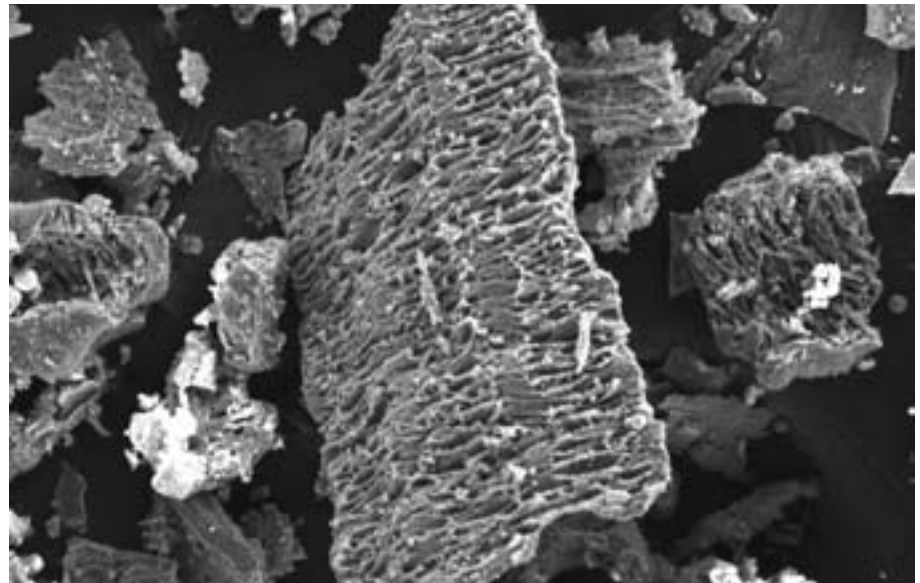


Figure 1 – The cellular structure is retained after controlled combustion.

WHAT IS RHA?

Rice husks are an abundant agricultural waste product. Around twenty percent of the weight of dried, harvested rice paddy is husk.¹ Controlled burning of the husks produces an ash that is twenty percent of the weight of the husk.¹ Rice husks are economical and suitable for use as a fuel for power generation. They contain approximately 50 percent of the energy value of coal.¹ The power delivery potential is between 1,080 and 1,235 KW-h/tonne of husk. According to the International Rice Research Institute, 645,711 million tons of rice were harvested globally in 2007.¹ This corresponds to a potential global supply of 28.44 million tons of rice husk ash that could be made available for use as a complementary cementing material (CCM).

In 2006, U.S. rice production was 9.7 million tons, which could potentially provide 388,000 tons of domestic RHA. If this RHA were used in typical concrete to replace 10 percent of the portland cement, 25,870,000 tons of improved concrete would be produced (345,000,000 yd³ of concrete). RHA used in this way would result in 338,000 tons of avoided CO₂ emissions.

In the developing world, RHA was traditionally used in block making. The earliest investigations of rice husk ash as a binder component of a concrete mix were published by P.K. Mehta^{1,2} and D.J. Cook.¹ There has been an increased interest in investigating the material properties and performance characteristics of rice husk ash in the developing world, where rice husk fuelled power plants are becoming more common.

Like coal fly ash, RHA is a pozzolanic material. Pozzolans are well known to significantly improve the durability of concrete while also increasing long-term strength. Good quality RHA typically contains well

Table 1. Rice Husk Production

2005-2007 Rice and Husk Production (M Tonnes)						
	Total	USA CA	ARK	ASIA		GLOBAL
	(2006)	(2006)	(2006)	INDIA (2005)	CHINA (2005)	(2007)
Rice Paddy	8.8	1.8	4.3	137	182	645
Rice Husks	1.76	0.36	0.86	27.4	36.4	129
RHA potential	0.35	0.07	0.17	5.48	7.28	25.8

Data compiled from various sources: FAO, USDA, IRRI

Table 1 summarizes the RHA potential in the USA, Asia and globally.

