ISSUE 2 • 2015

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Applications, Science, and Sustainability of Coal Ash

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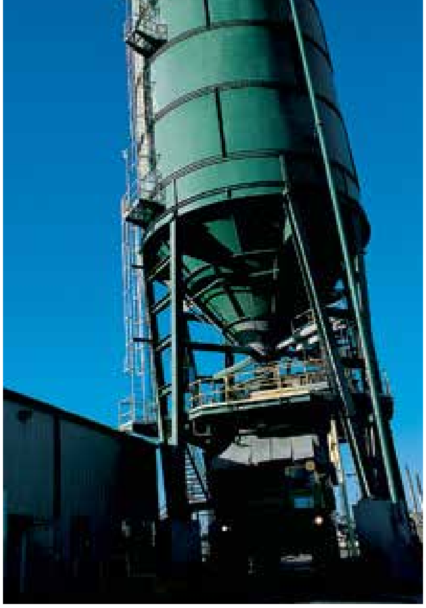

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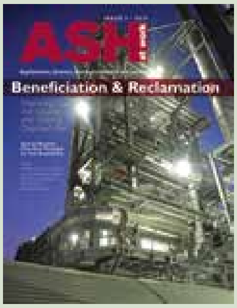

A Staged Turbulent Air Reactor (STAR) system installed by SEFA Group at Santee Cooper's Winyah Generating Station in South Carolina is being used to help reclaim previously disposed coal ash.

FINALLY, A RESPITE FROM PLAYING DEFENSE

By Hollis Walker, ACAA Chair

“The left hand doesn’t know what the right hand is doing.” This idiom is learned early on in life and is usually associated with family members not communicating well. Typically, the consequences associated with poor communication, when we learned this idiom, were not severe. Thus, the “left/right hands” saying is more associated with mundane mistakes, such as each partner thinking the other has a task to perform and the task goes uncompleted. However, the very same communication deficit exists on grand scales that have no proper idiom to describe.

As a young adult entering the workforce, you see this common household problem of ineffective communication exists elsewhere, and many times in a big way. In fact, the larger a company is, the bigger the problem and ramifications of ineffective communication tend to be. Now, expand this concept out to an industry and it’s daunting. Instead of the left hand not knowing what the right hand is doing, it’s more like the Atlantic Ocean doesn’t know that the Pacific Ocean exists, and they’re as far apart as North America is wide. Let’s take an industry near and dear to us in this association: coal combustion products (CCPs). As we begin, let’s recognize that this includes many who identify the industry as CCRs, CCBs, and even CCWs (I refuse to spell these out in large print, so if you don’t know the “R”, “B”, and “W,” they are in very fine print at the end).[*]

On one hand, we have part of the industry scrambling trying to find CCPs that may be in short supply during many weeks of the fall and spring (this phenomenon is starting to be repeatable on a yearly basis). This faction of our industry is growing concerned that ash and gypsum are in dwindling supply and are evaluating how to manage with short, and potentially lessening, supply. On the other hand, we have many in the industry trying to figure out how to build or acquire space in massive landfills that will hold tens of millions of tons of CCPs over the next decade. One faction says, “Quick! Let’s spend hundreds of millions to build landfills because this material has nowhere to go!” At the same time, another faction says, “Ash and gypsum are going away and we need to look at alternate materials!” The truth, as often is the case between opposing opinions, is in the middle; and this middle is miles away from either faction’s understanding. The industry does have too much ash and gypsum right now at most power plants, and the industry does have too little quality ash and gypsum available to the market…so, we do have too much, and we do have too little.

What will change this paradox is a little bit of time. As utilities move to dry collection systems associated with compliance of environmental regulations, such as Effluent Limitation Guidelines, more quality material will be available for use. Also, as the market begins investment in large bulk storage, the seasonal operation of coal will become less of an issue on the fairly steady CCP market. Further investment in transportation modes at the source will enable CCPs to move to markets where historical supply has been retired. Fully supplying the needs of the CCP market will capture lost opportunities experienced today, allow for market share growth, and open the door to new entrances of CCP users.

