ISSUE I • 2008

ASH at work

Applications, Science and Sustainability of Coal Ash

TOOTHPASTE TO RAILROAD TIES

CCP USE OVER THE PAST FOUR DECADES

40 YEARS AND GROWING

ACAA CELEBRATES AND REFLECTS

PRODUCTION AND USE SURVEY

INCREASING USE, EXPANDING MARKETS

COAL FLY ASH

CONCRETE'S MOST POWERFUL SUSTAINABILITY TOOL

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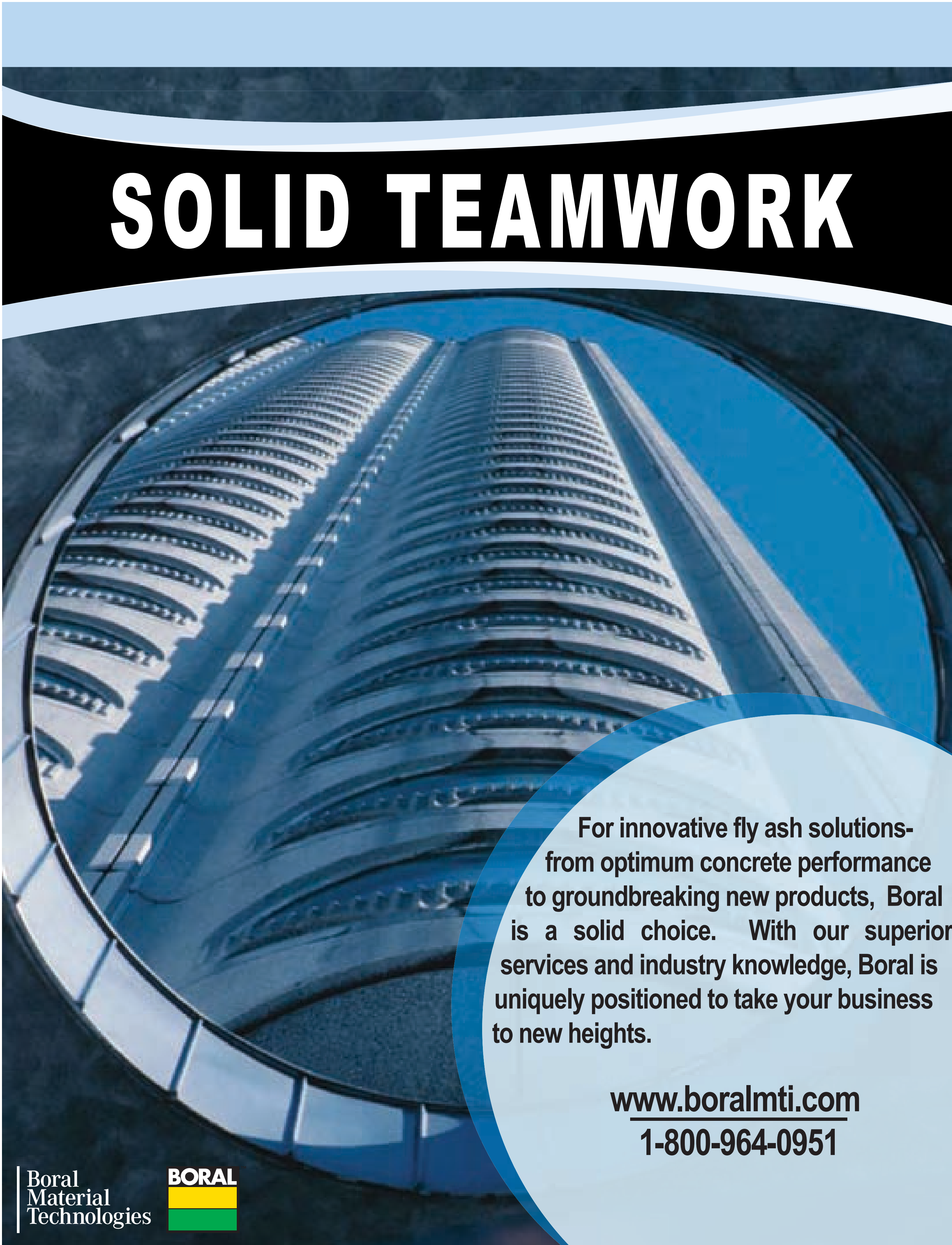
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ACAA CELEBRATES 40 YEARS:

CCP USE GROWS FROM CONCRETE TO TOOTHPASTE TO RAILROAD TIES AND MORE

By Dave Goss, American Coal Ash Association

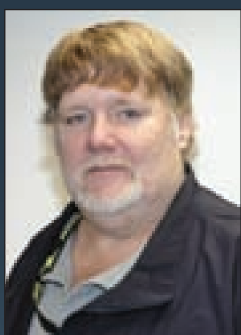
ACAA's 40-year history seems brief compared with an American city such as New Orleans, the site of our January meeting and anniversary celebration. This locale has undergone its share of challenges and changes – hurricanes Katrina and Rita being the most recent. ACAA also has weathered changes to arrive at a time when our industry's significance is gaining momentum. New Orleans, like ACAA, has gained valuable insights on how to move forward including lessons learned from predecessors. We embrace protecting our environment for future generations, becoming more supportive of a sustainable global community, while using coal combustion products in ways that are technically sound and commercially competitive.

When the National Ash Association (now ACAA) was formed in 1968, fly ash in concrete was an emerging commercial technology whose time had come; early NAA members recognized the benefits fly ash provided in dam construction and road building. But 1968 was really the beginning of an all-out effort to educate producers and end-users of the many values of fly ash and other power plant materials. Early *Ash at Work* articles in 1969 addressed subjects such as "flyash" concrete masonry blocks, "flyash" soil conditioners, "flyash" concrete in stabilized base, and "flyash" as mineral fillers for bituminous roadways. In the 1970s, *Ash at Work* discussed emerging technologies and potential new applications for fly ash. They included using cenospheres to produce synthetic foam for deep-sea vehicles. Tire treads containing fly ash were found to exhibit improved traction and skid resistance. Experiments at West Virginia University were looking at producing mineral wool from "coal ash wastes." The University of Utah reported that fly ash had been used successfully in controlling "snowmold," a disease that reduces winter wheat yields. If we fast-forward to today, haven't we been approached by those wanting to recover petroleum products and precious metals from CCPs? Forty years ago who would have considered FGD gypsum suitable for toothpaste and soil conditioning? Even fly ash in polyurethane composite railroad ties seems to be an unusual application today.

Thinking of ideas whose introductions were unique four decades ago (but commonplace today) would indicate we need to keep open minds and be ready for the next idea coming around the bend. As we focus on FGD gypsum, we are working with a material in 2008 that is in a similar position held by fly ash in 1968. Its flexibilities and opportunities are neither fully understood nor fully recognized, yet, it's a material whose time has come. Through research, partnerships and regulatory support, we might be able to build markets for coal combustion products quicker than was possible 40 years ago. We are wiser and have learned from our earlier lessons – haven't we? ❖

40 YEARS OF GROWTH AND EVOLUTION, MUCH MORE TO COME

By Al Christianson, Great River Energy



ACAA is celebrating its 40th anniversary at an exciting and changing time in the history of energy; we are knee-deep in the second energy boom.

The mission has evolved over the years to embrace the multitude of new coal combustion products being developed as a result of the industry researching and developing ways to produce cleaner and more efficient energy.

As the association approaches its anniversary, so are much of the workforce and leadership in the industry. Many are readying for retirement and approaching the what's-next-in-life phase. These leaders are training new, talented young people that will be in charge of the energy future. A great way for us to continue this is through strengthening the ACAA Educational Foundation. As we move forward, all of us should contribute to its continuing growth and the rewards the industry will receive from the use of its resources.

A wide variety of environmental changes have caused the creation of many new products and that will only continue to grow. ACAA is in the position of providing continuity and knowledge during the industry change and succession of personnel. ACAA will also promote the use and application of these new coal combustion products in a safe and friendly manner.

As my term as Chairman ends, I see an organization that is strong, growing and responsive to its members. The credit goes to those who stepped up in the past and had the vision to see the need and acted. Those of us who inherited their work will be forever grateful. ❖

FORTY YEARS WITH THE NATIONAL ASH ASSOCIATION AND ACAA

By Oscar Manz, Civil Engineering Department, University of North Dakota

Editor's Note:
ACAA invited Mr. Oscar Manz, professor emeritus of the University of North Dakota, to share his recollections about the last 40 years of the U.S. ash industry. This article gives his story, which includes reminiscence of early technical issues, personalities and other events that will help to celebrate the 40th anniversary of the ACAA and its predecessor, the National Ash Association (NAA). It also relates his involvement with the early industry, as well as that of John Faber who was instrumental in forming the NAA in 1968.

As a Canadian, I spent the summer of 1945 as a laborer in a clay sewer pipe plant in Medicine Hat, Alberta. That fall, I enrolled in ceramic engineering at the University of Saskatchewan, graduating in 1951. During my schooling I worked at Medicine Hat Potteries. After one year as superintendent of production at the Dominion Firebrick plant in Claybank, Saskatchewan. I was hired by the University of North Dakota in Grand Forks, N.D., to work with North Dakota clays and shales. Clay testing involved brick, light-weight aggregate and other uses. In 1953, I began teaching material engineering and concrete testing to civil engineering students. I also learned about North Dakota volcanic ash as a pozzolan. In 1963, I gave my first fly ash paper and realized that North Dakota lignite fly ash did not meet ASTM C 618 for use in concrete. Performance of lignite ashes was different from bituminous ashes. The only other lignite power plants at that time were the Saskatchewan Power Boundary Dam Station near Estevan, and the Big Brown Station in Texas; they both had some experience with concrete containing fly ash.

In 1965, I met John Faber at a lignite meeting in Bismarck, N.D. and attended my first ASTM meeting. In 1967, at the first Ash Symposium in Pittsburgh, I met with John Minnick (chairman of the C 618 committee for fly ash in concrete) and Bryant Mather, a director with the Army Corps of Engineers in Vicksburg, Miss. They soon agreed it was best to try to define a new class of fly ash for high calcium oxide lignite ashes. They became very supportive of ASTM over the next nine years as did Craig Cain, president of Chicago Fly Ash Company, and Bob Styron with AMAX Resource Recovery Systems in Atlanta. Twice a year for nine years with planning sessions in between, I made presentations about this high calcium ash from lignite coal. In 1975, Class C fly ash was approved. With the development of the Powder River Coal Basin in Wyoming in the 1970s, subbituminous Class C fly ashes became available.

In 1975, I took leave from the university for a year to work with Bob Styron in Atlanta along with Bart Thomas and Dennis Jones (president and vice president, respectively) and Tom Hendrix as chief salesman. This was excellent exposure to the industry, but I discovered there is more freedom in academic life than industry. In 1976, I returned to the University of North Dakota and formed the Coal Byproducts Utilization Institute. We tested several thousand fly ashes for ASTM C 618 compliance and conducted research for ash vendors. Our lab was CCRL (Cement and Concrete Reference Laboratory) approved.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Oscar Manz (right) is seated next to NAA executive director, John Faber. Dr. Alan Fletcher, dean of engineering at North Dakota University (left) hosted this meeting in his office in 1970.

We gave several workshops with lectures and lab demonstrations. We developed a thick three-ring binder of ash information and created "Think Fly Ash" T-shirts to make people aware of the benefits of this material. Participants at the workshops included John Faber, Craig Cain, Dean Golden, as well as many ash vendors and utility people. I was a member of 13 different ASTM committees involving coal ash and made numerous semi-annual reports to ACAA. After participating in ASTM C1, C9 and other committee meetings for over 30 years, I was made an honorary member.

JOHN FABER, FOUNDER OF NAA

In 1965, John Faber took me under his wing and encouraged my career. In 1958, when John was a chemical engineer with Bureau of Mines of Morgantown under the direction of Harry Perry, he began working with the Coal Committee of the U.N. Economic Committee for Europe. In 1960, the first of 12 meetings with the group working on utilization of coal ash was held. In 1966, they became the "Group of Experts" and all met at the 1st Ash Symposium in Pittsburgh. I was privileged to meet the following experts: Henry Deadman, U.K.; Adolphe Jarrige, France; Anton Paprocki, Poland; and Herman Erythropel, West Germany. There were 650 attendees at that first symposium sponsored by Edison Electric Institute, the National Coal Association and U.S. Bureau of Mines. John Faber was in charge of the event. He wore a red jacket and used a copper gong to announce sessions. The formation of an ash association was discussed during the symposium by the U.N. committee members and several Americans, including John Tillinghast, Jerry Gambs, Ron Morrison and John Faber.

In October 1967, 50 representatives from coal companies, utilities and railroads met in New York with John Faber. The NAA was formally incorporated on March 8, 1968 in Washington, DC. The office opened in Washington on July 8, with John as the executive director. John always insisted on the office being in Washington, because, in his words, "That is where the action is." Thus began the most exciting and productive 12 years of the NAA. John brought Al Babcock in as his right-hand man as author and producer of the *Ash at Work* publications, which continue to this day. John produced four more very successful ash symposiums, with large attendances. I, too, had a busy time as part of the symposiums, workshops, informational meetings with DOT, university and utility people, trade shows, etc. To save money, I would usually stay in John's hotel suite. Faber believed that presidents and vice presidents of the various companies who were members of NAA should govern the NAA. For a variety of reasons, however, these people were replaced by employees of lower rank. John confronted the board of directors with this concern. Unable to change this practice, John stepped down as executive director in 1980. For many years, however, he continued as an energetic ASTM member. Since 1980, there have been five executive directors with varying results. Since the present director, Dave Goss, took office and moved the office out of Washington, DC, the ACAA has taken new direction and gained membership.

John Faber was proud to be a hillbilly from West Virginia and could deal with anyone, including company presidents, university professors, truck drivers and foreign dignitaries. I recall two ash haulers, John Tonkovich and his son, as well as Walter Blocker, who helped with trade shows. John was very practical and intelligent, but determined. He built several homes and enjoyed going to big car auctions. I was very fortunate to attend five foreign ash conferences with John, in Trondheim, Norway; Madrid, Spain; London, England; Pretoria, South Africa; and Ankara, Turkey. The international ash group was a very close knit group and I treasure my many foreign acquaintances. In addition to ash related meetings, my wife Dorothy, and John and his wife Jean, had many pleasant trips together. It is unfortunate that John passed on. I cherish my memories of him.

U.S. AND INTERNATIONAL SYMPOSIUMS

The first ash symposium in Pittsburgh was the impetus for many succeeding ash symposiums and conferences. There have been 15 fly ash utilization symposiums in the United States, sponsored by NAA or ACAA, as well as EPRI (Electrical Power Research Institute) largely through the efforts of Dean Golden. I attended every one until the first World of Coal Ash. In 1993 I was privileged to receive honorary membership in ACAA.

The University of Kentucky Center for Applied Energy Research also sponsored international ash utilization symposiums in Lexington, Ky., beginning in 1995. In 2005, ACAA joined with the University of Kentucky, DOE's National Energy Technology Laboratory, and Office of Surface Mining to sponsor the first World of Coal Ash Symposium. I expect it to become another highlight in the history of the coal ash industry.

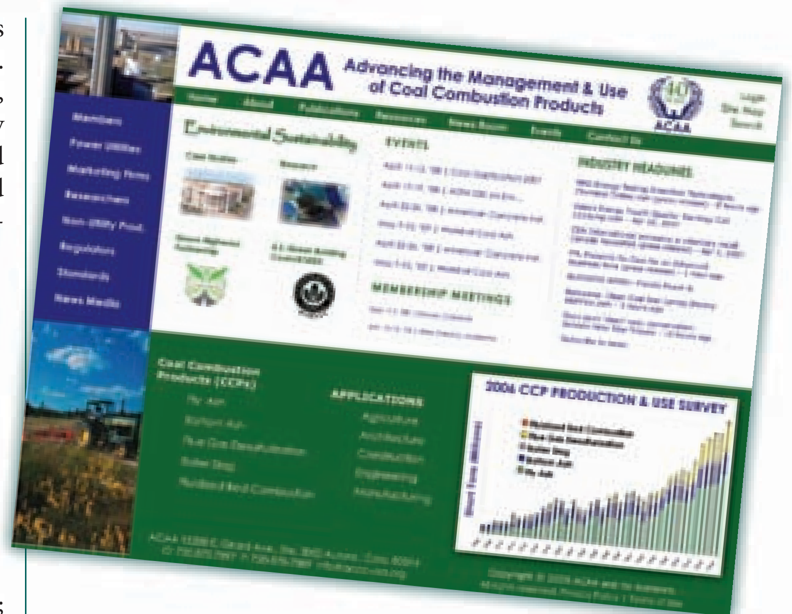
Eight international conferences on fly ash, silica fume, slag, and natural pozzolans in concrete have been sponsored by the Canada Center for Mineral and Energy Technology (CANMET), and American Concrete Institute. Dr. Mohan Malhotra of CANMET has organized all eight conferences. They were held in Montebello, Que.; Madrid, Spain; Trondheim, Norway; Istanbul, Turkey; Milwaukee, Wis.; Bangkok, Thailand; Madras, India; and Las Vegas, Nev. I had the privilege of attending the first six of these conferences and was especially honored by receiving the International Abdun–Nur award in Istanbul, Turkey in 1992 for my work in fly ash. Over several years, I conducted surveys of the worldwide production and utilization of coal ash and usually presented my surveys at the international ash conferences. My last complete survey was in 1989. It was the last year, 1991, before the fall of the Iron Curtain that I was able to receive data from Eastern Europe. As mentioned before, there have been ash conferences in the United Kingdom, Japan, South Africa, India, Canada, etc.