Please note: When searching for articles on RHA, include both terms – “hull,” as well as “husk.”

over 85 percent amorphous silica (SiO_2), which classifies it as a highly reactive pozzolan.¹ However, the rice husks must be incinerated under controlled conditions for the resulting pozzolanic ash to be sufficiently reactive. The temperature should be relatively low, in the range of 900 °F to 1,500°F, depending on heat exposure time.¹ The objective of combustion is to remove the cellulose and lignin while retaining the cellular structure, as shown in Figure 1. The unique inverted corn-cob shape of RHA has an enormous specific surface area, which helps boost early strength development in concrete mixes. The combustion conditions also affect the form of silica obtained; generally, temperatures above 1,700°F will produce the inert and crystalline form known as cristobalite. As with other CCMs, a glassy, amorphous, non-crystalline form of the SiO_2 content is required for reactivity. The reactivity and rate of early strength gain increases with an increase in specific surface area^{8, 1, 2} and amorphous content.

Currently, there is no standard or guideline for the proportioning of RHA in concrete mixes. Designers should bear in mind that due to RHA's large surface area, it typically causes a slight increase in water demand. Quality RHA can influence the rheological and physiochemical behavior of concrete in a manner similar to silica fume. Therefore, the proportioning of RHA should generally not exceed 20 percent, by weight, of the binder mix.

Table 2. Experimental program binder components, by mix.
Portland Cement & Complementary Cementing Material (%)

Mix #	Portland Cement	Fly Ash	Rice Husk Ash	Limestone Flour
1*	100	-	-	-
2*	70	30	-	-
3	60	30	10	-
4	50	30	20	-
5	50	30	15	5
6*	60	40	-	-
7	50	40	10	-
8	40	40	20	-
9	40	40	15	5

* Denotes reference mix

Table 3. Rice husk ash grinding progress record.

Ash	Grind Time cumulative (mins)	Unit Wgt (g/vol)	Mean Diameter (μm)	Optical microscope observations	Specific Surface Area (m^2/kg)
RHA0	0	58.8	129.0		43,308
RHA1	15	88.7	38.8		44,013
RHA2	30	89.1	23.5		44,544
RHA3	60	89.5	17.0		42,624
RHA4	90	92.8*	12.7	similar to RHA3	n/a**
RHA5	120	95.0	9.7	smaller than RHA3	41,274

* By interpolation

** Due to an insufficient sample size, accurate measurement was not possible

RESEARCH

The author recently completed research on the use of RHA as a cement replacement. The research program consisted of nine concrete mixes (Table 2) including binary, ternary and quaternary blends of cementitious, pozzolanic and ultrafine materials. Portland cement was replaced in various proportions by three industrial byproducts: Class F fly ash, RHA and limestone flour (an ultra-fine byproduct of quarrying operations). The intent of using ternary and quaternary blends was to find a mix with better early strength gain performance than binary blends of portland cement and Class F fly ash. The results show rice husk ash and limestone flour positively affect concrete by improving early strength gain and further reducing permeability.

RICE HUSK ASH PROPERTIES AND PREPARATION

The rice husk ash used came from the Agrilelectric power plant in Louisiana. The Agrilelectric ash product typically contains 93 percent amorphous silica and 5 percent carbon. The carbon content is acceptable; however, there is evidence to suggest that even 5 percent carbon can distort surface area measurements (wherein the surface areas measured include micro-porous carbon, which means the surface area of the RHA is actually lower¹).

The mean particle size of the RHA material received was 129 microns – too large

for an effective binder. The RHA was then ground to an average size of 10 microns. No guideline for grinding RHA to a useful size currently exists. The grinding requirement is a barrier to the adoption of RHA as a mineral admixture in the USA. The particle size analysis (PSA) tests were used to measure grinding progress, and BET nitrogen adsorption surface area tests were conducted to track the effect of grinding on surface area. These results are summarized in Table 3. The raw RHA and ground RHA5 used in the program are shown in Figures 2 and 3.



Figures 2 and 3

STRENGTH

The focus of this investigation was the analysis of performance of ternary and quaternary RHA blend mixes at early ages. There is an emphasis on the analysis of three- and seven-day results (Figure 4), because it is at this stage that large volumes of fly ash can hamper performance. Slow strength gain has been an effective argument for those who want to avoid using CCMs and changing their construction practices for the better. Strength results at 28, 56 and 90 days are of particular interest in determining relative pozzolanic activity (Figure 5).