A fully supplied CCP market, along with the growth that will occur from capital investments, will greatly lower the forecasted volumes of CCPs destined for disposal. While utilities need the certainty that CCPs have a place to go long-term, it is imperative that landfill plans are designed to be incremental in their build-out, ash and gypsum separated, and flexibility for reclaim of these materials included. This will allow for minimal cost of building landfills (minimizing impacts to electrical rates), provide generators with certainty of storage in cases of CCP market downturns, and promote a deferred spending mindset that motivates CCP beneficial use at their source of generation.

While these points may sound logical to most reading this, I can tell you these two factions in our industry are like the Atlantic and Pacific Oceans in terms of being a behemoth doing their own thing without regard to the other. While it is likely these two oceans will remain apart, I’d like to see them only separated by the Panama Canal instead of being separated by a distance as wide as the United States.

This association has made an investment in getting the first part of this message out—CCPs are here to stay and the supply will be strong for the long term. (This issue of *ASH at Work* features a special section “Key Findings” report that supports this message.) The other side of the message needs my utility colleagues to carry the flag inside their corporations that the beneficial use market is strong and growing. We must be the communication mediators that let the left hand and right hands not only know about each other but also know what they are doing. Or, in our case, the left ocean and the right ocean; and let’s be the Panama Canal of information. ❖

[*]CCR – coal combustion residuals
CCB – coal combustion by-products
CCW – coal combustion wastes

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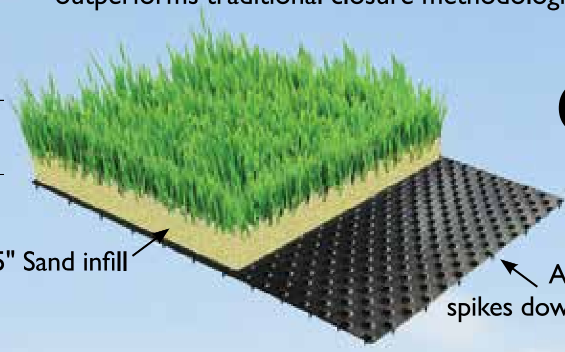

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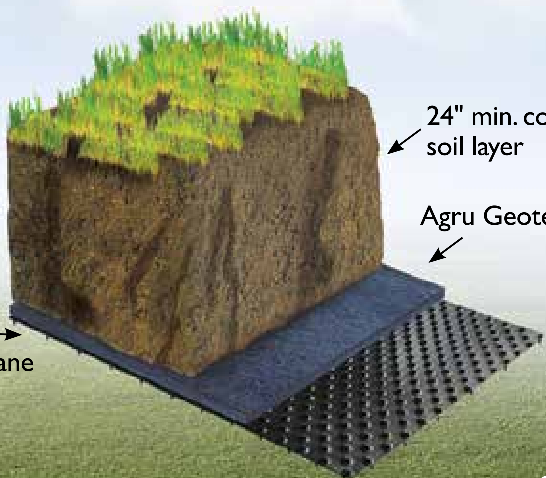

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ONCE UPON A TIME…

By Thomas H. Adams, ACAA Executive Director

It is said that "change" is one of the few constants in life. And that is absolutely true. Some changes are predictable, such as the changing of the seasons. Unless you live in San Diego, CA, winter, spring, summer, and fall show up about the same time every year. Some changes are dramatic and come quickly and unexpectedly, such as the resignation of Speaker of the House John Boehner. But other changes take quite a while and are very subtle. Such is the case with the change in the perception of fly ash for use in concrete.

Those who opposed fly ash warned that you could expect problems entraining air, low compressive strengths, finishing complaints, delayed setting, discoloration, halitosis, cough due to cold, and on and on if you used even modest quantities.