ACAA thanks Oscar for his memories and willingness to share his perspectives. Over the last 40 years, Oscar and many others have shaped this association into a respected organization with a national and international reputation for quality. Thanks to the vision of Oscar Manz, John Faber, Craig Cain, Al Babcock and many more, we expect this industry to continue well into the next four decades. ❖

Oscar Manz is a professor emeritus in the Civil Engineering Department at the University of North Dakota, Grand Forks, N.D. He can be reached at flyash@wiktel.com

ACAA WEB SITE RECEIVES A **FACE LIFT TO CELEBRATE 40**

The ACAA has launched a refreshed version of its Web site to celebrate the organization's 40 years. The new design updates the site's appearance, while audiences with varying interests can easily locate relevant information. The home page features new and emerging technologies, recent case studies, current events and news, regulatory issues, and other up-to-the-moment content to keep the site fresh and dynamic. Members can log on to an exclusive section of the site, offering "committee back rooms" for sharing updates on various initiatives and uploading/storing key documents. The new site introduces a news room, where journalists can find news releases, fact sheets, reports, photos and other information, as well as register to receive updates from ACAA. Transactions such as membership dues, merchandise purchases and event registrations can be handled online. Throughout 2008 a series of additional features will be introduced, including a job bank; campaign feature that coordinates industry response to key issues; custom surveys; news aggregator (RSS); online training/education; content refinements and more!



PUBLICATIONS LIBRARY

The library contains abstracts and full text copies of many papers and presentations from previous ACAA symposia. Presentations given at ACAA and other meetings over the past several years are available to members. More than 2,400 technical reports are available to members through the association's in-house topical database. These documents are mostly in PDF format and include recent articles and reports as well as historical proceedings and papers from as far back as the mid-1980s. The association also reviews periodicals and technical journals each month and includes synopses of their contents in the database. All the early issues of *ASH at Work* dating back to 1968 are in PDF format in this library; also, the past editions of ACAA *E-News* are available.

PHOTO GALLERY

The ACAA maintains a gallery of more than 700 digital photographs that members can download for use in presentations and publications. Our staff routinely fulfills requests to provide suitable photos of CCP-related activities for use in newspapers, magazines or other publications.

MEMBERSHIP DIRECTORY

Membership has grown more than 50 percent over the past several years and our numbers continue to rise. Visitors to the ACAA Web site can find out who's who in the coal combustion products industry and target inquiries to their needs.

COAL COMBUSTION PRODUCTS PRODUCTION AND USE SURVEY

Finally, complete results of ACAA's annual CCP Production and Use Survey are posted online and easy to locate on the new site's home page. (See page 14 for more information on this survey.) ❖

Visit the site today at www.acaa-usa.org!

Valley Block of Loveland, Colo., displays the various colors of retaining wall block they manufacture using Rawhide f y ash.

SPRAY DRYER ASH FINDS A MARKET

By Jon Little, Platte River Power Authority

Platte River Power Authority generates and delivers reliable, low-cost and environmentally responsible electricity to its owner communities of Estes Park, Fort Collins, Longmont and Loveland, Colo., where it is distributed by each municipal utility to residents and businesses. Platte River's headquarters is located in Fort Collins and its generating and transmission facilities are located along Colorado's Front Range, in northwestern Colorado and near Medicine Bow, Wyo.

Platte River owns and operates the Rawhide Energy Station, a power plant comprised of a 274-megawatt coal-fired generator and four 65-megawatt natural gas single-cycle generators. Rawhide Unit One, the coal-fired generator, incorporates a spray dry desulfurization system that produces approximately 75,000 tons of fly ash and FGD materials per year. Most of these materials are placed in a monofill.

Rawhide Unit One burns ultra low-sulfur Powder River Basin Coal. Its ash conforms to the chemical requirements for Class C fly ash as specified by ASTM C 618. Several analyses of Rawhide ash have yielded the average chemical levels listed in Table 1.

Table 1

Silicon dioxide (SiO_2) plus aluminum oxide (Al_2O_3) plus iron oxide (Fe_2O_3)	60.63%
Sulfur trioxide (SO_3)[1]	3.70%
Moisture content	1.33%
Loss on ignition	1.64%

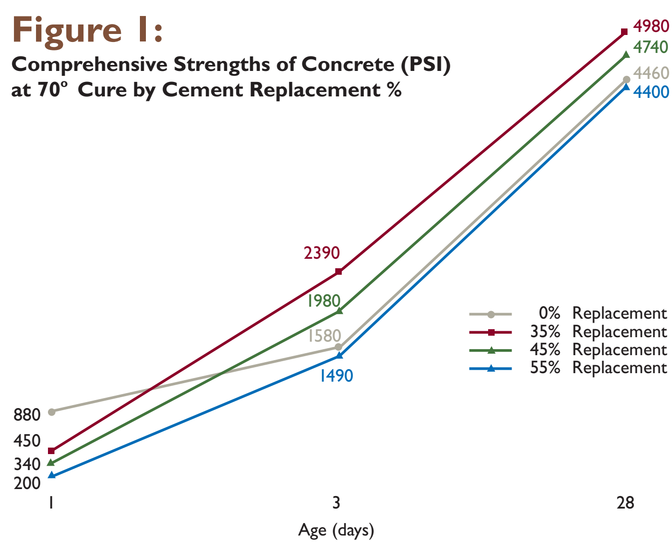
[1] Using wet gravimetric method.

With goals of conserving monofill space, avoiding disposal costs and saving natural resources, Platte River has been working to develop markets for Rawhide fly ash. In 2006, Platte River contracted with North American Aggregate, Inc. (NAA) of Webster, Wis., to market its fly ash to manufacturers of concrete articles. North American Aggregate has experience marketing similar ash produced at Xcel Energy's Sherburne County plant in Minnesota. NAA works with concrete block manufacturers to educate them on how to use dry scrubber ash in their mix designs.

NAA studied the Rawhide ash and determined that it has excellent pozzolanic properties. Extensive testing was done that evaluated long-term performance as well as shrinkage. In all tests the material performed well. Tests performed on concrete cylinders made with up to approximately a 50 percent ash-for-cement substitution rate have shown that although initial strengths are lower, three- and 28-day compressive strengths are as high as, or higher than, those utilizing cement alone.

Figure 1:

Comprehensive Strengths of Concrete (PSI) at 70° Cure by Cement Replacement %



For the past year and a half, Rawhide fly ash has been successfully used as a cement substitute by an architectural block manufacturer in Colorado. The manufacturer currently utilizes a 35 percent ash-for-cement substitution rate. The manufacturer likes the consistent physical properties of the ash, including its color. The ash seems to enhance the pigment used in some block, resulting in more vivid colors.

In coming months, Platte River and NAA plan to get more manufacturers of architectural block and pre-cast concrete items to use Rawhide fly ash in their mixes.

Rawhide fly ash has also been used by the owner of a dairy cow feedlot to fill muddy holes in its feed pens. The fly ash hardens into a durable substance when mixed with the right amount of moisture and compressed. Solid footing allows yearling heifers to remain more comfortable and grow stronger. Standing in mud and manure can lead to hoof problems and mastitis, an inflammation of the mammary gland usually caused by bacteria. The feedlot owner has also mixed Rawhide fly ash with soil to create a hard level floor for its trench silo. The silo has been dug out of the side of a hill and holds approximately 10,000 tons of feed corn. Before using Rawhide fly ash, ruts and potholes in the silo's floor caused front loaders to spill about $23,000 worth of silage per year. ❖

Editor's Note: The success that Platte River Power Authority has had in finding a use for spray dryer material is encouraging, as many more of these units will be added to plants in the next five to 10 years. Their creative approach and partnership has enabled them to take an otherwise rarely used CCP and make it into a useful product for both block manufacturing and feedlot management.

This photo shows one way fly ash has been used at a feedlot. The area around the gate had become a large sink hole. The mud and manure was shoveled out, filled with fly ash and compacted. This was done to protect the health of the cows and to improve access into the pen. If you look closely, you can see some of the grey fly ash spread around in the foreground.

InBulk Technologies creates new logistics solutions for **cement**

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During 2006 Lafarge North America became the first North American owners and operators of the intermodal bulk container known as the ISO-Veyor.

Lafarge North America's Montreal office completed successful trials of the 20 ft H type ISO-Veyor for marine shipments by Oceanex of cement powder to Newfoundland customers from the Port of Halifax and Montreal. The flow has been successfully operating for almost a year now and Lafarge NA have now ordered several additional units to cover an increase in the scale of the project.

The ISO-Veyor is truly intermodal, facilitating easy transition between road and rail and sea. It consists of a cylindrical vessel with a 25 m^3 capacity constructed within the frame dimensions of a 20 ft ISO unit. It can be handled exactly as a standard ISO container, utilising currently available trailer chassis and rail car rolling stock. It 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.

Once the ship arrives at the port, the ISO-Veyor is lifted from the Quayside onto a conventional skeletal trailer.

The rest of the journey takes place by road. On arrival the ISO-Veyor can be loaded onto the ground. It now becomes a temporary silo. No need for the driver to wait around.

The ISO-Veyor can be stacked up to 9 high. The units can be drawn upon and discharged as demand dictates, ensuring a smooth and seamless supply of cement and cement substitute materials.

The ISO-Veyor represents a step forward in dry bulk transportation.

Pressurised 'dry' bulk containers have been available as tipping tanks which require hydraulically operated tipping chassis. These are expensive and also carry H&S issues at many sites, as there is the possibility of being blown over during high winds. So far, horizontal discharge tanks have been an extension of the 'belly tanker concept', where the internal cones take up valuable space and reduces payload.

InBulk Technologies recognised a significant opportunity to extend their 30 years of expertise within the 'dense phase pneumatic conveying' industry by applying their knowledge to pneumatic discharge tank containers.

Jim MacLean, InBulk's Business Development Manager for Canada and North America comments:

"We are delighted with this additional sale of ISO-Veyors to Lafarge NA. We are pleased to build on this contract with the world's largest cement producer. The whole flexibility of the ISO-Veyor is an excellent way for cement suppliers to minimise the risks, keep costs to a minimum and maximising their supply chain efficiencies whilst recognising their sustainability obligations."

In conjunction with the ISO-Veyor technology, work has recently been completed on InBulk's new storage concept, the **ISO-Silo**.

The idea is simple – it's a combined storage silo and pneumatic transfer system. The ISO-Silo is available in 40 ft dimensions offering up to 53 m^3 capacity.

The major advantage over traditional silos is that the ISO-Silo can be erected and ready to operate in a matter of hours. The completely prefabricated unit only needs to be lifted into position and placed onto a precast concrete base to hold it in position in case of high winds.

An important design criterion was to have all serviceable equipment at ground level, avoiding the need to access the top of the silo (a significant safety benefit). All units are supplied with integral plc control systems and self contained dust filtering system.

Another prime benefit over traditional equipment is that the ISO-Silos can be considered as a 'temporary facility' therefore planning permission may not be necessary.

Transportable silos for dry powders and granules that are filled by road tankers have been known for many years. These simple holding devices of 20 – 50 tonnes need to be accompanied by a mechanical or pneumatic conveying system to move the material. The ISO-Silo overcomes many of these problems. The ISO-Silo is a self contained pneumatic conveying vessel; as an option, it can come supplied with mechanical feeding devise such as screw feeder for short distances.

The ISO-Silo can be easily transported on trucks, rail or sea by using the infrastructure and equipment already used throughout the world to lift and move containers. On arrival at its end location, it is lifted vertically by a crane onto a concrete base.

The ISO-Silo is also a pressure vessel, which is designed to 2 Barg. After filling, the ISO-Silo itself can be pressurised to become a pneumatic conveying system that can convey the material to the point of use, avoiding the need for an additional conveying system that would be required with a conventional silo.

As the ISO-Silo can be pressurised, the airflow from the tanker truck can be restricted at the filter outlet so that the pressure in the filter and silo rises to approximately half the tanker truck pressure. By restricting the air flow through the filter, the surge of airflow at the end of the truck unloading can be avoided. The net result is a filter of approximately 1/3 the filter area of a conventional silo. The ISO-Silo filter has a much smaller pipe or duct, 100 mm diameter due to the fact that it operates under pressure and has a flow limiting restriction on the filter outlet.

To avoid the requirement to fit a high level probe in the top of the ISO-Silo, a level probe is mounted on the small hopper underneath the filter unit, at ground level. If the ISO-Silo becomes 'overfilled' by accident, the bulk material being unloaded will be conveyed down the vent pipe into the filter unit hopper. This level probe will automatically close the airflow valve at the filter and will prevent any further transport from the tanker truck. To enable the customer to know how much material is left in the silo at any time, load cells can be fitted between the ISO-Silo and the concrete base as an option.

For applications where it is not necessary to transport the material more than a few metres from the base of the ISO-Silo, the filter unit is located above the screw conveyor as it exits the base. The screw conveyor is also capable of being pressurised. The valve on the screw conveyor outlet is closed during ISO-Silo filling and the dust collected in the filter will fall into the screw conveyor.

For powders, the design of the ISO-Silo can be changed to incorporate a fully fluidised cone with a low angle to the horizontal, providing maximum storage capacity.

InBulk Technologies are working with a number of companies looking to explore the concept for various applications and industries. Many of the companies are looking at new ways to cut back on the number of hours that drivers are required to wait around to discharge loads. 'Driver controlled deliveries' can greatly assist haulage companies that are looking to combat the negative economic effects of the Working Time Directive. Indeed, driver controlled deliveries are common in the retail petroleum market and as a result tanker fleets used in this market obtain very high utilisation rates compared with other industries.

ISO-Silos can be controlled by the truck driver, ensuring that their time is utilized more effectively, a situation made worse by the recent working time directive for truck drivers. ISO-Silos effectively hand this control to the drivers.

A full prototype unit is available for trials very soon. Jim MacLean continues, "If there are any US and Canadian companies wishing to examine the possibilities of transportation and storage solutions utilising ISO-Veyors or ISO-Silos, we urge them to pick up the phone and give us a call."

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

James Maclean PEng
Business Development Manager

Telephone
506 452 7933

Toll Free (US & Canada)
866 890 000

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BENEFICIAL USE OF COAL COMBUSTION PRODUCTS CONTINUES TO GROW

ACAA RELEASES 2006 CCP PRODUCTION AND USE SURVEY RESULTS

By Michael MacDonald, American Coal Ash Association

BOTTOM LINE RESULTS = GOOD NEWS FOR THE CCP INDUSTRY

In August 2007, ACAA distributed the results of its 2006 Coal Combustion Products Production and Use survey.[1] Production was 124,795,000 tons, while beneficial use was 54,203,000 tons – a utilization rate of more than 43 percent or 3 percent greater than 2005 and the highest use-to-production rate in 40 years of data collection (see Chart 1).

The year 2006 was the latest of seven consecutive years of increasing beneficial use, i.e., from more than 32 percent in 2000 to, as indicated above, 43 percent. This is a cumulative increase of more than 11 percent – good news for the EPA and the CCP industry, both of which set the goal of 50 percent beneficial use by 2011 (see Chart 2). This goal is attainable, if not exceedable, with continued current educational and business initiatives by CCP stakeholders.