SUMMARY OF STRENGTH RESULTS:

- Strengths that meet the requirements for the vast majority of concrete applications were reached at early and middle ages.
- RHA enhances strength at 3 days. Strength development improves even more after the onset of the pozzolanic activity at around 5 to 7 days¹.
- Limestone flour (LF) helps strength development at both three and seven days. However, later strength gain is adversely affected by the lower pozzolan content.
- The later age strength gain in RHA blends is superior to fly ash only blends.
- Notes: Mix one out-performed all mixes at 56 and 90 days due to low reactivity of the fly ash and an overdosing of superplasticizer; mix three under-performed due to an under-dosing of superplasticizer.

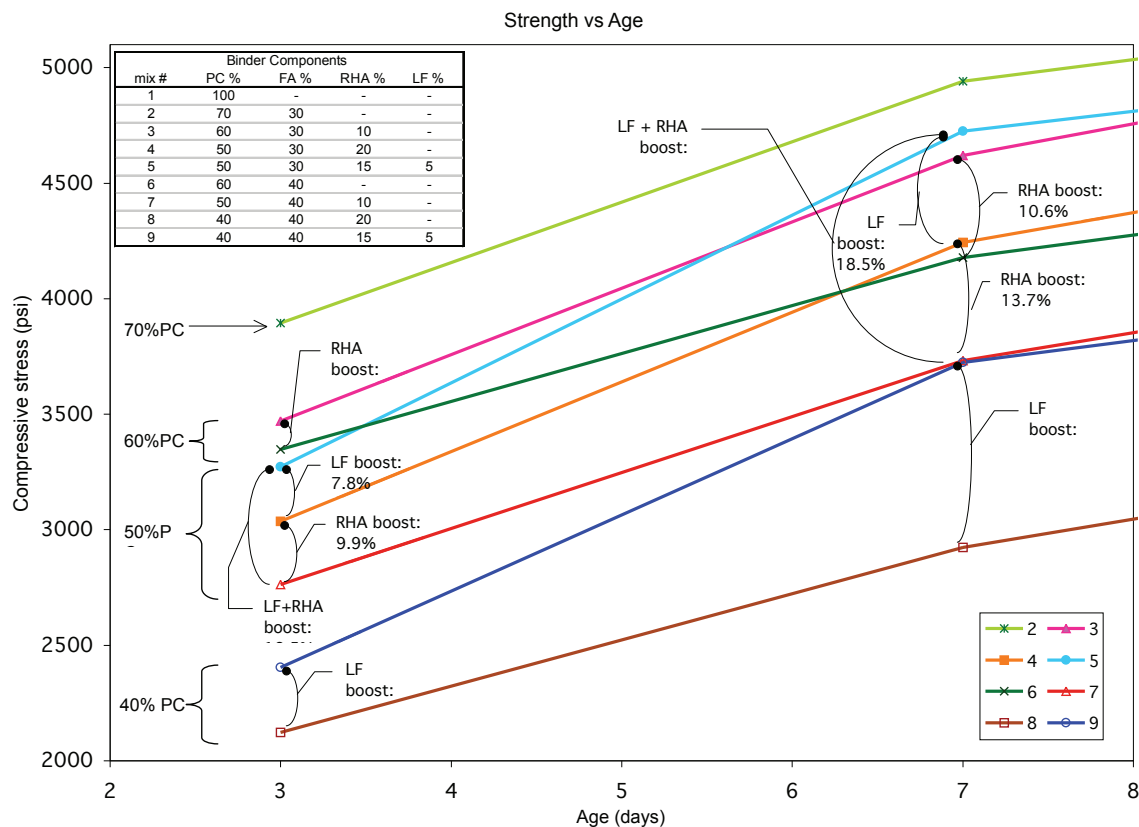


Figure 4. Compressive strength at 3 and 7 days.

DURABILITY

The permeability of concrete is a very good indication of its performance with respect to durability. This is especially true for steel reinforced concrete – the vast majority of concrete structures. Permeable concrete allows for the influx of water and this puts metal elements at risk for corrosion. A reliable determination of permeability is the Rapid Chloride Ion Penetration Test, ASTM C 1202. This test measures the flow of chloride ions through a concrete sample. The ion flow is monitored by its electrical current for six hours. The total charge is reported in coulombs and this value is used to compare the permeability of various samples, as shown in Figure 6.