Once upon a time, the use of fly ash in ready mixed concrete was something to be avoided by ethical producers. In the early years, most fly ash use was on very specialized projects, such as dam construction and other mass placements. As researchers reported lab findings and results from those specialized applications became known, things started to move into more commercial applications. Ready mixed concrete producers started to investigate the potential benefits to be derived from fly ash use. Still, the general perception was that fly ash was a waste to be avoided. Those who opposed fly ash use warned that you could expect problems entraining air, low compressive strengths, finishing complaints, delayed setting, discoloration, halitosis, cough due to cold, and on and on if you used even modest quantities. Anything that was a problem with a concrete mixture immediately was assigned to the use of fly ash. Even when problems were encountered with mixtures that did not contain fly ash, people were quick to accuse the ready mixed concrete supplier of slipping fly ash in to the concrete and not telling the customer. Fly ash had a real public relations problem.

Today fly ash is regarded as an important part of the answer to challenges faced by architect/engineers and concrete producers.

As time went on, problems such as loss on ignition, early compressive strength development, and changes in finishing techniques were investigated and mitigated. The use of fly ash was gradually but steadily expanding. The economic and performance benefits were too powerful to ignore. This "waste" was proving to be pesky. Those producers who were learning to handle this "waste" were gaining significant market advantage. It was becoming hard to defend the traditional thinking that only additional quantities of portland cement could enhance concrete performance.

An industry was developing to manage and market fly ash. As with all emerging industries, companies formed, failed, expanded, and merged as the industry started to grow up.

And it was dawning on the generators that fly ash was of some economic value. Sources that previously gave the "waste" to anyone who would come to the power plant and pick it up were starting to change their thinking.

There was even a trade association formed to encourage the use of fly ash and other coal combustion products.

Over time, the appearance of Class C fly ash, alkali-silica reactivity (ASR) mitigation, high-performance concrete mixtures, beneficiation processes to improve ash quality, high-volume applications, and other developments helped change the way the market viewed fly ash. No longer was this powder merely a cheap alternative to replace portland cement. Fly ash was becoming a primary tool to overcome technical challenges.

How things have changed! Today, fly ash is regarded as an important part of the answer to challenges faced by architects, engineers, and concrete producers. Whether the challenge is ASR mitigation, reducing permeability for enhanced service life, producing high compressive strengths, or other challenges, the use of fly ash in concrete clearly is regarded as a valuable component. Fly ash is now a respected member of the concrete tool kit. Once upon a time, this finely divided residue resulting from the combustion of coal was called a "waste," and even a "hazardous waste" by some. Change indeed! ❖

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A NEW SOLUTION FOR A LONG-STANDING DILEMMA

"The cost of disposing of coal ash just went up. Again."

By Jimmy C. Knowles and Bill Fedorka

While the utility industry has become accustomed to hearing this familiar phrase over the last several decades, previous increases in ash disposal cost are expected to pale in comparison to increases coming after October 14, 2015. On that date, the requirements of the U.S. Environmental Protection Agency's (EPA's) final rule regulating new and existing coal ash landfills and ponds will go into effect. These new requirements are nearly identical—and just as costly—as those for municipal solid waste landfills.

What about the millions of tons of coal ash previously disposed of in unlined ponds? According to the EPA, many of these impoundments will need to be closed and the ash either covered or removed.

Fortunately, the EPA has provided a path to avoid high disposal costs and the long-term risks associated with the new requirements. The solution: "encapsulated beneficial use." This approach is consistent with what the industry has been doing for years: using ash as a performance-enhancing additive in concrete and other composites. Consequently, utilities have an even greater incentive to see that coal ash goes to beneficial uses such as concrete—namely, reducing their disposal costs and improving environmental stewardship.

From the perspective of a commercial customer for coal ash, the decision to use ash has become more difficult. Every year there is less fly ash being produced and the quality of that fly ash is deteriorating. In some markets, fly ash beneficiation has helped improve the quality, thereby increasing the supply. And yet, even markets with access to quality product lacked the year-round availability of fly ash necessary to keep up with the seasonal fluctuations.

Coincidentally, hundreds of millions of tons of previously disposed coal ash were sitting idly in ponds all over the country. The industry was in need of a beneficiation technology that could not only process poor-quality fly ash into a high-quality additive for concrete but also transform previously disposed coal ash, such as pond ash, into a quality product for encapsulated beneficial use.