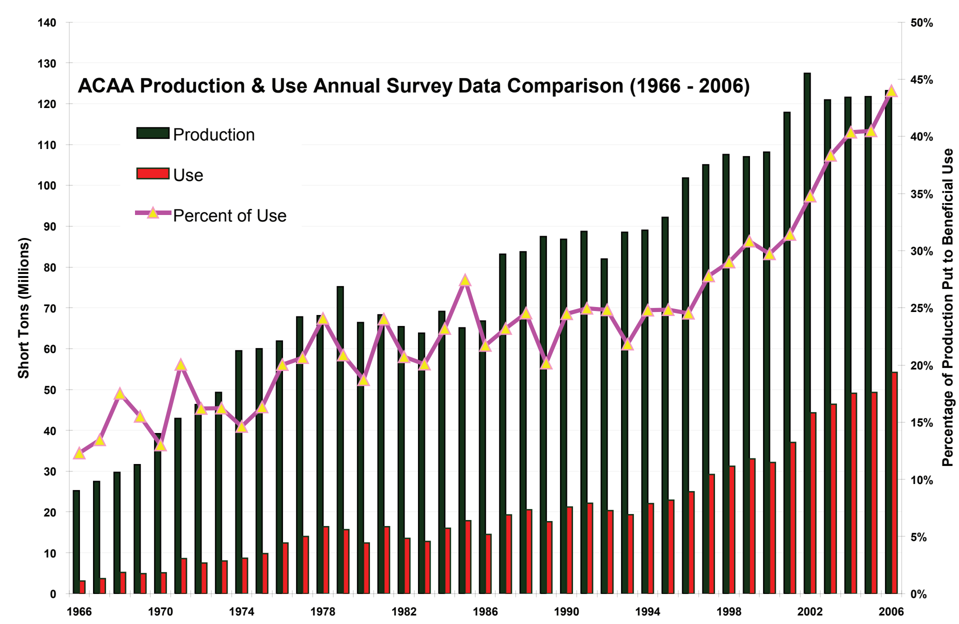
CCP SURVEY BACKGROUND

In 1967, ACAA (then the National Ash Association) and Edison Electric Institute began tracking the quantity of CCPs being produced and distributed for use by U.S. coal-fired electricity generating power utilities. Since the survey's early years, CCP *production* categories have expanded to include not only fly ash, bottom ash and boiler slag, but also flue gas desulfurization (FGD) gypsum, FGD wet and dry scrubber materials as well as fluidized bed combustion (FBC) ash. "Cenospheres sold" was added to the survey in 2004. *Utilization* categories also expanded – from an original 10 to the current 15. The categories show a wide range of products that exemplify CCP's environmental, economic and technical advantages.

Up to 60 percent of U.S. coal-fired power plants volunteer to provide survey data. The DOE's Energy Information Administration provides information that helps extrapolate the final

Chart 1.

Statistical Pattern of 40 Years of CCP Production and Use



figures.[2] Extrapolations apply to fly ash, bottom ash, FGD gypsum and FGD wet scrubber materials, but not to boiler slag, FGD dry scrubber materials and FBC ash. The EIA reports do not itemize these latter categories.

NOTABLE CCP CATEGORY STATISTICAL CHANGES

FLY ASH

Fly ash production in 2006 increased by 1.3 million tons from 2005 to 72.4 million tons. Almost 45 percent (32,423,569 tons) was used in 12 of 15 beneficial applications tracked by ACAA; this is an increase of about 5 percent from the previous year. Of the total used, 46 percent (15,041,335 tons) was consumed in concrete, concrete products and grout; an additional 4.1 million tons was consumed in cement production.

FLUE GAS DESULFURIZATION (FGD)

FGD materials include products from forced oxidation scrubbers and other processes that remove sulfur dioxide from the flue gas stream. FGD gypsum production was approximately 12.1 million tons of which 79 percent (9,561,489 tons) was used – mainly in gypsum panel products, such as wallboard. This is a slight increase (2.5 percent) over 2005.

BOTTOM ASH

Bottom ash production was 18.6 million tons of which 45 percent (8,378,494 tons) was used. Structural fills and embankments accounted for the largest application. Production figures increased by more than 1 million tons, while utilization increased about 4.5 percent as compared to 2005. Bottom ash, like fly ash is widely used in many applications.

BOILER SLAG

Boiler slag reached slightly more than 2 million tons of which 83 percent was used (1,690,999 tons) – a decrease from the 96.6 percent reported in 2005. Boiler slag is used primarily in blasting grit and as roofing granules, with lesser amounts in structural and asphalt mineral fills. The volume of available slag is expected to continue to decline in the coming years as older cyclone and slag-tap boiler units are retired.

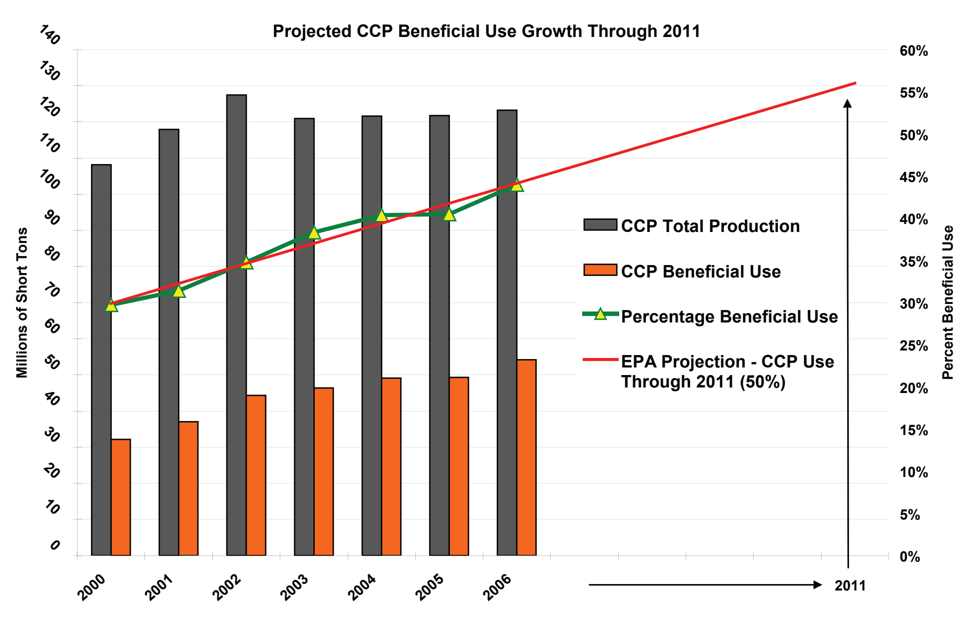
THE KEYSTONE OF CONTINUING INCREASES IN CCP BENEFICIAL USE

The keystone to increased beneficial CCP use, as reflected in this survey, is the result of hard work and involvement of highly dedicated professionals within industry, academia and throughout local, state and federal government agencies. Evidence of this is publicly available through the Internet, books, conferences, trade magazines, advertising, news articles, patent records, educational materials and research and innovation documentation. These sources continue to grow exponentially as revealed by Internet keyword searches on virtually any aspect of CCPs. These key contributors include the following:

- U.S. Environmental Protection Agency, Office of Solid Waste.
- U.S. Department of Transportation, Federal Highway Administration.
- U.S. Department of Energy, National Energy Technology Laboratory.
- U.S. Department of Interior, U.S. Geological Survey.
- U.S. Department of Agriculture, Agricultural Research Service.
- State departments of natural resources, environmental protection and transportation.
- Coal-fired electric utility companies.
- CCP marketing companies.
- Physical and chemical engineering and related research departments of American universities.
- Engineering and architectural consulting firms.
- CCP transport companies.
- CCP related equipment-processing companies.
- CCP trade associations and their dedicated member organizations.

Chart 2.

Projected Trend of Beneficial CCP Utilization



ACAA thanks everyone involved for their contribution to its annual survey and those who lend their positive influence and participation to affect greater growth and awareness of beneficial coal combustion products utilization.

For most of us who do not physically work with coal combustion products on a daily basis, production and use tonnage statistics, by themselves, generally do little to communicate the implications of the volume reported. For this reason, it might be helpful and interesting to visualize those millions of tons in terms we can better understand, such as road distances. Thus, when ACAA reports that in 2006, U.S. CCP beneficial utilization was 54,203,000 million tons (i.e., 43 percent of production), beneficial use can be equated to six, 11-foot-wide traffic lanes, 12 inches thick (CCP materials only) stretching 4,444 miles. In other words, a six-lane freeway from Los Angeles to New York nearly twice over.[3] ❖

[1] *ACAA 2006 CCP Production and Use Survey, August 15, 2007.*

[2] *DOE EIA 767 Report (2006) Steam-Electric Plant Operation and Design Report is no longer published (last data available: 2006), but will be re-incorporated in other EIA reports in 2008.*

[3] *Calculation based on the volume of one short ton (2,000 pounds) of fly ash (i.e., generic CCP) equaling 28.5 cubic feet or approximately a cubic yard (or 1 cubic foot equaling 70 pounds).*

Chart 3. 2006 Coal Combustion Product (CCP) Production and Use Survey

American Coal Ash Association
15200 E. Girard Ave., Ste. 3050
Aurora, CO 80014-3955

Phone: 720-870-7897
Fax: 720-870-7889
Internet: www.ACAA-USA.org
Email: info@acaa-usa.org

2006 Coal Combustion Product (CCP) Production and Use Survey

CCP Categories (Short Tons)	Fly Ash	Bottom Ash	Boiler Slag*	FGD Gypsum	FGD Material Wet Scrubbers	FGD Material Dry Scrubbers*	FGD Other*	FBC Ash*
CCP Production Category Totals**	72,400,000	18,600,000	2,026,066	12,100,000	16,300,000	1,488,951	299,195	1,580,912
CCP Production Total								**124,795,124**
CCP Used Category Totals***	32,423,569	8,378,494	1,690,999	9,561,489	904,348	136,639	29,341	1,078,291
All CCP Used Total								**54,203,170**
CCP Use By Application****	**Fly Ash**	**Bottom Ash**	**Boiler Slag**	**FGD Gypsum**	**FGD Material Wet Scrubbers**	**FGD Material Dry Scrubbers**	**FGD Other**	**FBC Ash**
1. Concrete/Concrete Products /Grout	15,041,335	597,387	0	1,541,930	0	9,660	0	4,571
2. Cement/ Raw Feed for Clinker	4,150,228	925,888	17,773	264,568	0	0	0	0
3. Flowable Fill	109,357	0	0	0	0	9,843	0	0
4. Structural Fills/Embankments	7,175,784	3,908,561	126,280	0	131,821	0	0	360,115
5. Road Base/Sub-base/Pavement	379,020	815,520	60	0	0	249	0	453,602
6. Soil Modification/Stabilization	648,551	189,587	0	0	0	299	1,503	179,003
7. Mineral Filler in Asphalt	26,720	19,250	45,000	0	0	0	0	0
8. Snow and Ice Control	0	331,107	41,549	0	0	0	0	0
9. Blasting Grit/Roofing Granules	0	81,242	1,445,933	0	232,765	0	0	0
10. Mining Applications	942,048	79,636	0	0	201,011	115,696	0	0
11. Wallboard	0	0	0	7,579,187	0	0	0	0
12. Waste Stabilization/Solidification	2,582,125	105,052	0	0	0	0	27,838	81,000
13. Agriculture	81,212	1,527	0	168,190	0	846	0	0
14. Aggregate	271,098	647,274	416	0	0	0	0	0
15. Miscellaneous/Other	1,016,091	676,463	13,988	7,614	338,751	46	0	0
CCP Category Use Totals	**32,423,569**	**8,378,494**	**1,690,999**	**9,561,489**	**904,348**	**136,639**	**29,341**	**1,078,291**
Application Use To Production Rate	44.78%	45.05%	83.46%	79.02%	5.55%	9.18%	9.81%	68.21%
Overall CCP Utilization Rate								**43.43%**
Cenospheres Sold (Pounds):	**11,146,420**							

* As submitted based on 57 percent coal burn.
** CCP Production totals for Fly Ash, Bottom Ash, FGD Gypsum, and Wet FGD are extrapolated estimates rounded off to nearest 50,000 tons.
*** CCP Used totals for Fly Ash, Bottom Ash, FGD Gypsum, and Wet FGD are per extrapolation calculations (not rounded off).
**** CCP Uses by application for Fly Ash, Bottom Ash, FGD Gypsum, and Wet FGD are calculated per proportioning the CCP Used Category Totals by the same percentage as each of the individual application types' raw data contributions to the as-submitted raw data submittal total (not rounded off).

FOLLOW THAT

Avoiding release of mercury captured by power plant pollution control equipment

Editor's Note: The following article by Mr. Linero has been edited to allow us to include it in this issue. The complete version can be accessed by going to: http//www.acaa-usa.org/ASHatWork.htm

INTRODUCTION

A previous *Ash at Work* article (Aljoe, et al, Summer/Fall 2005) provided an estimate of approximately 75 tons per year (TPY) of mercury (Hg) entering coal-fueled units as a chemical constituent of pre-burn coal. Approximately 48 TPY of Hg were emitted into the atmosphere from those units, while the remaining 27 TPY of Hg were retained within 107,000,000 TPY of produced coal combustion products.

Pursuant to the Clean Air Mercury Rule (CAMR) promulgated by the EPA, Hg emissions will be reduced to approximately 15 TPY by 2018. While there is a general expectation that Hg controls may be novel and highly sophisticated, the fact is that most reductions will be effected by the well-known pollution controls employed for reduction of the traditional pollutants such as sulfur dioxide (SO2), particulate matter (PM) and nitrogen oxides (NOx).

Modern coal-fueled units already have such controls that typically consist of: low NOx burners (LNBs) and selective catalytic reduction (SCR) for NOx; fabric filters (FFs) or electrostatic precipitators (ESPs) for PM; and lime spray dryer absorbers (SDA) or wet limestone flue gas desulfurization (FGD) scrubbers.

Pursuant to EPA's Clean Air Interstate Rule (CAIR), the Title IV Acid Rain provisions of the Clean Air Act, various ozone remediation plans, and some high-profile enforcement settlements, many existing and older coal-fueled units in the eastern U.S. are installing controls for NOx and SO2. These controls will provide most of the required Hg reductions, at least in the eastern U.S. where bituminous coal reigns.

MERCURY!

By Alvaro A. Linero,
Florida Department of Environmental Protection

MERCURY EMISSIONS TRADING

Future emissions of Hg will be capped at 15 TPY and will be measured by required in-stack continuous emission monitoring systems (Hg-CEMS). The system will be enforced by a system of allowance allocations and subsequent trading among utilities who can sell allowances beyond their respective allocations or must buy allowances to make up shortfalls should their Hg emissions exceed their allocation.

MECHANISMS FOR MERCURY CONTROL

Other than use of low Hg coal, the mechanisms of Hg capture are very complicated. The reader is referred to the many EPA CAMR technical background documents available at: www.epa.gov/ttn/atw/utility/utiltoxpg.html

The basic mechanisms are summarized as:

- Adsorption of Hg by injected sorbents or by unburnt carbon in high loss on ignition (LOI) fly ash, particularly when LNBs are employed.
- Oxidation across SCR catalyst thus making Hg more collectable in downstream pollution control equipment.
- Collection of particulate Hg and fly ash in the PM control devices.
- Capture in other streams such as wet FGD scrubbers.

Numerous studies have been conducted by the testing arms of the Portland Cement Association and the concrete associations that attest to fly ash being used directly in various types of concrete, with the resulting products often stronger and longer lasting. Similarly, efforts have been aimed at showing that products such as gypsum wallboard and concretes that use CCPs retain, to a large extent, the contained metals. A number have shown a high degree of retention of Hg. Again, the ideal situation is immobilization of Hg in the ultimate products made from CCPs. The reader is referred to the following Web site for the relevant papers given by international experts on all of the mentioned topics: http//www.flyash.org/

EFFECTS OF CAIR/CAMR ON CCPS

It has been recognized for several years that the principle control technologies for NOx affect fly ash and can render it less usable in concrete. The reasons are well known to most readers and in summary are: high LOI caused by reducing conditions in the furnace or insufficient burnout time, and high ammonia (NH3) from the SCR system. There are a number of remediation processes that deal with these issues and produce concrete compatible products. In such cases, it is important to determine the fate of Hg to insure that it is not released during remediation or subsequent use of non-concrete streams. A comparison of the processes is worth another article.