SUMMARY OF DURABILITY RESULTS:

- At 90 days, the ordinary portland cement (OPC) mix is *far* more permeable than all other mixes.
- There is no correlation between impermeability and strength.
- Rice husk ash provides the greatest resistance to chloride ion penetration, 65 percent to 85 percent improvement over fly ash alone.

FUTURE DEVELOPMENTS

There are at least two rice husk fueled power plants operating in the USA (California and Louisiana) and there are a number of Clean Development Mechanism (CDMⁱⁱ) plants in the developing world, but this fuel option has yet to realize its potential. A market for rice husks has the further environmental benefit of providing incentives to rice farmers against crop burning and waste dumping – sources of CO₂ and CH₂ emissions and atmospheric pollution. Biomass dumping is environmentally harmful because as husks ferment they release methane (CH₂) which has a CO₂E value of 21. Controlled combustion in a power plant does useful work while providing filtration of particulate emissions. For power or heat generation with rice husks, the main technology issue is implementing appropriate and standardized combustion practices so that a value added waste ash product results. Recent projects in Thailand are hopeful signs that this waste resource is being developed with material products in mind. ♦

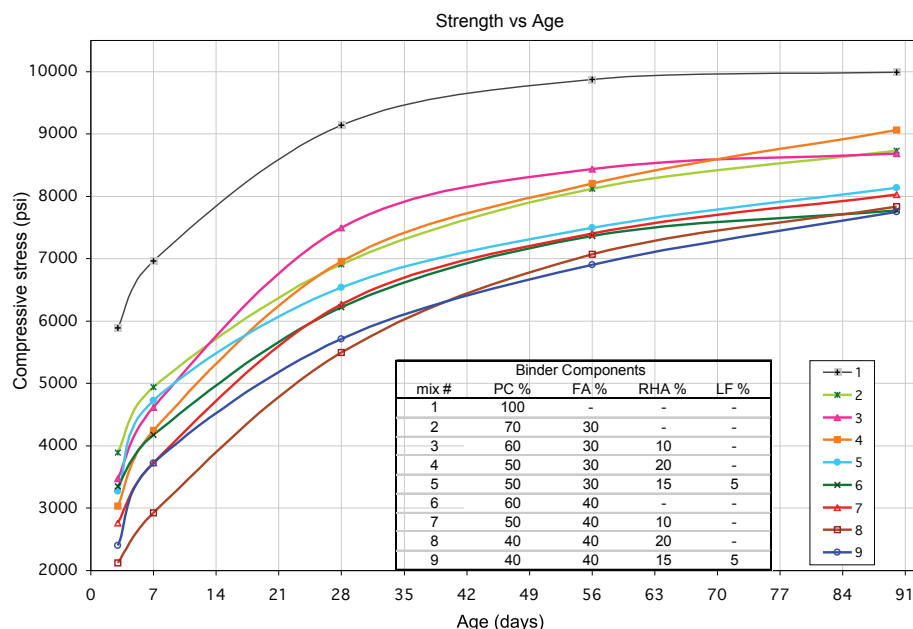


Figure 5. Compressive strength up to 90 days.