ENTER STAR

The technology, known as staged turbulent air reactor (STAR), was first commercialized in 2008 and the latest facility came online early 2015 at Santee Cooper's Winyah Generating Station (WGS). The Winyah STAR Plant processes fly ash as it is produced at WGS. More importantly, however, it also processes coal ash that was produced decades ago as it is reclaimed from on-site ash ponds.

For years, The SEFA Group has been a long-term service provider to Santee Cooper—initially for ash marketing and more recently for ash beneficiation and marketing. When Santee Cooper was faced with the task of cleaning out and removing millions of tons of coal ash from several of their ponds, they turned to SEFA for help. In 2013, SEFA first successfully demonstrated commercial-scale beneficiation of pond ash at its McMeekin STAR Plant. The following year, SEFA decommissioned its currently existing carbon burnout beneficiation plant at WGS and replaced it with the next-generation STAR plant that could interchangeably beneficiate both freshly produced fly ash and previously disposed coal ash reclaimed from ponds.

Santee Cooper required an extremely flexible coal ash beneficiation technology. Each day, the Winyah STAR Plant adjusts to a wide range of coal ash from varied sources. For example, the Winyah STAR Plant routinely operates using only reclaimed coal ash from ponds and yet is able to switch its feed source at a moment's notice to process 100% dry fly ash as the WGS comes online.

The Winyah STAR Plant routinely processes coal ash with residual carbon contents ranging from 5% to over 25%. Because the plant is a stand-alone solution, it does not depend on WGS in any way and operates normally, even when all the WGS units are offline. In fact, even if any or all of the WGS units are decommissioned in the future, the plant could continue operating at full capacity for decades, limited only to processing the on-site pond ash.

Uninterrupted supply and consistent quality translate to increased demand for fly ash. Customers lose confidence in fly ash when they cannot rely on it being available when needed or if the quality of the fly ash causes problems with their production and processes. The Winyah STAR Plant allows Santee Cooper to maximize the annual amount of coal ash used from WGS by providing a continuous supply of quality product to its customer base.

Unless reclaimed pond ash is used at Winyah to augment feed material, the supply of STAR fly ash would never keep up with demand. Like most coal-fired power plants, the recent trend at WGS has been for less coal to be burned, especially during the spring and fall months when customer demand for fly ash is at its highest. Reclaimed coal ash from ponds provides continuous feed material for the Winyah STAR Plant and ensures uninterrupted supply for customers. For power plants, that offers the benefit of elimination or reduction in disposal costs and tangibly demonstrates its long-term commitment to environmental stewardship.

CONSISTENT QUALITY WITH CONTINUOUS PERFORMANCE

The enhanced quality of STAR fly ash is a critical element of its compelling value proposition. Typical by-product fly ash will have varying amounts of unburned carbon, which negatively affects the quality of products made from it, and which subsequently increases both the need and cost of the customers' quality control. Regardless of the carbon content of the source feed, STAR fly ash has little to no carbon remaining and therefore the presence of STAR fly ash does not negatively affect the customers' quality control practices in any way. The quality characteristics of Winyah STAR fly ash remain constant, regardless of whether it is produced from reclaimed pond ash or from fly ash produced by the WGS plant.

Of course, many of the other characteristics of STAR fly ash are changed for the better. For example, STAR processing improves the early strength and ultimate strength gain of any fly ash used in concrete, primarily by increasing the fineness of the fly ash. In the case of pond ash, due to prolonged exposure to water, the ash does not have the strength activity necessary to be marketed as specification-grade fly ash unless it is calcined at the high operating temperatures of a STAR plant.

STAR processing also removes additional contaminants from fly ash including, for example, ammonia, which would otherwise be a nuisance or represent a quality control problem for customers. Consequently, Santee Cooper is supporting research to develop diversified markets for Winyah STAR fly ash as additives in coatings, plastics, rubber, and other products.