A SPECIAL CASE (SCR/SDA/FF)

It is not possible in an article as brief as this one to examine all of the possible control technology options and their effects on fly ash. There is, however, one special case that is easily examined and which is known for its efficacy in Hg reduction. It is the use of SCR for NOx control and SDA for SO2 control prior

Table 1. Mercury Removal Characteristics of Bituminous Coal-fueled Units with SDA/FF Control

Plant/ Unit Name	Mecklenburg 1	Birchfield 1	Logan 1	Collier 2B
Control	SDA/FF	SCR/SDA/FF	SCR/SDA/FF	SDA/FF
Emissions (10^{-6} lb Hg/MWH)	1.1	2.4	2.8	1.1
Percent Hg Removed	98.8	97.8	97.8	95.2

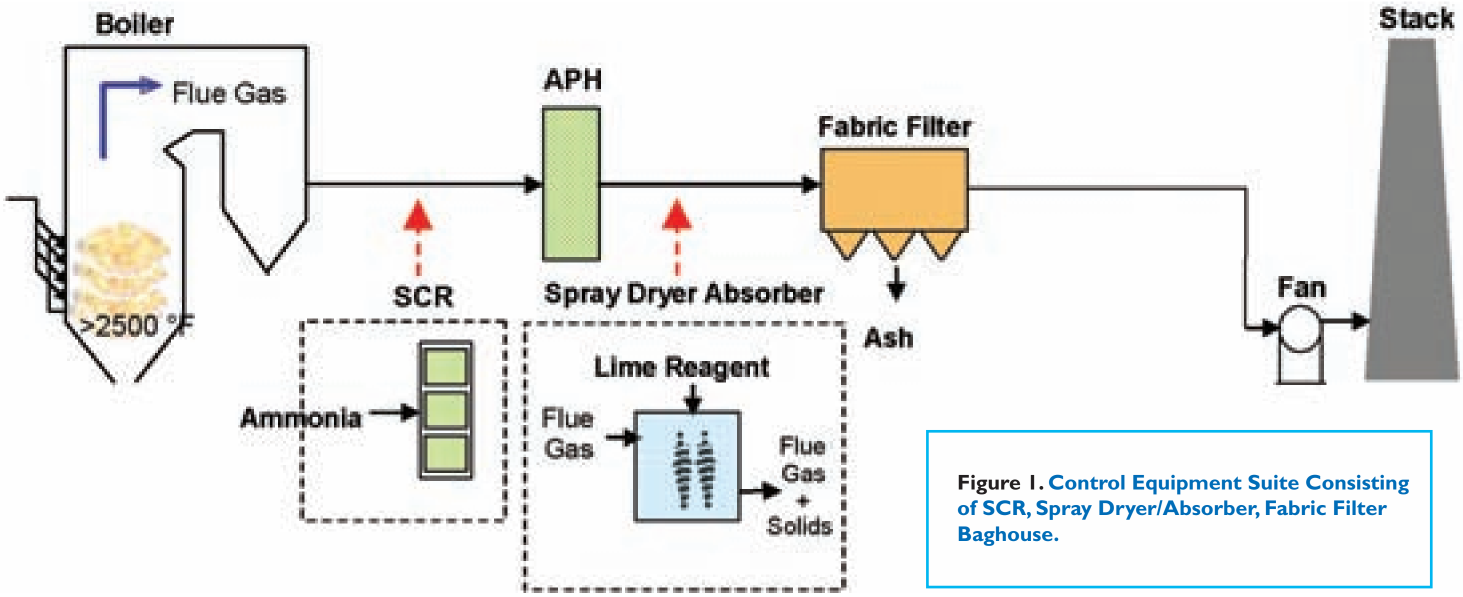


Figure 1. Control Equipment Suite Consisting of SCR, Spray Dryer/Absorber, Fabric Filter Baghouse.

to PM collection by FF (i.e., a baghouse). Refer to Figure 1. In this scenario all Hg removed is trapped in the FF baghouse. Bituminous coal has been well established and documented by EPA in support of the Hg standard in 40 Code of Federal Regulations Part 60, Subpart Da – Standards of Performance for Electric Steam Generating Units.

Table 1 above is derived from information in a key support memorandum for the limitation of 20 x 10^{-6} pounds Hg per megawatt hour (lb/MWH) applicable to new bituminous coal-fueled units. All of the units mentioned in the table have at least the SDA/FF part of the configuration and two also have SCR. The average removal efficiency is greater than 97 percent for these units. The average Hg content of the incoming coal was approximately 0.1 parts per million (ppm).

Assuming these units each burn approximately 1 million TPY of coal, the removal by the fly ash equals roughly 200 pounds/year/unit and emissions are on the order of 5 pounds/year/unit.

The suitability of the fly ash from these units for direct beneficial use as a CCP is unknown to the writer, but it is reasonable to assume that the fly ash from the two units that include SCR is less usable. This fly ash will have elevated NH3 content.

If such fly ash were used in cement production there is the possibility of release of *all* Hg collected by the power plant control equipment. Without special measures, the potential amount released by pyroprocessing is 25 times the amount emitted by the source power plant. Such a scenario would completely defeat the benefits of the Hg removal equipment.

The value of the Hg allowances represented by the potential additional emissions of the cement plants using the fly ash from a single one of these units is on the order of $7,000,000 per year.

WHAT HAPPENS IN A CEMENT PLANT?

In modern dry process preheater/calciner (PH/C) cement plants, every effort is made to turn all raw materials into product with no waste. The final dust control device is part of the process equipment. The dust is actually considered as feed and is returned to the process.

Figure 2 was developed from a diagram in a European Cement Bureau (CEMBUREAU) report. The circuit shown in red represents volatile species, such as Hg, that enter primarily with the raw materials via the raw mill. The raw mix entering the raw mill is intimately contacted with

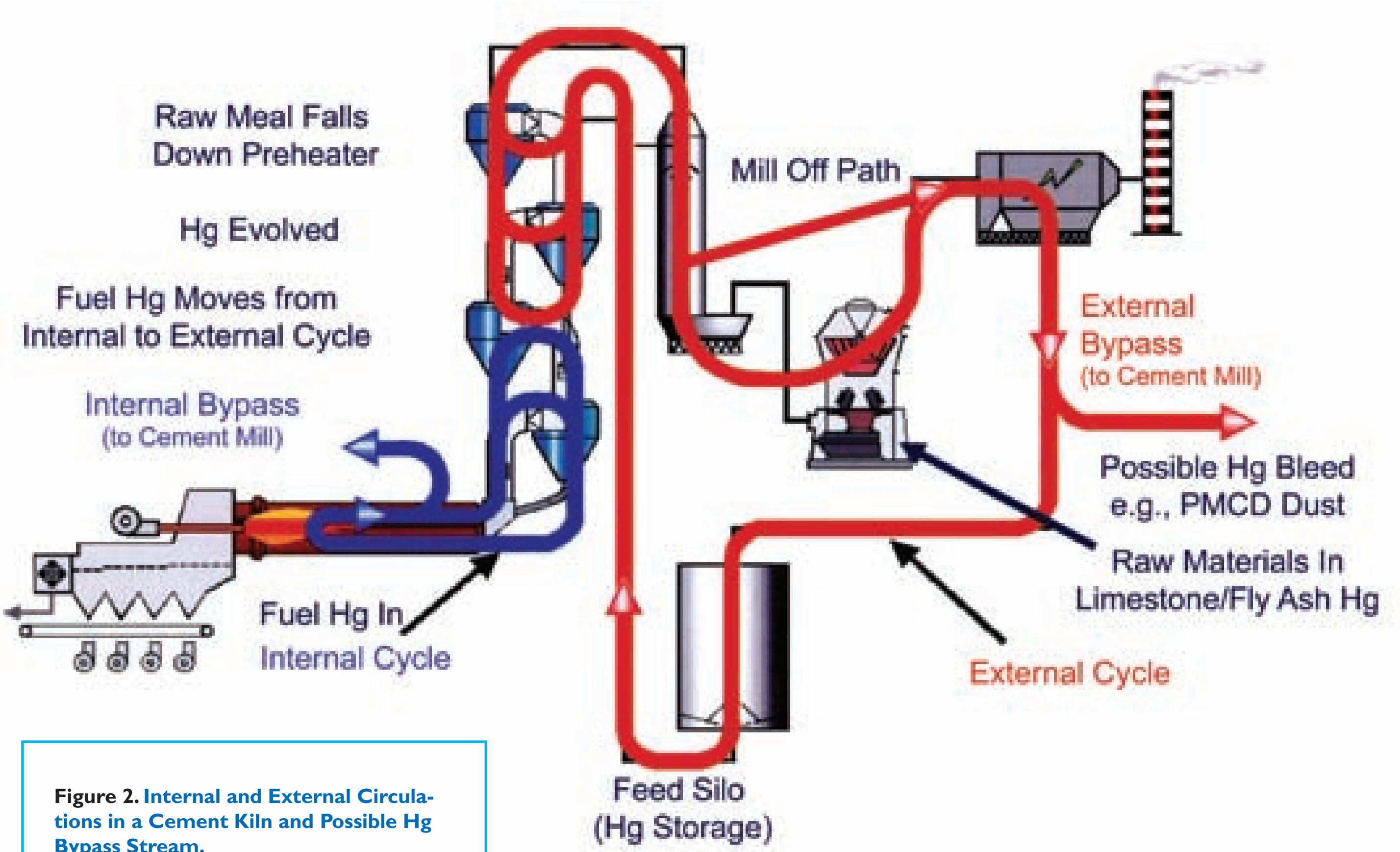


Figure 2. **Internal and External Circulations in a Cement Kiln and Possible Hg Bypass Stream.**

exhaust gases traversing the kiln, calciner and preheater.

Raw mix is ground and actually adsorbs additional Hg from the exhaust gases, some of which is also of fuel origin from the internal cycle (blue circuit). The concentration of Hg builds up in the red circuit until the amount entering via the raw materials and fuel equals the amount that exits the stack.

If the raw mill is turned off and the process continues using raw meal from the feed silo, a great portion of the Hg trapped in the red circuit is released until the raw mill is restarted.

It is unrealistic to expect that any Hg will leave via the clinker because it will be vaporized long before reaching the kiln exit. The only mitigation possible is by the purposeful withdrawal of a portion of the dust from the dust control equipment and either wasting it or, as commonly practiced in Europe, combining it with clinker at the cement finishing mill. This practice is combined with the operation of the dust control equipment at lower temperature during the time that the raw mill is down. This reduces the Hg vapor pressure and hence emission.

There is resistance to this step because it either wastes material or brings into question the acceptability of the product cement as a Type I cement in accordance with the standards of the American Association of State Highway and Transportation Officials (AASHTO) and the American Society for Testing and Materials (ASTM).

CEMENT PLANT REGULATIONS

EPA did not establish Hg emission limits for existing cement plants in the latest version of 40 CFR 63, Subpart LLL (December 20, 2006). Few cement plants in the U.S. have Hg permit limits and those that do, typically have relatively high allowable emissions (100 to 225 pounds per year) by present day considerations. Contrast these values with the expected 5 pounds Hg per year from a very well controlled coal-fueled unit. Operators of such cement kilns might typically operate at levels about half of their allowed emissions and believe they are doing quite well. They might also believe that they are well within their rights to take Hg-laden fly ash from the power plants as long as their own emissions are within the permitted cement plant limits even though the Hg removed by power plants is re-emitted. EPA was sued by the PCA because of the Hg limits established for new kilns, and by several states and environmental groups for the lack of limits on existing ones.

FUTURE DEVELOPMENTS

If a cooperative effort can be quickly launched between the cement companies, the state departments of Transportation, EPA and, ideally, the CCP marketers, a situation can be avoided that may result in the removal of a substantial amount of fly ash from the CCP market. The case cited above (SCR/SDA/FF) is the extreme. The same situation can occur to some extent for all fly ash not directly usable as a CCP if no control is employed by the cement plant.

Both the cement industry and the power industry have been slow to recognize and deal with this matter. This is not surprising given their unrealistic expectation that federal rulemaking would have already addressed this situation. Another obstacle is the manner by which new information is considered and is hampered by the legal process in rulemaking, especially once rules have been challenged. Finally, there are inherent difficulties in trying to achieve consensus among members of trade associations.

One of the possible alternatives is anticipation of or pursuant to establishment of Total Maximum Daily Load (TMDL) allocations under Section 303(d) of the Clean Water Act. Under recent EPA guidance to its regional offices (March 2007 from the Office of Wetlands, Oceans, and Watersheds), where a state has in place a comprehensive Hg reduction program it may put its waters impaired by atmospheric Hg mercury within a subcategory of their Section 303(d) list and defer the development of Hg TMDLs. It is probable that several states will find and plug the regulatory holes identified in this article when developing comprehensive Hg reduction programs. This eventuality should be considered when entering long-term CCP contracts. ❖

Disclaimer: References in this article to any commercial product or service are to facilitate understanding and do not imply endorsement by the writer or his employer. The views expressed are those of the writer and do not necessarily represent those of his employer.

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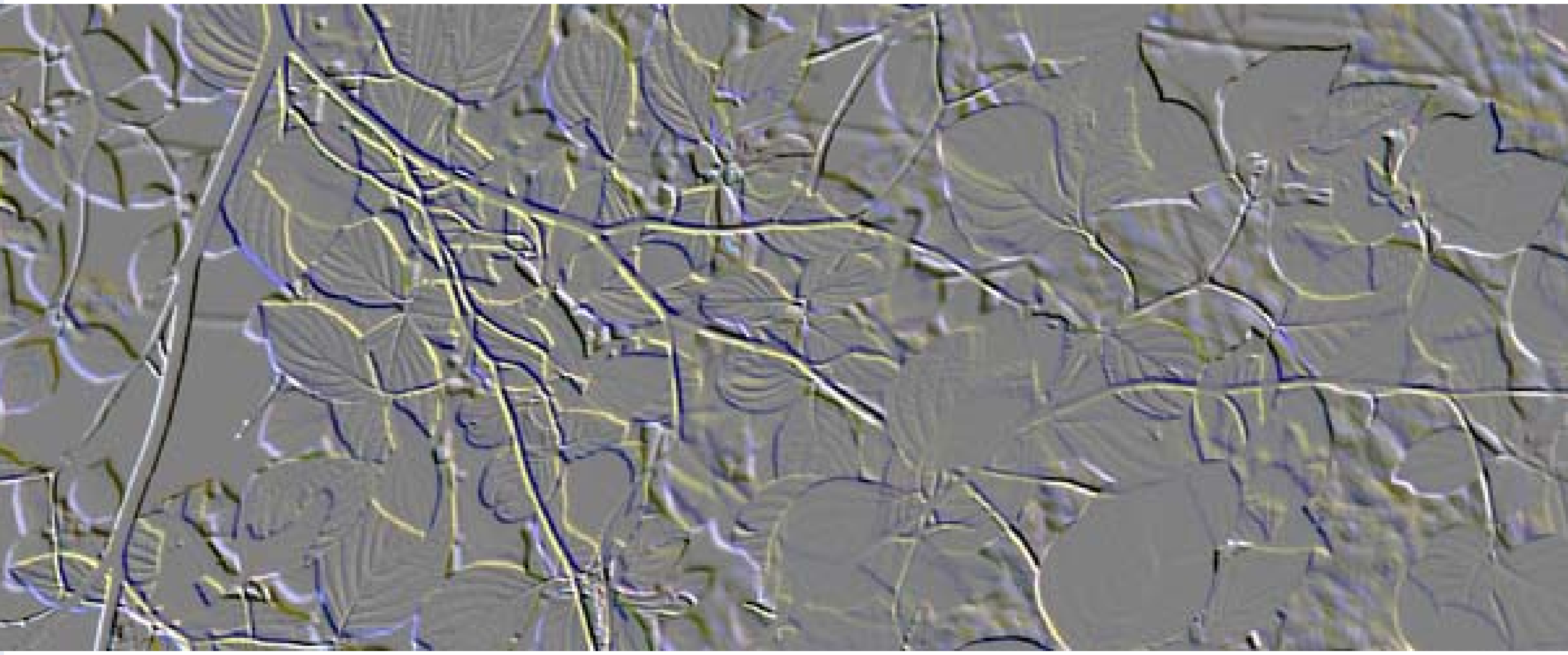


AGRICULTURAL AND INDUSTRIAL USES OF FGD GYPSUM

Workshop explores FGD material applications

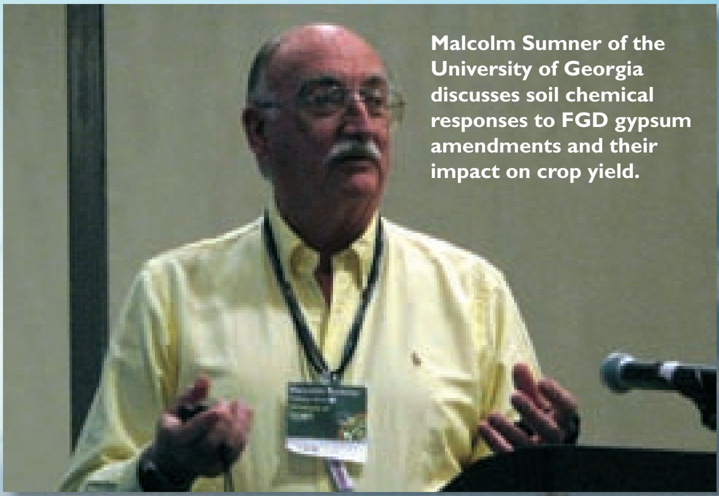
A workshop entitled, "Agricultural and Industrial Uses of FGD Gypsum" was held in Atlanta, Ga., Oct. 23 to 24, 2007. The event was organized by the Electric Power Research Industry and ACAA, in partnership with The Ohio State University, ACAA Educational Foundation, United States Department of Agriculture and Environmental Protection Agency.