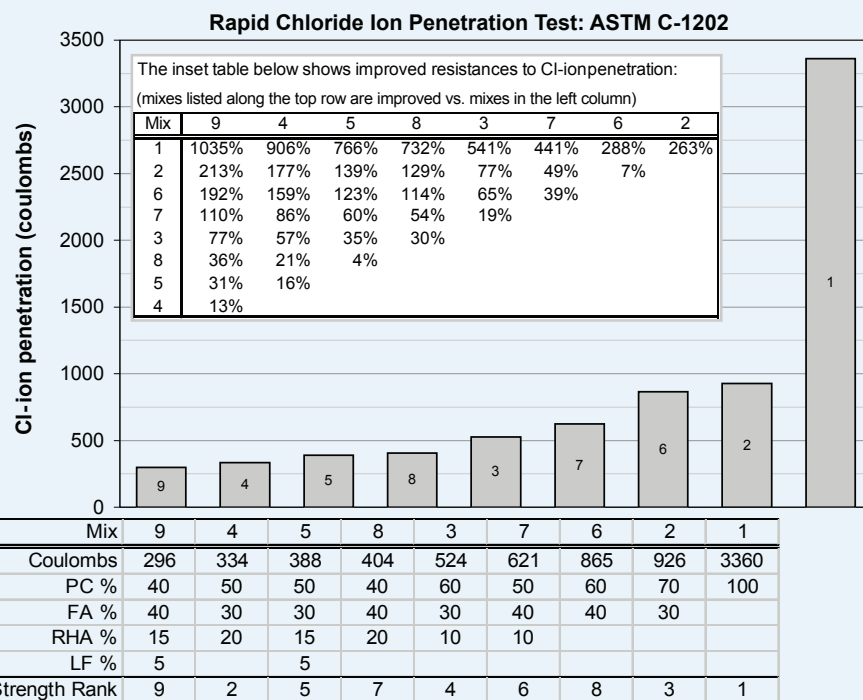


Figure 6. Results for ASTM C 1202.

TRADITIONAL AND NONTRADITIONAL USES OF COAL COMBUSTION PRODUCTS

Projects showcase CCP performance in Canada



Fine finish of York University's Schulich Complex (Toronto).

PHOTO COURTESY OF MONICA CONTRERAS, UNIVERSITY OF TORONTO.



Fifty percent fly ash reduced heat of hydration for Calgary Courthouse concrete footing.

PHOTO COURTESY OF WALTER DOBSLAW, INLAND CEMENT.



Laser guided grader levels ash for Edmonton sports field.

PHOTO COURTESY OF ART MAAT, WILCO CONTRACTORS NORTHWEST, INC.

The Association of Canadian Industries Recycling Coal Ash (CIRCA) and the University of New Brunswick's Department of Civil Engineering have collaborated on an independent study course featuring the origins, nature and diverse applications of coal combustion products (CCPs). The course is designed to complement undergraduate civil engineering curricula and industry's continuing education programs. The format also makes the course ideal for industry professionals, practitioners and other students of materials engineering who want to stay current with developments in the field.

"This independent study tool stands out by virtue of its detailed approach and far-ranging scope," said Anne Weir, CIRCA's executive director. "It's convenient, accessible and comprehensive."

As the merits of beneficial use enjoy growing recognition, appreciation for CCPs' versatility is rising. Less traditional areas are being explored, such as manufacturing, soil remediation, mining, and agriculture. Beneficiation technologies can produce specific end-use characteristics that enhance performance in a wide range of applications.

The individuals involved from the University of New Brunswick included Theodore Bremner, Ph.D., professor emeritus and honorary research professor, and Michael Thomas, Ph.D., P. Eng., professor of civil engineering. Both men are experts in concrete materials. The faculty of civil engineering is also home to the UNB Materials Group, which conducts advanced research on materials and concrete technologies.

CIRCA is a non-profit association of CCP producers and marketers dedicated to increasing the technically sound, environmentally responsible, and commercially competitive use of CCPs as mineral resources in Canada. ♦

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- Over fifty years of acquired experience and technical expertise in the ash business
- One of the largest suppliers, and users of concrete-quality fly ash and other CCPs
- A leading consumer of fly ash, bottom ash, and gypsum for use in raw feed
- One of the largest consumers of synthetic gypsum for use in wallboard
- A leading supplier of CCPs for geotechnical applications

Bottom line: Lafarge is an ideal partner for marketing your CCPs

To learn more, contact Shrief Kabis at 1-800-482-5749 or visit us at lafargenorthamerica.com

Materials for Building our World



CEMENT

AMERICA'S LEADING

COAL ASH MANAGER and MARKETER

DEVELOPING TECHNOLOGIES

for Fly Ash Quality

- *Ammonia Removal*
- *Carbon Fixation*



INTRODUCING PRODUCTS

for Increasing Ash Utilization

- *FlexCrete™ Aerated Concrete*
- *Concrete Block and brick*
- *Innovative solutions for FGD material and off-spec ash*



EXPANDING SYSTEMS

for Coast to Coast Marketing

- *Nationwide network of source locations and terminals marketing millions of tons annually for traditional concrete production*



PROVIDING SERVICES

for Coal Ash Generation

- *Landfill design, construction, operation and closure*
- *Environmental site assessment and permitting*
- *Utility and industrial equipment and site maintenance*