LONG-TERM COST IMPLICATIONS

The landfill industry is highly regulated and more stringent environmental regulations have made it more costly to own and operate landfills. Significant amounts of capital are necessary to permit, construct, operate, and monitor sites. New coal combustion residuals (CCR) regulations are intended to mirror nonhazardous municipal solid waste (MSW) landfill rules and standards (RCRA Subtitle D). As a consequence, it has been projected to cost more than $1 million per acre to permit, construct, operate, close, and monitor a landfill in compliance with the new regulations. Permits will require 30 years of environmental monitoring after a landfill closes. It should go without saying that a financial commitment of this magnitude needs to be evaluated and planned well in advance.[1]

In June 2014, the EPA published an economic impact analysis (EIA) for MSW landfills to study the impact of proposed amendments to the Standards of Performance. Figure 1 illustrates one finding from the EIA with respect to MSW landfill cost increases. As discussed previously, the new CCR regulations mirror for the most part those for MSW landfills because both are controlled under RCRA Subtitle D. The EIA presents a model originally published in 2005 to help estimate costs[2] for a hypothetical landfill based on known market conditions and cost data.

EVALUATING THE BENEFITS IN MORE WAYS THAN ONE

A cost analysis comparing two options—1) The "do-nothing," or 100% landfilled options; versus 2) investment in STAR and removing material offsite through sales of thermal beneficiated ash—helps to demonstrate the potential cost difference.

---

1 The cost to dispose of MSW at a landfill is commonly known as a "tip fee" or "gate fee." In September 2012, the average national spot market price to dispose of one ton of waste in a U.S. landfill was roughly $45, up 3.5% over 2011. This compares to average national tip fees of approximately $32 in 1998 and $8 in 1985. Between 1985 and 1995, the national average tip fee increased by 293%. In the subsequent 10-year period, the national average tip fee increased by 7% per year.

2 Landfill costs fall into the following categories: site development, construction, equipment purchases, operation, closure, and post-closure. Site development includes site surveys, engineering and design studies, and permitting fees. Construction costs encompass building the landfill cells as well as development of permanent on-site structures needed to operate the landfill. Evacuation of the landfill site comprises a notable portion of the construction costs. Installation of a liner can also vary greatly in cost depending on the site's geology. Operating costs are relatively small when compared to the capital costs and include staffing, equipment, leachate treatment, facilities, and general maintenance.