FGD gypsum is a powder-like substance derived from forced-oxidation flue gas desulfurization systems, which remove sulfur from coal-fueled power plant emissions with either lime or a liming reagent. The substance is nearly identical chemically to mined natural gypsum.

The workshop began with discussion comparing FGD gypsum with natural gypsum and progressed to specific agricultural applications, as well as addressing gypsum panel products, cement uses and various FGD systems. Case studies from several regions throughout the United States were presented by a variety of well-known experts representing the USDA, EPA, university community, the FGD gypsum industry and agri-business. The event also addressed such topics as the impact of trace elements, mercury, land applications, crop yields and ongoing research. ❖

To access presentations, please visit ACAA's Web site: http://www.FGDProducts.org

Peter Gravatt discusses the EPA's role in promoting safe, beneficial uses of FGD gypsum in agriculture.



Malcolm Sumner of the University of Georgia discusses soil chemical responses to FGD gypsum amendments and their impact on crop yield.

Guests learn about various uses for FDG gypsum industry from experts throughout the United States.

Our fly ash solution isn't just

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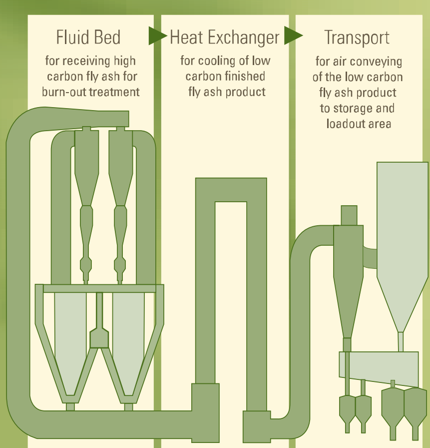

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Michael Van Sickel
General Manager, Branscome Concrete, Inc.

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NEW ACAA TASK TEAM **TACKLES THE ISSUES**

Emerging role for coal combustion products in addressing global climate change

By John N. Ward, Headwaters Incorporated

A recent online poll conducted by the Portland Cement Association asked the question: "In the 100 years since the Chicago Cubs last won the World Series, what are the greatest innovations in concrete?" Almost half of the respondents chose "Use of byproducts (supplementary cementing materials)" — beating out other innovations such as air entrained concrete, high strength concrete and self-consolidating concrete.

It's true that the steadily increasing use of recovered materials like coal combustion products or "CCPs" constitutes a revolution in construction technology. Concrete made with coal fly ash, for instance, can be stronger and more durable than concrete made with cement alone. But in a world that is increasingly focused on environmental issues, the role for CCPs is expanding again.

In October 2007, former vice president Al Gore received the Nobel Peace Prize for his role in bringing the issue of climate change to the top of the political agenda in the United States and internationally. According to the Pew Center on Global Climate Change, at least 36 states have begun or completed climate action plans, and five regional initiatives on climate change are under way. Congress is also beginning to move forward more aggressively toward the creation of a national regulatory program for reducing greenhouse gas emissions.

One likely feature of a national regulatory program may be a cap and trade system for greenhouse gas emissions. Under a cap and trade system, the government sets an overall limit on emissions, but allows companies that can easily reduce emissions to sell credits to other companies for which reductions would be more difficult. This flexible system encourages markets to find the most cost effective ways to reduce emissions. Cap and trade systems have worked well in the United States for reducing emissions of pollutants such as sulfur dioxide and nitrogen oxide.

Coal combustion product utilization could make a significant difference in helping the United States accomplish reductions of greenhouse gas emissions. The reductions could come in a couple of ways.

First, it is well known that use of coal fly ash in concrete can displace emissions of carbon dioxide from cement manufacturing. Generally speaking, a ton of fly ash can be used to replace a ton of cement in making concrete. By eliminating the need to manufacture that ton of cement, a ton of carbon dioxide emissions is avoided. Last year the United States used about 15 million tons of fly ash for that purpose. That's like eliminating the carbon dioxide emissions of 2.5 million cars for the entire year.

Another opportunity using CCPs is in the agricultural sector. For instance, FGD gypsum from power plant SO2 scrubbers can be used as a soil amendment to enable no-till farming – another key greenhouse gas reduction strategy.

Acceptance of these strategies by regulatory authorities is not assured, however. If a cap and trade system is enacted, the projects seeking to participate in that system will need to meet strict standards for scientific justification, project documentation, third party monitoring and verification, and other considerations.

To prepare for this potential opportunity, the ACAA Government Relations Committee has formed a Greenhouse Gas Emissions Trading Task Team. The ultimate goal of this team is to prepare the CCP industry for the emergence of greenhouse gas regulations in the United States. If the industry is properly prepared, those regulations could provide a tremendous boost to increasing utilization of an under-utilized resource. And more aggressive utilization of this resource could go a long way in helping the United States achieve its climate change goals.

When the Cubs finally do win another World Series – you pick the time frame – let's hope that CCPs are recognized not only as a great innovation in concrete technology, but also as a major contributor in addressing climate change. ❖

John N. Ward is a vice president with Headwaters Incorporated and serves as chair on the ACAA Government Relations Committee.

(Participation in the ACAA Greenhouse Gas Emissions Trading Task Team is open to all ACAA members. For more information contact John Ward at jward@headwaters.com or Dave Goss at dcgoss@acaa-usa.org)

WORLD OF COAL ASH ANNOUNCES RECIPIENT OF THE **BARTON A. THOMAS MEMORIAL AWARD**

M. Roderick Jones: WOCA 2007 winner of the Barton A. Thomas Award for outstanding presentation.

The Barton A. Thomas Memorial Award honors the memory of Barton A. Thomas, an innovative and pioneering leader in the field of coal combustion byproduct utilization. It is presented after the conference to the person whose oral presentation is chosen by a panel of judges to be the most outstanding of the conference. The award is made possible by Virginia Thomas and is sponsored by the University of Kentucky Center for Applied Energy Research.

The 2007 recipient is M. Roderick Jones, Division of Civil Engineering, Concrete Technology Unit, University of Dundee, Dundee, Scotland. His presentation was entitled "Utilising Class F Fly Ash to Offset Non-ideal Aggregate Characteristics for Concrete in Chloride Environments." It was given on May 5, 2007, in the Cement and Concrete I session.

More than 500 professionals from around the world attended World of Coal Ash 2007. Topics covered FGD gypsum, technologies and research mitigating high carbon fly ash, fly ash concrete chemistry (ASTM C 618), mining applications, aggregates, impacts of fuel blending and much more. The next WOCA will be held May 4 to 7, 2009 in Lexington, Ky. For details, please visit http://www.worldofcoalash.org ❖

RMRC UPDATE

By Jeffrey Melton, Recycled Materials Resource Center

The Recycled Materials Resource Center serves as a partner laboratory for the Federal Highway Administration helping to promote recycled materials in construction. These materials include reclaimed pavements, secondary-use materials, byproduct materials, and construction and demolition debris.

The partnership's goal is to provide a cohesive approach to the complex materials and environmental issues surrounding the use of recycled materials, with a particular focus on their physical and environmental performance. The RMRC also serves as a principal outreach agency and evaluates information for FHWA.

The center was initially established in September 1998 and then renewed in June 2007 for an additional four years. Over the past nine years the RMRC evolved into a collaborative effort between the University of New Hampshire and the University of Wisconsin-Madison, drawing on the expertise of both institutions.

Early on, the RMRC tackled barriers to greater use of coal combustion products in high volume applications. While high-quality fly ash is often used as a substitute for all or part of portland cement concrete, there are significant volumes of "non-spec" CCPs that could be used for soil stabilization or as fill material. In general, the engineering properties of CCPs are fairly well understood and pose no significant technical challenges for use in high-volume applications. There seems to be, however, a widespread misperception among potential users that the environmental properties of CCPs are not that well understood, and that construction with CCPs would require expensive environmental controls such as liners. This belief would prevent CCPs from being cost effective. The RMRC works to address these perceptions through research and outreach.

One RMRC project of particular interest is entitled, "Project 32: Monitoring and Analysis of Leaching from Subbases Constructed with Industrial Byproducts." Five test sections were constructed along a stretch of Wisconsin STH 60 near Lodi, Wis. Four of the test sections were constructed with a layer of industrial byproducts (foundry sand, foundry slag, bottom ash, or fly-ash-stabilized soil) between the existing soft subgrade and the base course layer. One of the test sections was a control constructed with a layer of crushed dolostone instead of industrial byproducts.

Leachate draining from the test sections was collected in pan lysimeters and analyzed for concentrations of cadmium, chromium, selenium and silver. The leachate commonly had cadmium, selenium and silver concentrations exceeding Wisconsin groundwater quality standards. Application of dilution factors to account for the reduction in concentration expected between the bottom of the pavement structure and the groundwater table, showed that concentrations exceeding groundwater quality standards would not occur if the byproducts layer is at least 16 feet above the groundwater table. For a separation distance of 3 feet, only cadmium would modestly (30 percent) exceed the groundwater quality standard directly beneath the centerline of the pavement. Curiously, a rise in selenium concentration was observed in all of the field lysimeters (including the control pavement section) towards the end of the project. The presence of elevated selenium concentrations in all lysimeters (and at similar concentration) suggests that selenium is leaching from another source within the pavement structure, and not the byproducts. One potential source is the crushed rock or recycled asphalt in the base course layer. This observation illustrates that leaching from pavement structures is not limited to byproducts layers, and that other potential sources of contaminants should be considered when evaluating impacts to groundwater attributed to the use of industrial byproducts in highway construction.

A test site in New Hampshire has been constructed to evaluate the environmental impact of using fly ash in a structural fill.

A new research project being conducted by the RMRC is monitoring leachate from a soil berm with a fly ash core. The core consists of 56 yds^3 of fly ash from Schiller Station in New Hampshire placed in a 50- by 10- by 3-foot layer at a 5-foot depth within an existing soil berm. The core was covered with 2 feet of soil.

The environmental properties of the core are being monitored with a number of instruments placed at the bottom of the ash. Time domain reflectometry sensors are being used to monitor soil moisture throughout the ash core and at 1-foot intervals below the core. Leachate from the berm is being collected by two systems. The first is a series of suction lysimeters located below the ash core at 1-foot intervals, starting at 1 foot and ranging down to -3 feet. Leachate is also being collected directly by a geo-membrane mat located at the bottom of the core that diverts water to a PVC irrigation pipe and into a collection bin off to the side of the core. The leachate and soil moisture data are being collected monthly throughout the year, except in winter when the frost depth will exceed the depth of the core.

Fly ash is placed above a geo-membrane mat in the test site. A collection system and lysimeters are used to determine composition of leachate in the berm.

With funding from the EPA's Office of Solid Waste the RMRC is updating the CCP section of the 1998 "User Guidelines for Waste and Byproduct Materials in Pavement Construction." The guidelines provide information about using recycled materials in different applications related to pavement construction. Reference materials more than 10 years old are being updated by new research published since the mid-1990s. Special attention is being paid to updating the environmental data available about CCPs. When released in early 2008, the updated guidelines will provide much more timely information about using CCPs in high volume applications.

For more information about the research and outreach efforts being conducted by the RMRC, please visit:
http//www.recycledmaterials.org/ ❖

EPA SEEKS OUTSTANDING ACHIEVEMENTS IN CCP USE

The Coal Combustion Products Partnership (C2P2) is calling for entries in its biannual awards program, sponsored by the EPA and others. Partners (C2P2 members) are recognized for their outstanding achievements in the beneficial use of coal combustion products.

To be eligible, organizations must meet the following requirements:

- C2P2 Member (details follow).
- Possess no significant environmental compliance problems.
- Submit awards application and supplemental information no later than **Feb. 15, 2008.**

Partners should submit their nomination with supporting materials in no more than 10 pages. Please note that attachments and supporting materials will not be returned. While not required, providing an executive summary and photographs will be helpful in preparing promotional materials featuring award winners. Entrants must also complete a form, available at: http://www.epa.gov/epaoswer/osw/conserve/c2p2/pubs/07awardsv2.pdf

Entries should specify one of the following award categories:

- **Innovation** – including new uses of CCPs, a conversion of a test or demonstration process/project using CCPs to a full-scale process/product, or any other innovative activity.
- **Enhanced CCP Utilization** – including significant increases in the beneficial use of CCPs or the conversion of an existing use into a higher-value application.
- **Communication/Outreach** – including projects that demonstrate outreach activities to new audiences or significantly impact an existing use into a higher-value application.
- **Partnership** – including activities that bring groups together to promote or increase the use or acceptance of CCPs.
- **Environmental Achievement** – based on a demonstration of environmental benefits through reducing greenhouse gases, conserving of natural resources, and/or reducing landfilling related to use of CCPs.
- **Research** – including research into the use and properties of CCPs.

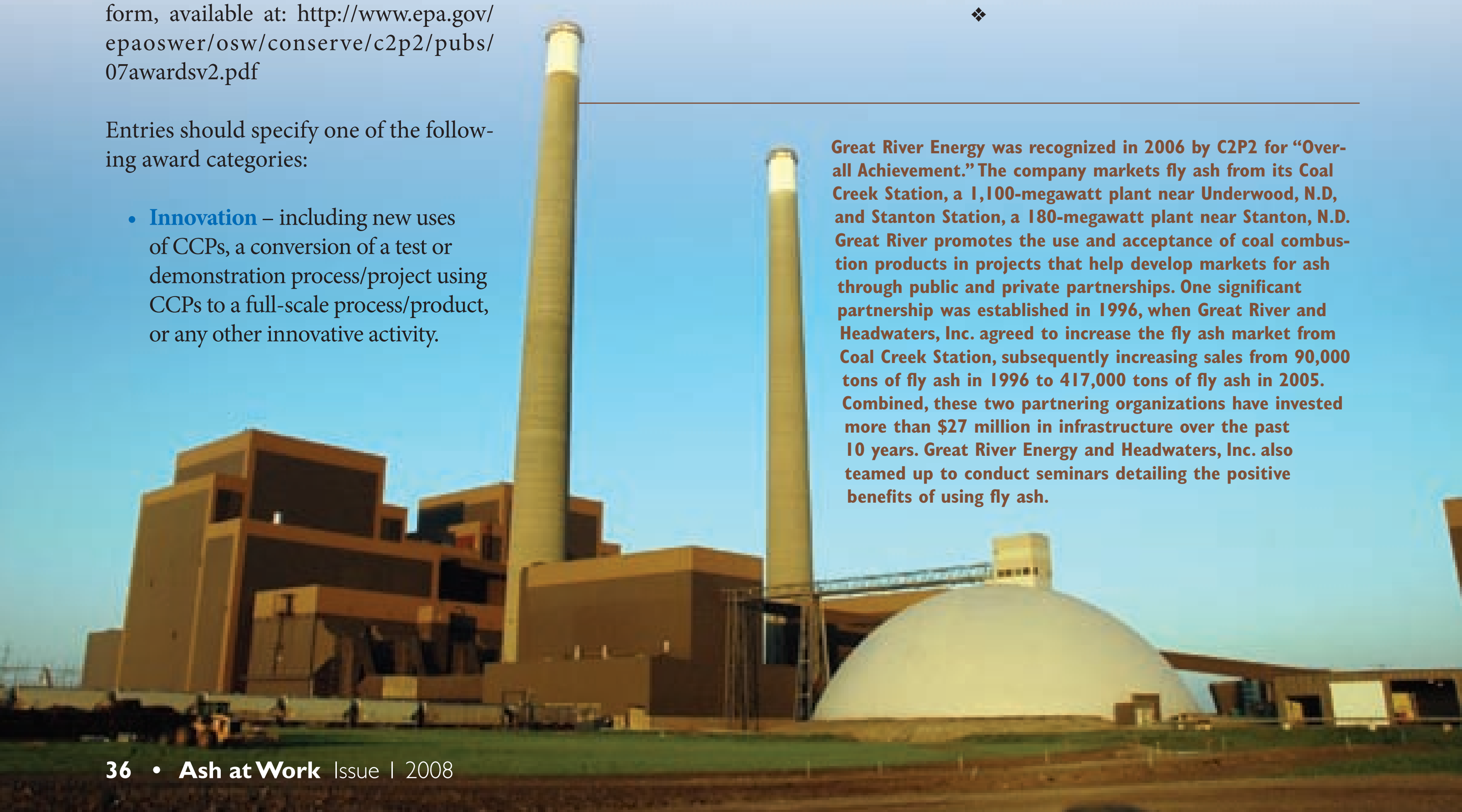
The awards ceremony will take place during the ACAA's 40th anniversary meeting in Washington, D.C., July 2008. In addition to recognition during the event, winners will be featured on EPA's and ACAA's Web sites and announced in an EPA news release.

To join C2P2, go to the EPA Web site: http://www.epa.gov/epaoswer/osw/conserve/c2p2/join.htm

There is no cost involved, but simply a commitment to support the use of CCPs. To view past winners please visit: http://www.epa.gov/c2p2/awards2.htm

Please send award entries and contact information to:
C2P2 Awards Program
c/o ACAA
15200 E. Girard Ave., Suite 3050
Aurora, CO 80014-3955

If you have any questions or require any assistance, please contact John Sager at EPA at 703-308-7256; sager.john@epa.gov ❖



Great River Energy was recognized in 2006 by C2P2 for "Overall Achievement." The company markets fly ash from its Coal Creek Station, a 1,100-megawatt plant near Underwood, N.D, and Stanton Station, a 180-megawatt plant near Stanton, N.D. Great River promotes the use and acceptance of coal combustion products in projects that help develop markets for ash through public and private partnerships. One significant partnership was established in 1996, when Great River and Headwaters, Inc. agreed to increase the fly ash market from Coal Creek Station, subsequently increasing sales from 90,000 tons of fly ash in 1996 to 417,000 tons of fly ash in 2005. Combined, these two partnering organizations have invested more than $27 million in infrastructure over the past 10 years. Great River Energy and Headwaters, Inc. also teamed up to conduct seminars detailing the positive benefits of using fly ash.

COAL FLY ASH:
THE MOST POWERFUL TOOL FOR SUSTAINABILITY OF THE CONCRETE INDUSTRY

By P.K. Mehta, Civil and Environmental Engineering, University of California, Berkeley

Editor's Note:
ACAA thanks Dr. Mehta for this excellent perspective on the sustainable nature of fly ash. Given space constraints we regret we have abridged his paper, however, the complete version is available with details on CO2 emissions, cement production, HVFA construction, and accompanying tables and photos. Please be sure to read the full article at:
http//www.acaa-usa.org/ASHatWork.htm

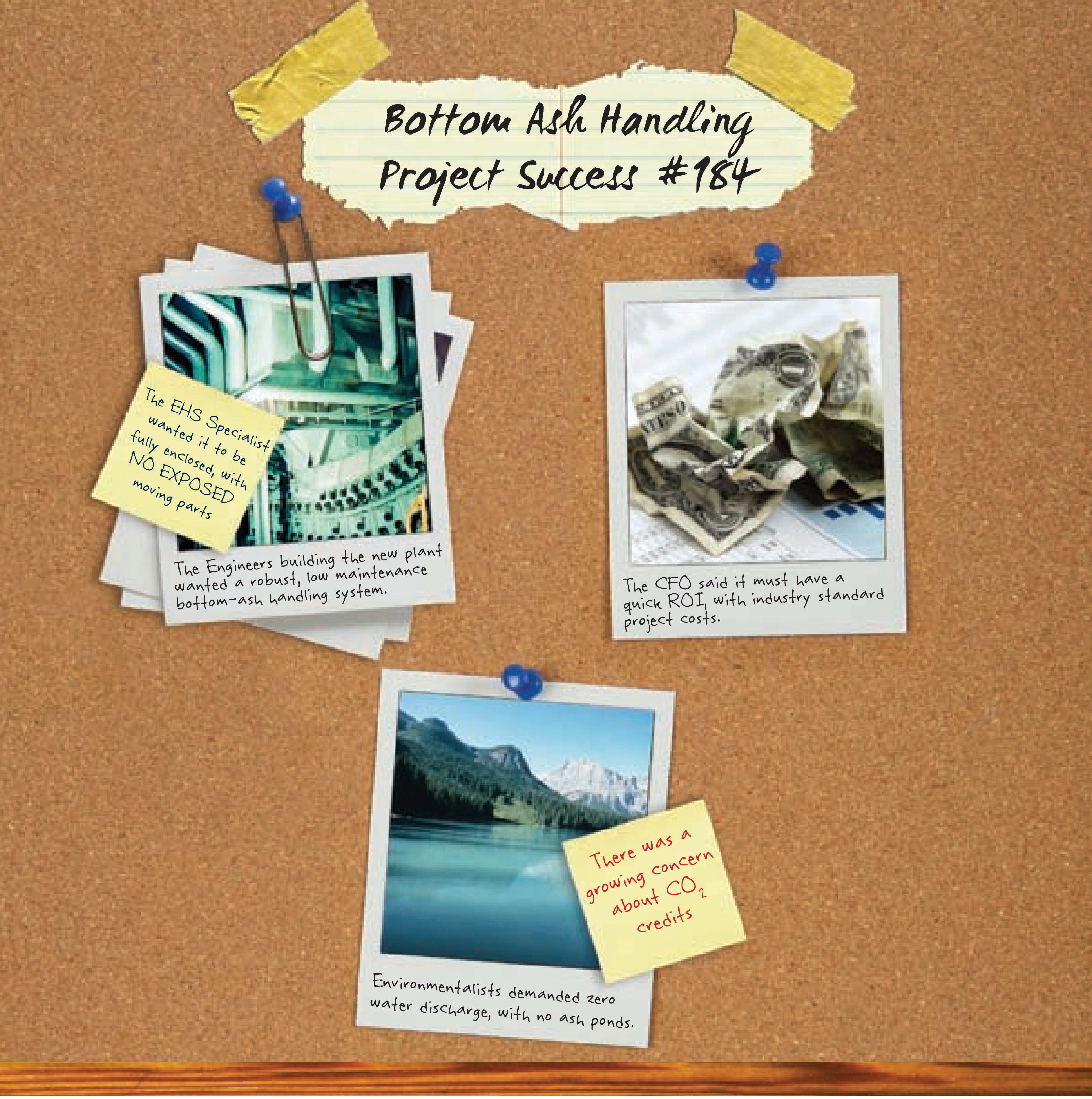
INTRODUCTION

Burning fossil fuels to meet the energy and transportation needs of the world is the largest source of CO2 emissions. Significant amounts are also released during the manufacture of building materials, such as cements, clay bricks and steel. Although climate change is a global phenomenon, it has to be tackled by every country individually, and within their respective economies. Both for the short and long term, fly ash is highly effective in reducing the carbon footprints associated with the use of portland cement clinker – the principle ingredient of modern cements.

CARBON DIOXIDE EMISSIONS FROM CEMENT KILNS

The subject of environmental impact of the cement industry is covered by numerous publications referenced in the full article. Typically, ordinary portland cement is composed of 95 percent clinker and 5 percent gypsum. Pozzolanic additives like coal fly ash, when used as cement replacement materials, considerably enhance the performance of portland cement concrete mixtures, and are emerging as an important player in sustainable development. Therefore, instead of being referred to as *supplementary cementing materials* (SCM), it is

Heavily reinforced columns under construction CITRIS Building, University of California, 2007



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more appropriate to refer to them as *complementary cementing materials* (CCM).

According to Cembureau, global cement consumption in 2005 was 2,502 million tons. Due to a gradual increase in the use of CCM, it is reported that the average clinker factor was down to 0.84. Also, in 2005, due to an increase in the use of alternate, low-carbon fuels for burning clinker, the average CO2 emissions rate dropped to .99 ton per ton of clinker. This means that in 2005, 2,094 million tons of clinker was produced, with 1,873 million tons of direct CO2 released to the environment. In conclusion, during the last 15 years the global cement industry has almost doubled its annual rate of direct CO2 emissions.

REDUCING THE CO2 EMISSIONS – THE CHALLENGE

In the portland clinker manufacturing process, direct release of CO2 occurs from two sources, namely the decomposition of calcium carbonate (the principal raw material) and the combustion of fossil fuels. There are some cements that do not require calcium carbonate as a raw material (e.g., magnesium phosphate cements), but they are neither economical nor technically feasible for large-scale production. The annual rate of cement consumption in the world has nearly doubled during the last 15 years. At the current rate of economic growth in developing countries, the cement requirement in the next 15 years is expected to go up to about 4,253 million tons a year.

TOOLS FOR REDUCING THE CO2 EMISSIONS

If over-consumption of energy and materials is the root cause of the sustainability crisis, then a sure remedy for successful resolution of the problem lies in the golden rule, "*Consume less.*" There are three ways the cement industry can reduce the direct CO2 emission attributable to clinker production:

Reduce the consumption of concrete: Architects and structural designers must develop innovative designs that minimize the consumption of concrete. New housing developments should give preference to smaller homes which require less construction materials of construction. Service life of repairable structures should be extended as far as possible by the use of proper materials and methods of repair. Foundations, massive columns and beams of concrete and pre-cast building components that can be assembled or dis-assembled as needed, should be made with highly durable concrete mixtures such as described in this paper.

Reduce the cement paste volume in concrete mixtures: Mix design procedures that involve prescriptive codes lead to considerable waste of cement, besides adversely affecting the durability of concrete. Such prescriptive codes have outlived their usefulness and must be replaced with performance-based specifications that promote durability and sustainability. For example, as discussed below, the enhancement of the durability of concrete does not only depend on the w/cm, but also on the cement paste content.

The water content should be minimized through optimum aggregate grading and the use of plasticizing admixtures and fly ash. The cement content can be reduced by specifying 56- or 91-day strength for those structural components that do not require a minimum 28-day strength.

Reduce the clinker factor of cement: Every ton of portland clinker saved through the use of CCMs would reduce the direct CO_2 release from cement kilns by an equal amount. Concrete products made with cements of low clinker factor would be much more durable than ordinary portland cement products.

STRATEGIES FOR SUSTAINABILITY

In the next 15 to 20 years, we should bring down the clinker factor of cement to 0.5 or less by using one or more CCM(s). Abundant supplies of fly ash are available and if it were possible to enhance the durability of cement-based products by a factor of three or more, this would be an excellent strategy for minimizing the wasteful consumption of cement and other concrete ingredients. According to one estimate, approximately 1,323 million tons of fly ash will be generated in 2020. It would indeed be a challenging task to make sure that nearly two-thirds of the fly ash produced by coal-fired power plants is used as a CCM. This could be accomplished if the producers of fly ash, the manufacturers and the consumers of cement and concrete, and individuals or organizations responsible for specifications, work together to overcome the problems described below.

In spite of proven technical, economic and ecological benefits from the incorporation of high volumes of fly ash in cements and concrete mixtures, the fly ash utilization rate remains low. Obsolete prescriptive codes, lack of state-of-the-art information to architects and structural designers, and lax quality control in power plants are among some of the reasons. Also, not all of the currently produced fly ash is suitable for use as a CCM.

The author believes that codes and guidelines of recommended practice advocated by organizations such as ACI and USGBC, can play an important part in accelerating the sustainability of the concrete industry. The USGBC point-rating system (LEED) for new buildings has already become a powerful driving force for sustainable designs. A driving force is needed to accelerate sustainability of the global cement and concrete industries. The USGBC and other organizations can advocate rating the structural materials on the basis of CO_2 emissions associated with their production.

SUSTAINABLE CEMENTS AND CONCRETE MIXTURES

Sustainable portland clinker based cements can be made with 0.5 or even lower clinker factor using a high volume of granulated blast furnace slag (gbfs), or coal fly ash (ASTM Class F or C), or a combination of both. Cements containing a high-volume of CCMs can now be manufactured in accordance with ASTM C 1157 – a performance based standard for hydraulic cements.

For reducing direct carbon emissions attributable to clinker production, high volume fly ash (HVFA) concrete is an excellent example showing how highly durable and sustainable concrete mixtures, with clinker factor of 0.5 or less, can be produced by using ordinary coal fly ash. HVFA concrete is composed of ordinary portland cement together with at least 50 percent fly ash by mass of the total cementing material. The mix has a low water content (169-219 lbs/ft^3), and a low content of cementing materials (e.g., 506 lbs/ft^3 for ordinary strength and max. 674 lbs/ft^3 for high strength).

The BAPS Hindu Temple, Chicago, 2004. High-volume fly ash was used for monolith foundations and drilled piers

Compared to portland cement concrete, the HVFA mixtures can be designed to achieve the same 28-day strength and exhibit superior workability without segregating. HVFA concrete can be designed to be highly resistant to alkali-aggregate reaction, sulfate attacks, and reinforcement corrosion. Furthermore, the HVFA concrete mixtures are less vulnerable to cracking from both the thermal shrinkage and the drying shrinkage. The ability of HVFA concrete to enhance the durability by factor of 5 to 10 makes it a highly suitable construction material. Some recently built structures in North America, such as the Hindu Temples in North America, the Utah Capitol Building and the CITRIS Building at the University of California at Berkeley have achieved large reductions in CO2 emissions resulting from the use of HVFA concrete.

CONCLUDING REMARKS

With business-as-usual, the direct CO2 emission from portland clinker production in the year 2020, would be triple the 1990 level unless immediate steps are taken to bring it down by making significant reductions in: (a) global concrete consumption, (b) volume of cement paste in concrete mixtures, and (c) proportion of portland clinker in cement.

Examples of recently built structures prove that by using high volumes of coal fly ash can produce low cost, highly durable, and sustainable cements and concrete mixtures that would significantly reduce both the carbon footprints of the cement industry and the environmental impact of the coal-fired power generation industry. Now, all segments of the construction industry – owners, designers, contractors, cement and concrete producers – should join hands to win the new game of building sustainable structures *using only sustainable materials*. ❖

P.K. Mehta is a professor emeritus of civil and environmental engineering, University of California, Berkeley, Calif.

EPRI'S COAL COMBUSTION PRODUCT USE RESEARCH

By Ken Ladwig, Electric Power Research Institute (EPRI)

Outdoor concrete-block test facility for alkali-silica reactions (ASR) expansion.

For more than 20 years, EPRI's Coal Combustion Product Use Program has been a leader in providing research to demonstrate the value of using coal combustion products (CCPs) in construction and manufacturing. Work is concentrated on large-volume uses, increasing use in traditional applications, and developing new markets. Recent research has also focused on protecting established uses in light of changes in CCP quality resulting from increased and new air emissions controls for nitrogen oxides (NOx), sulfur oxides (SOx), and mercury.

Currently, EPRI is investigating opportunities for using higher volumes of Class C ash in concrete; approaches for ensuring that mercury controls do not adversely af ect the use of CCPs; agricultural uses for products from flue gas desulfurization (FGD); possible markets for spray dryer absorber byproducts; and issues involved with the presence of ammonia in ash. Some recent results and future work are described on the following pages.