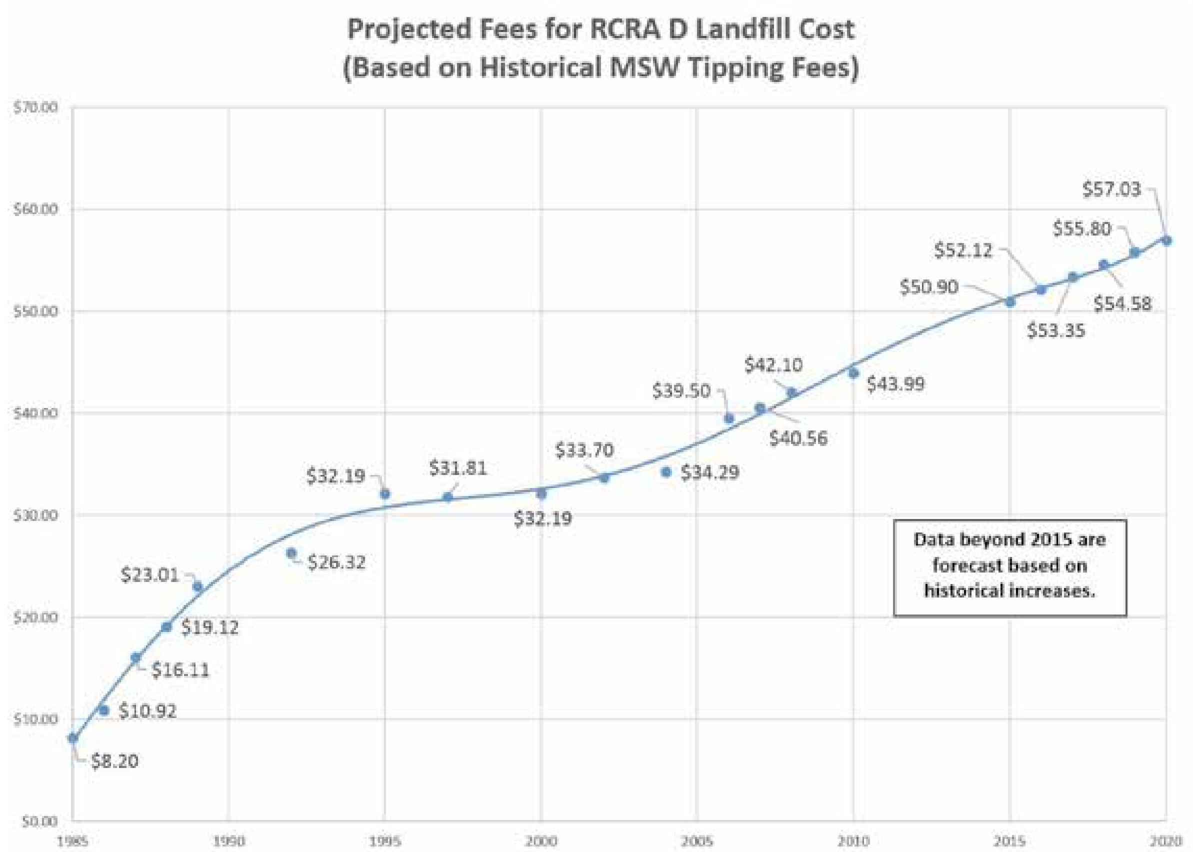


Fig. 1

To estimate the net present value (NPV) of a new landfill development project for CCRs, it was assumed that the site development costs, which include all engineering and permitting, would total a fixed $1 million.[3] The calculated operating factors and cost assumptions can be seen in Fig. 2.

For the "do-nothing" option, five 33-acre cells would need to be developed over the 20-year period to handle the 7.9 yd^3 of fly ash disposal. The NPV of all costs was determined to be $84 million dollars assuming a 7% discount rate and inflation of 2.5%. This represents an equivalent, "all-in" disposal cost of $20.82 per ton average over the 20-year period. The cost per acre, in today's dollars, would be approximately $985,000 per acre (see Fig. 3).

If nearly 6.5 million tons of ash were disposed of on site, the utility or landfill owner still has to deal with the 30-year post-closure period and all its associated costs, not to mention the perpetual liability of all that material buried underground.

Even if only 85% of the available fly ash could be beneficiated and taken offsite, only one cell would need to be developed with a life of nearly 40 years. Beneficiation would eliminate the liability and 30-year post-closure costs on 5.5 million tons of fly ash. At the end of the 20-year period, the beneficiation facility would be paid for, with plenty of years of productivity ahead as life extension costs are paid through the operation and management of the facility. Even if the power plant went dark or was mothballed, the STAR could still reclaim material from disposal sites, using it as raw feed.

For the 85% beneficiation option, the NPV of disposal costs would reduce to less than $19 million. Assuming a capital cost for a STAR facility in the $50 million range, the total investment for the beneficiation plus disposal option would be $69 million ($19 million disposal NPV plus $50 million beneficiation investment). This represents a savings of $15 million in today's dollars.

In addition, the beneficiation option would avoid disposal of 6.7 million yd^3 of material, and avoid all post-closure landfill costs, which, according to new regulations, will extend 30 years after closure. The sales of ash from the beneficiation facility would cover all operations and maintenance associated with the beneficiation facility and includes capital for life extension that will allow the plant to operate well past the 20-year period included in the analysis. In addition to the financial advantages, using STAR technology enhances public sentiment because of its broad environmental benefits and the opportunity to be a proactive industry leader.

SUMMING UP

Ultimately, each utility tailors its coal ash management program to its specific circumstances and there will not be a single magic bullet that will solve all of its problems. More likely, each utility will address its unique issues using a combination of several different ash management practices. Even so, it will be increasingly difficult to avoid the skyrocketing cost of ash disposal unless ash can be diverted from disposal to beneficial use. Fortunately, there is now a tool available:

3 An average value of $423,000 (adjusted from $350,000 in 2005 dollars) per acre was used for the landfill construction costs in accordance with the Duffy model. Likewise, the costs for installation of a cap and post-closure care were estimated to be $80,000 and $50,100 per acre, respectively.

SITE DEVELOPMENT OPERATING
FACTORS AND COSTS FOR
"DO NOTHING" OPTION

Operating Factors
1500MW / 75% Capacity Factor
9600 Btu/kWhr / Bituminous Coal
12,500 Btu/lb. Heat Factor
10% Ash content / 85% Fly Ash
321,667 Fly Ash Tons Per Year
23% Moisture - Conditioned Ash
1 Yd. Conditioned ash = 1 Ton

Operating Cost Assumptions
33 Acres Per Cell
60 Feet Maximum Height of Cell
3:1 Angle of Exterior Slope
$2.00 per ton hauling cost
$3.50 per ton to place/compact
$100,000 per year (misc. cost)

Fig. 2

the staged turbulent air reactor (STAR). STAR has the technical flexibility to continue to transform coal ash from both current operations and existing landfills and ponds into a consistent, high-quality product that can be sold as a value-added product for encapsulated use. This technology prevents coal ash from becoming or continuing to be a liability and expense as a landfill or pond waste product. ❖

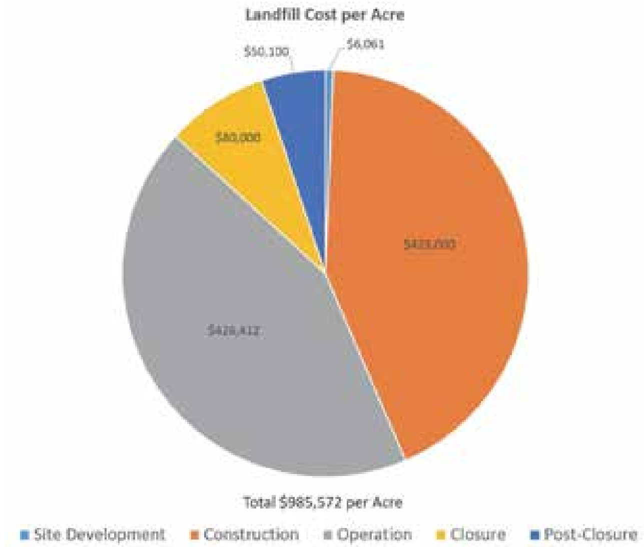


Fig. 3

Jimmy C. Knowles, Vice President of Market Development and Research, joined The SEFA Group over 30 years ago and has served in a variety of positions with the company.

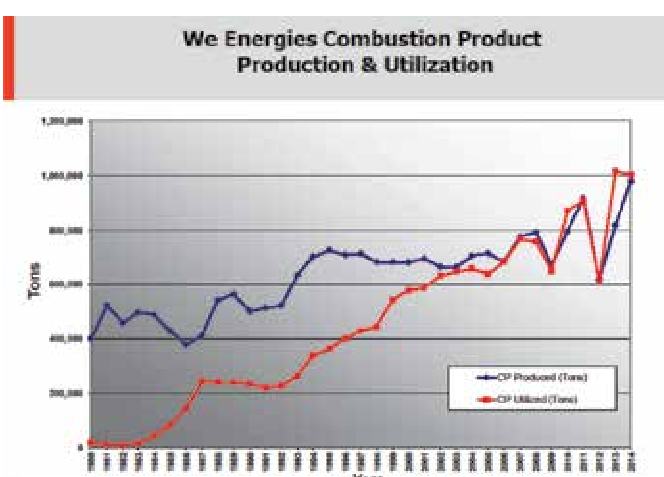
Bill Fedorka, Director of Engineering for The SEFA Group, is a Design and Project Engineer with over 20 years of experience in feasibility evaluation, process and mechanical design, project management, installation, start-up, and operations/maintenance for an extensive range of mechanical equipment and systems.

WE ENERGIES' COAL COMBUSTION PRODUCT BENEFICIATION, RECOVERY, AND USE

By James R. Rosenmerkel and Bruce Ramme

This article spotlights ACAA member company We Energies' efforts to bridge the gap between CCP production and beneficial use. Through various collaborations with other companies and researchers, We Energies has been involved with significant research related to CCP use and has successfully implemented both beneficiation and recovery processes. The technologies involved in this success are particularly important in today's business environment, which can include changes to CCP quality and a need to manage previously landfilled or ponded coal ash.