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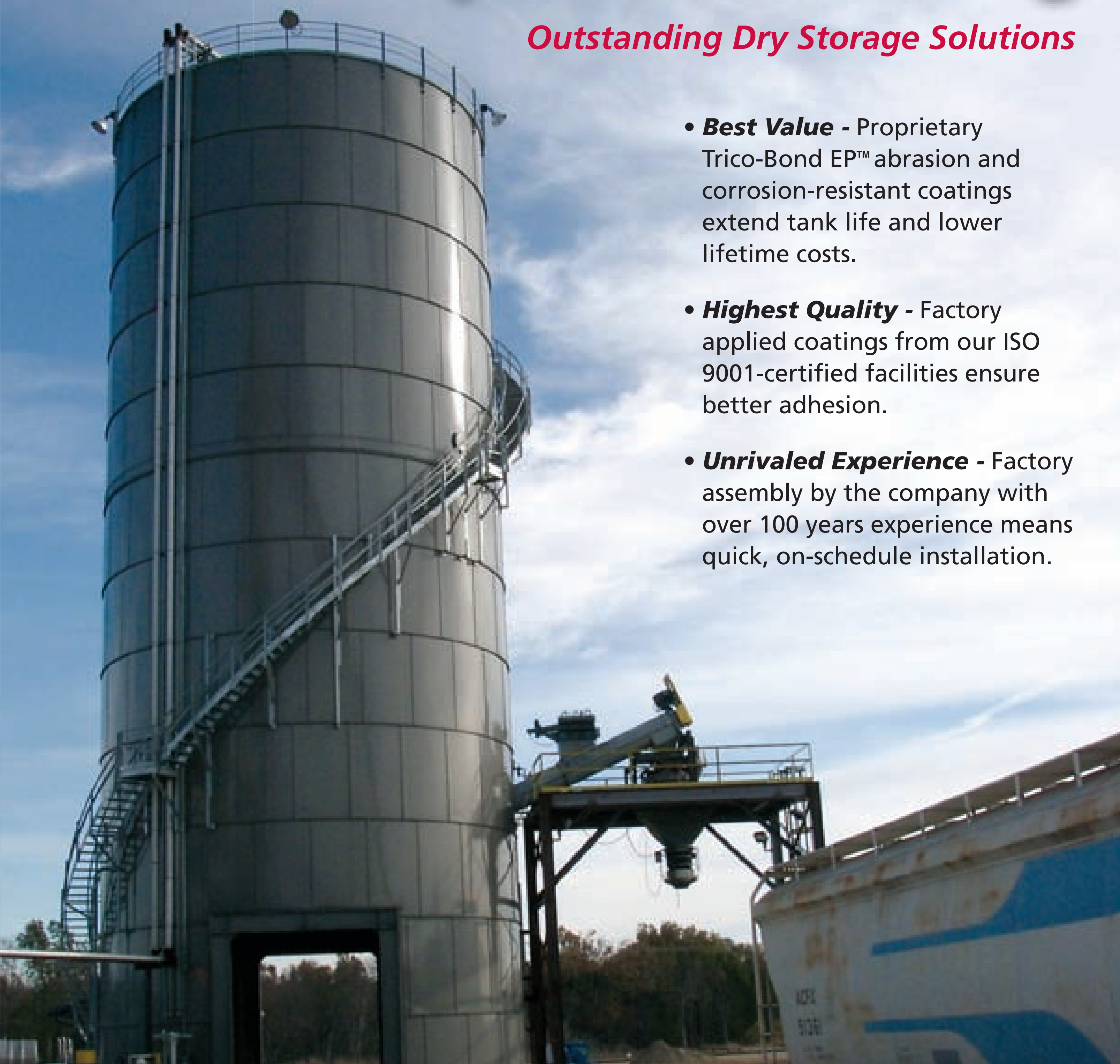

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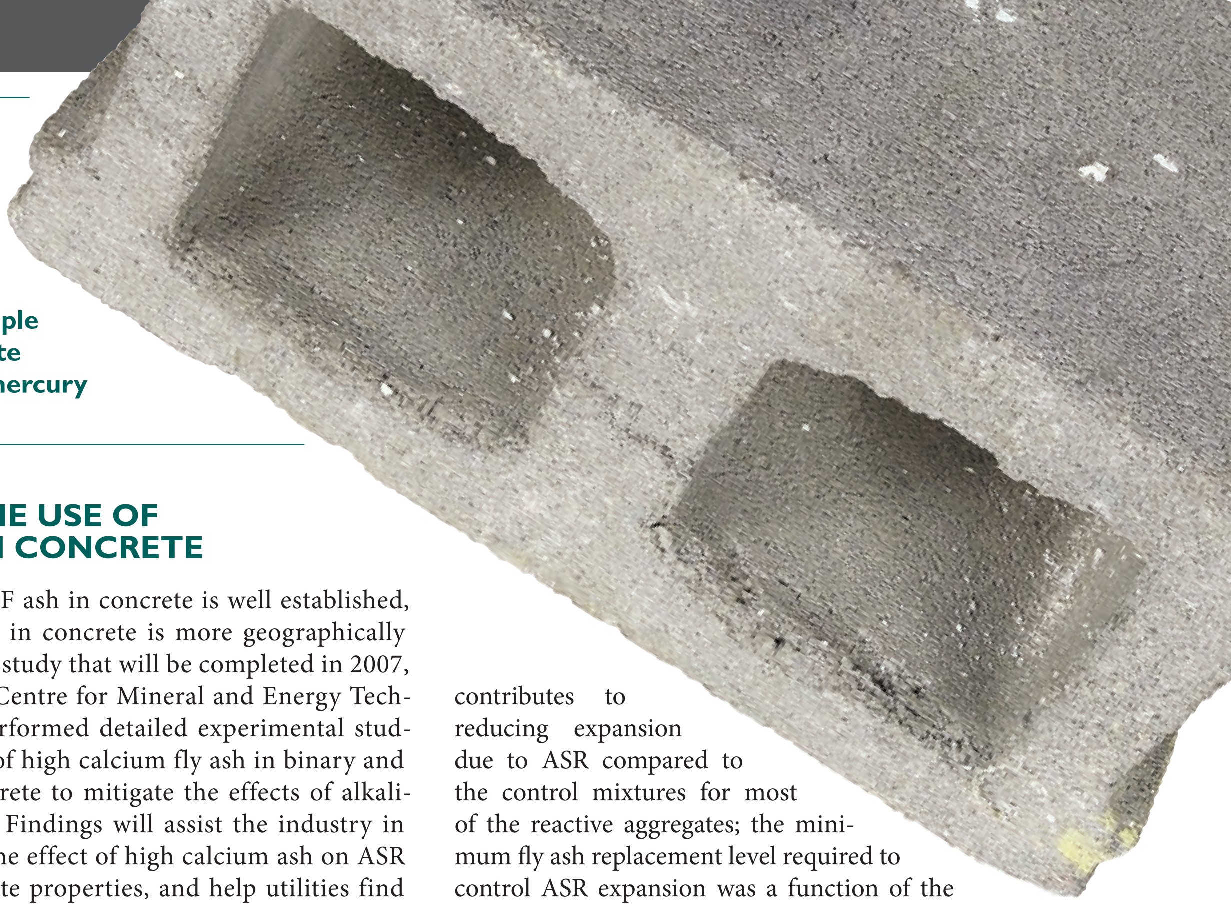

The concrete with fly ash and fly ash containing power activated carbon leached lower amounts of mercury than the control sample with no fly ash, despite having higher total mercury concentrations.

INCREASING THE USE OF CLASS C ASH IN CONCRETE

While the use of Class F ash in concrete is well established, the use of Class C ash in concrete is more geographically limited. In a long-term study that will be completed in 2007, EPRI and the Canada Centre for Mineral and Energy Technology (CANMET) performed detailed experimental studies to advance the use of high calcium fly ash in binary and ternary blends of concrete to mitigate the effects of alkali-silica reactions (ASR). Findings will assist the industry in better understanding the effect of high calcium ash on ASR as well as other concrete properties, and help utilities find cost-effective ways of using Class C fly ash in a broader range of applications. The test matrix included six fly ashes with varying levels of calcium oxide and alkalinity, seven reactive aggregates, and two non-reactive aggregates. Results to date show that the use of high calcium (>15 percent) fly ash contributes to reducing expansion due to ASR compared to the control mixtures for most of the reactive aggregates; the minimum fly ash replacement level required to control ASR expansion was a function of the composition of the ash as well as the reactivity level of the aggregates, varying from 25 percent to 60 percent. Ternary blends that included a small percentage of silica fume significantly decreased the minimum amount of Class C fly ash needed to control ASR.

The fly ash replacement percentages in the ASR study are higher in some cases than specified for typical concrete applications. To support using these higher replacement levels, EPRI recently completed a detailed literature evaluation on the ef ects of Class C fly ash on the performance characteristics of high-volume fly ash (HVFA) concrete. The study also identified data and research needed to increase those applications. The evaluation found that Class C ash has a beneficial ef ect on some HVFA concrete properties (workability, heat of hydration, late-age strength, and delayed formation of ettringite) and disadvantageous ef ects on other properties (bleeding, air entrainment, setting time, and early-age strength). Research priorities identified were to develop performance criteria for quality control, improve early strength gain, evaluate de-icer salt resistance, and mitigate carbonation ef ects. EPRI is currently initiating research on mechanism(s) governing early strength gain, and the impact of de-icer salt, particularly potassium acetate.

MERCURY IN CCPS

Increased removal of mercury from power plant air emissions may result in higher concentrations of mercury in the fly ash and FGD products, depending on the removal technology chosen. This represents a potential threat to the use of fly ash in concrete, and the use of FGD gypsum in wallboard and agriculture.

A series of EPRI studies completed in 2007, using several types of fly ash at 55 percent cement replacement levels and dif erent curing techniques, demonstrated that although minute

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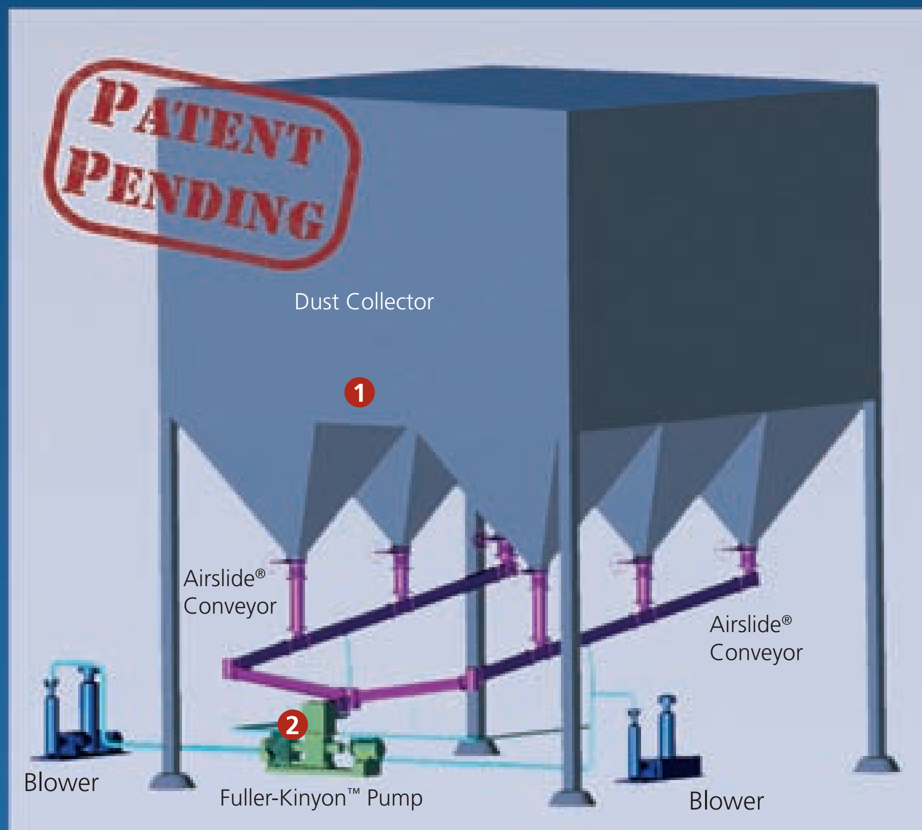

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quantities of mercury are released to air from concretes during the curing process, more than 99.5 percent of the mercury is retained in concrete made with fly ash. These tests included fly ash containing mercury-laden powder activated carbon (PAC), a sorbent used to capture mercury. The concrete cylinders were then broken and tested for leachability of the mercury. The concrete with fly ash and fly ash containing PAC leached lower amounts of mercury than the control sample with no fly ash, despite having higher total mercury concentrations. Less than 5 parts per trillion were leached from the fly ash and fly ash/PAC concretes in both 18-hour and 7-day laboratory leach tests.

Although mercury released from concrete made with fly ash containing PAC should not be a problem, the activated carbon itself may inhibit use in concrete due to increased need for air entrainment additives. EPRI researchers are also evaluating several strategies for using sorbents or chemicals to capture mercury without impacting the use of fly ash. In collaboration with Xcel Energy, Great River Energy, NRG Energy, AEP, and Luminant, EPRI is conducting full-scale studies to compare both the mercury removal performance and impact on ash use of dif erent sorbents and one boiler chemical additive (calcium bromide). In addition, the amount of PAC present in fly ash that can remove significant amounts of mercury (>70 percent) but not impact ash use for concrete applications is being determined. Other EPRI studies are investigating activated carbons that have been pre-treated to minimize/avoid impacting the concrete or the use of ozone to passivate the fly ash/activated carbon mix so it can be used ef ectively in concrete.

Many utilities may rely on the co-benefits of selective catalytic reduction (SCR) in combination with wet FGD systems to capture mercury, possibly increasing the mercury concentrations in FGD gypsum. Ongoing research is evaluating the potential for release of mercury from FGD gypsum used in wallboard and controlling the partitioning of mercury between the solid and liquid phase in the absorber. Additional studies are designed to document the fate and/or the ef ect of mercury when FGD gypsum is used in agricultural applications.

FGD PRODUCTS IN AGRICULTURE

In 2006, EPRI initiated a major research ef ort to demonstrate the agricultural value and uses of products from flue gas desulfurization systems. While the benefits of using both mined and FGD gypsum on agricultural land have long been recognized, only a small fraction of this potentially large market has been realized. The EPRI project represents a coordinated ef ort to obtain data that demonstrates in a rigorous manner the benefits of using FGD products for a broad range of soil and crop types. A national network of test sites will be used to systematically investigate increases in crop productivity and potential for environmental releases associated with using FGD products.

The Ohio State University is the primary research center for the national network. The work is being closely coordinated with the U.S. Department of Agriculture, This photo (right) shows alfalfa prior to harvest during a f eld study in Piketon, Ohio (Pike County). FGD was used as a sulfur nutrition source, increasing the yield 11 percent.

Flowering of canola crop (far right) in Wooster, Ohio (Wayne County). FGD material was applied as a sulfur nutrition source.

U.S. Environmental Protection Agency, and American Coal Ash Association. Test site participants to date include Duke Energy, Great River Energy, Entergy, Public Service of New Mexico, and Tennessee Valley Authority.

USES OF SPRAY DRYER MATERIAL

A new EPRI project is aimed at helping utility plant managers better understand the characteristics of spray dryer absorber (SDA) materials from coal-fired power plants, and potential commercial markets for the material. As a first step, researchers at the Energy and Environmental Research Center (EERC) conducted an extensive literature review and summarized information on SDA material characteristics, production, and use, with particular emphasis on applications suitable for the higher fly ash content of most SDA material produced in the United States. In 2008, EPRI will be performing detailed characterization of chemical and physical properties of SDA materials from a number of dif erent power plants to provide the framework for developing appropriate uses.

EPRI's CCP use research portfolio is diverse and designed to meet the changing needs of the industry. Overall, EPRI research seeks to find and demonstrate new CCP uses, provide the power industry and its CCP marketing/processing partners with data on the performance benefits and environmental acceptability of CCP use, and engage in collaborative research to foster greater opportunities for CCP use. ❖

Ken Ladwig is program manager of EPRI's Coal Combustion Product Use Program, and can be reached at keladwig@epri.com. More information about the program can be found at www.epri.com

UTILIZING FLY ASH PARTICLES TO PRODUCE **LOW-COST METAL MATRIX COMPOSITES**

By Graham Withers, Ultalite.com, Melbourne, Australia

Editor's Note: ACAA has been introduced to Mr. Graham Withers (who owns Ultalite.com) and his colleague Dr. Steve Midson of Denver, Colo. Mr. Withers has been working extensively with the use of fly ash to make metal matrix composites for which he believes there is a potential U.S. market. Based on his work in Australia, we invited him to provide an article to this issue of Ash at Work.

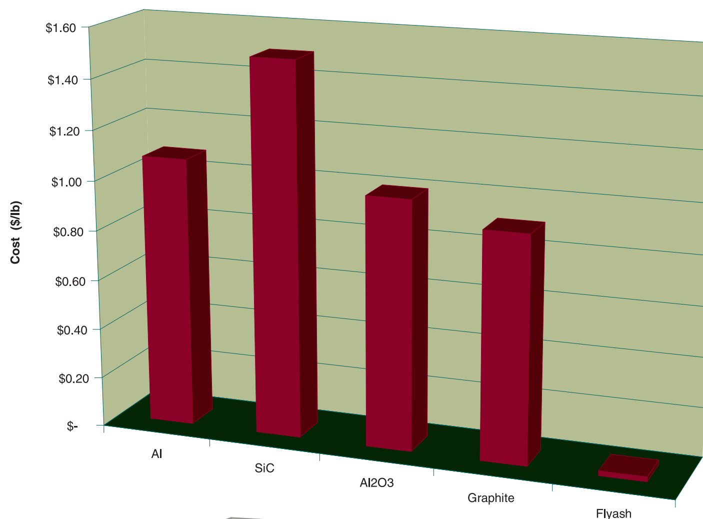


Figure1. **Comparison of costs of materials used to produce metal matrix composites**

WHAT ARE METAL MATRIX COMPOSITES?

Metal matrix composites (MMCs) are a blend of fine ceramic particles mixed together with metals such as aluminum or magnesium. The ceramic particles are normally about 10 to 100 microns in size, and the composites typically consist of 10 percent to 30 percent ceramic particles and 70 to 90 percent aluminum or magnesium alloys. The MMCs retain the lightweight nature of these alloys, but provide a significant improvement in other properties compared to these monolithic lightweight alloys, such as wear resistance and stif ness.

In the past, a number of dif erent types of ceramic particles have been mixed into aluminum to produce composites, including silicon carbide (SiC), aluminum oxide (Al2O3) and graphite. However, as shown in Figure 1, those ceramics are similar in cost or more expensive than aluminum. In contrast, fly ash is significantly cheaper than any of the alternate ceramic particles, and therefore helps to reduce the cost of the MMC.

Figure 2 compares material costs (exclusive of mixing and processing costs) for fly ash composites versus conventional Al-SiC material. Due to the low cost of the fly ash particles, the aluminum-fly ash composite cost drops sharply with increasing reinforcement content, so at 30 percent ceramic content the material cost for the fly-ash composite is less than 60 percent of that for conventional aluminum-SiC composites. This makes fly ash composites attractive to many end-users, but especially to automakers who are continuously striving to reduce both the weight and cost of materials used in cars.

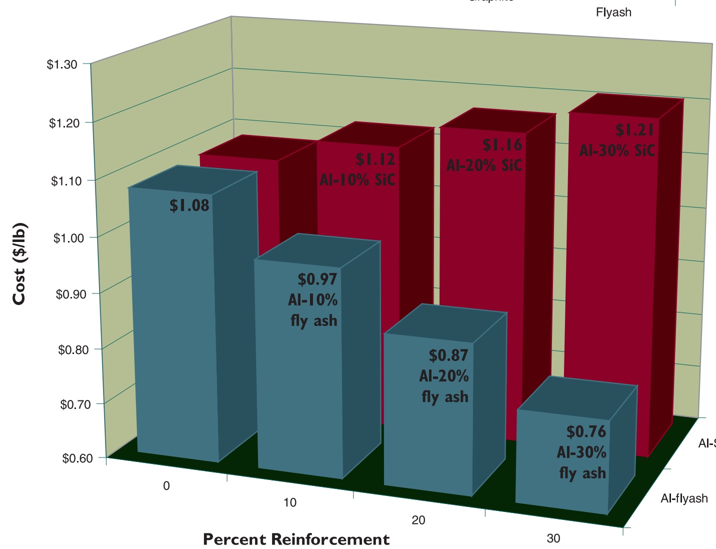
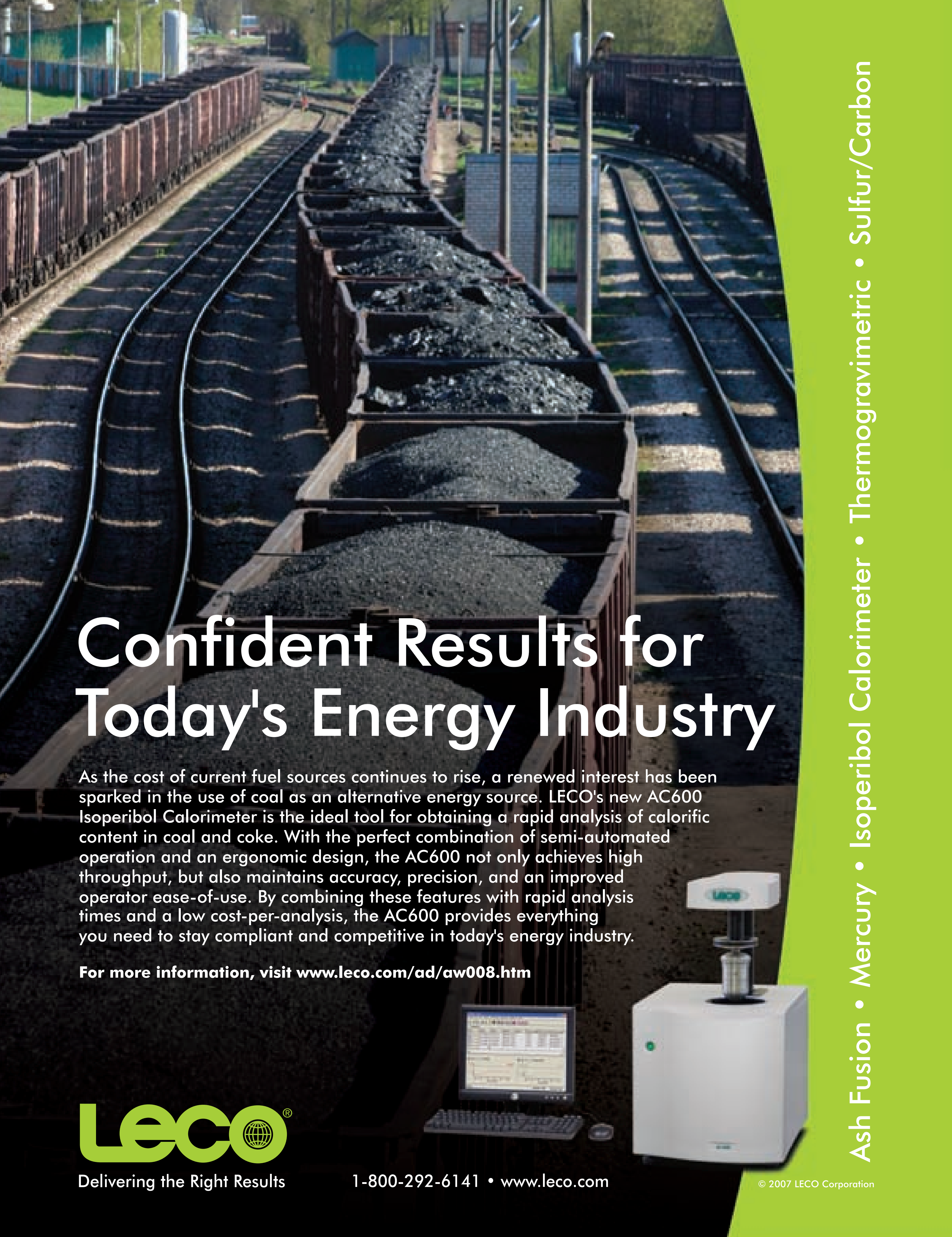


Figure 2. **Comparison of materials costs (exclusive of mixing and processing costs) for composites made using fly ash or silicon carbide**

PRODUCTION OF METAL MATRIX COMPOSITES

There are a number of ways of making MMCs, but by far the cheapest is to stir the ceramic particles into a bath of molten metal. The concept of stirring fly ash particles into molten metal to produce inexpensive composites was first patented by Prof. Bob Pond, Sr. of the Johns Hopkins University. That patent, together with other proprietary technology, is now controlled by Ultalite.com.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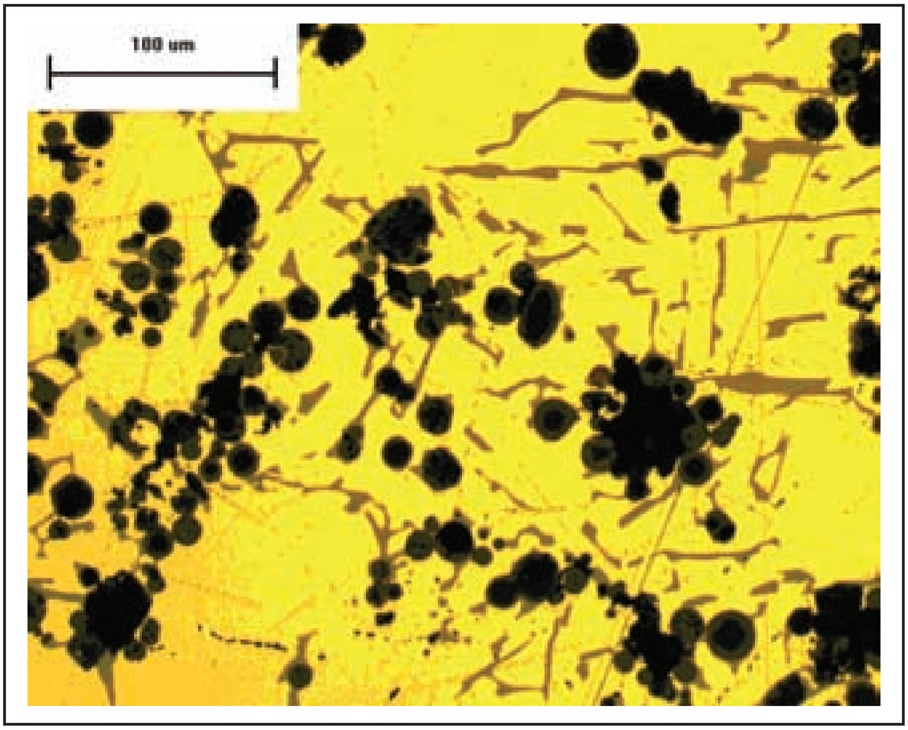

Figure 3. Photomicrograph of the Ultalite composite (the yellow is the aluminum matrix and the black spheres are the fly ash particles)

Although a number of researchers, including a project funded by EPRI, have examined the production of aluminum-fly ash composites, those researchers focused on mixing raw fly ash into the aluminum. Raw fly ash contains a wide range of particle sizes (less than 1 micron to greater than 200 microns), as well as several types of undesirable particles, such as the low density cenospheres, which are difficult to stir into the aluminum as their low density causes them to float.

Our approach has been to focus on the cleaning and classification of raw fly ash particles. A preliminary study was performed by Dr. Tom Robl and co-researchers at the University of Kentucky's Center for Applied Energy Research, which used technology originally developed for the production of high-grade pozzolan for concrete manufacturing. Their study identified classification and froth flotation techniques to extract the spherical, precipitator particles with an average size of about 20 microns from the raw fly ash. Figure 3 shows the microstructure of an aluminum MMC produced using Robl's starting material.

We have been consulting with ACAA members such as Cheri Miller from Gypsum Parameters and Debra Pflughoeft-Hassett from the University of North Dakota's Energy and Environmental Research Center among others to identify the best commercial method of procuring beneficiated fly ash. A list of optimum requirements of the fly ash needed to make MMCs is listed in Table 1.

Table 1: Optimum requirements for beneficiated fly ash particles
Use output from base load power station
Use output from bituminous or possibly lignite coal burning station
The fly ash should have low CaO content
Size fraction – 20 to 40μm
Carbon content – want zero
Cenospheres – want a very low percentage
Moisture content – not important
Density – not important

Once the desired particles have been extracted from the fly ash, they are stirred into the molten aluminum. Proprietary stirring systems have been developed to provide sufficient shear in the melt to produce rapid wetting of the ceramic particles, leading to a uniform distribution of ceramic particles within the melt (see Figure 3). The molten composite is then poured into ingots for shipment to a casting facility where the brake rotors or brake drums are produced.

BRAKING APPLICATIONS

Over the past 10 years or so, metal matrix composites produced using expensive silicon carbide particles have been used in several automotive applications, including brake rotors and drums, pistons, cylinder liners and valves. Normally these types of automotive components are fabricated from high density metals such as cast iron or steel, but metal matrix composites provide significant weight savings (Figure 4). Cars that have utilized low-weight composite brake rotors include the Lotus Elise and the Plymouth Prowler. However, these types of composite components have generally been limited to low volume, specialized applications, due to the high cost of these composite materials.

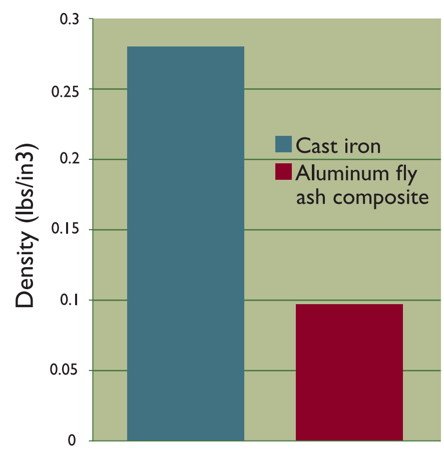

Figure 4. Comparison of density for cast iron and the aluminum fly ash composite

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- U.S. Environmental Protection Agency, Region 3
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Figure 5: Photographs of brake drums squeeze cast from the aluminum-fly ash composite, which provide more than 60 percent weight savings compared to cast iron drums

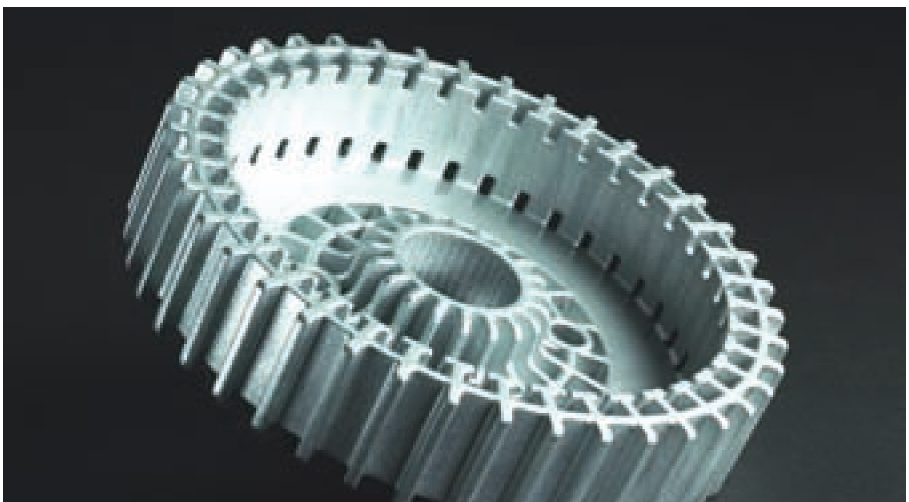

Figure 6: Photograph of a brake drum designed to exploit the properties of the aluminum-fly ash composite

As noted in Figure 2, using fly ash in the composites significantly decreases the cost of the composite material, making aluminum-fly ash composites attractive to a wider automotive market. Figure 5 shows brake drums squeeze cast from Ultalite.com aluminum-fly ash composite material which was developed in Australia (the braking components are being marketed as Ceramatec). These 8-inch diameter drums weigh only 5 pounds, less than half the weight of a conventional cast iron drum, and were produced for Peugeot in Europe. Total potential weight saving for a car using Ceramatec braking component is 20 pounds or more. The base alloy for the drums shown in Figure 5 is aluminum-7 percent, silicon-2 percent, and magnesium, containing 20 percent fly ash particles.

We have also redesigned brake drums to exploit the properties of the Ultalite composites, and such a drum is shown in Figure 6.

TESTING OF THE COMPOSITE BRAKE DRUMS

Dynamometer testing has been performed on a number of 8-inch diameter composite brake drums and compared to the performance of conventional drums fabricated from cast iron. The dynamometer testing was performed at Brake Testing International (BTI), which is located in Hinckley, England, and it followed procedures laid out in SAE specifications. Testing of the aluminum-fly ash composite drums showed the following favorable features:

- The aluminum-fly ash composite brake drums demonstrated a significantly higher brake factor, being about 33 percent better than cast iron drums.
- The aluminum-fly ash composite brake drums always exceeded cast iron performance during brake fade tests.
- Overall drum wear was similar for the aluminum-fly ash composite and the cast iron drums.
- Wear tests indicated that overall lining wear was actually a little lower when using the aluminum-fly ash composite drums. Excessive lining wear has been a problem in the past with other composites materials, where lining wear has been so high as to require the use of special linings. Testing with the aluminum-fly ash composite brake drums showed that special brake linings are NOT required. This is probably due to the spherical nature of the ceramic reinforcement particles used with the aluminum-fly ash composites. Other MMC materials generally use angular ceramic reinforcement particles that can tear up the linings due to their abrasive nature.

The ongoing development of MMCs may open the door to new opportunities for producers and marketers in the U.S. ❖

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