Over the years, ACAA has provided educational opportunities and programs to learn about the details of burning coal to produce electric power and appropriately manage the coal-combustion products (CCP) that are produced. Key to its mission, ACAA works to promote long-term beneficial use of CCP while minimizing the need to landfill these materials. Members include utility companies, coal combustion product management companies, university faculty members, engineers, contractors, and other CCP promotional organizations. ACAA conducts national meetings regularly so advances in regulatory compliance, power plant design and modifications, and beneficial use of CCP can be shared throughout the industry. These efforts are critical to sustaining and growing the beneficial use of CCP while accounting for various future challenges.



CCP HISTORY

We Energies began keeping detailed records comparing CCP production use around 1980. Back in the early 1980s, there was an approximately 400,000 ton gap between production and use. Through various efforts, the gap was reduced to approximately 100,000 tons by 2000, while total production of CCP increased. Between 2000 and the present, not only did the gap virtually disappear, but CCP use exceeded production in some years due to development of processes for landfill ash recovery and coal ash reburn. This success took place while We Energies nearly doubled its total annual CCP production. Today, nearly a million tons of We Energies CCP including fly ash, bottom ash, and gypsum are produced and used annually.

COAL ASH RECOVERY AND REBURN BENEFICIATION

One challenge We Energies faced in achieving greater percentages of beneficial use was finding sustainable high volume uses for coal ash with high unburned carbon levels. Based mainly on the type of coal burned, the size of the boilers, and the firing technology employed, several units within We Energies' fleet produced high carbon fly ash and bottom ash, with the majority of this coal ash getting landfilled. The high carbon (or %LOI) was viewed as wasted fuel opportunity, but efforts to improve combustion on these units were limited to small gains. With this existing challenge, We Energies embarked on designing systems at one of its other power plants that could receive the high-carbon ash and meter it into the coal system and boiler with the goal of both recovering the left over fuel value and beneficiating the ash.

Ultimately, this initiative resulted in the installation of both a dry and wet coal ash reburn system at We Energies' Pleasant Prairie Power Plant. The dry system includes a silo capable of receiving dry fly ash delivered from other power plants in pneumatic tankers. This dry, powdered ash is then metered into distribution pipes and blown into the boiler burners, where it enters the furnace with pulverized coal. The wet coal ash reburn system includes a receiving hopper and conveyor system for handling wet or conditioned ash delivered by end dump style trucks. This coal ash is added to the plant's coal prior to delivery to the pulverizers, burners, and boiler furnace.

Over the years, the vast majority of the fly ash produced at Pleasant Prairie has been widely used as supplementary cementitious

Dry ash reburn delivery system at Pleasant Prairie Power Plant

Wet ash reburn system at Pleasant Prairie Power Plant

Recovered ash use on Interstate 94 upgrade project

Landfill ash recovery processing

material in concrete and concrete products, so one of the goals of the reburn system included preserving the high quality of the fly ash. Early testing of the reburn process revealed that the high-carbon coal ash sources could be added to the coal at Pleasant Prairie and actually improve the properties of the final fly ash product. Since 2000, We Energies has successfully processed over 1 million tons of high-carbon coal ash through these systems. The results include the availability of an additional 580,000 tons of beneficiated high-quality fly ash available to the commercial market and about 150,000 tons of bottom ash available for use as geotechnical fill material in construction projects. The unburned carbon from the coal ash addition has contributed a fuel value of nearly 3000 rail cars worth of coal to the plant.

Based on the success of the reburn systems at Pleasant Prairie, We Energies installed a coal ash reburn system for use at its recently completed Oak Creek Expansion Units. This system is available for adding wet or conditioned ash from other plants or recovered from existing coal ash landfills. The coal ash is delivered to an enclosed storage building, added to a live bottom hopper, and metered through a conveyor system to the coal delivered to the plant boilers.

In addition to recovering coal ash from landfills for reburning, We Energies has successfully recovered and reclaimed coal ash from its landfills for use as construction materials. Since 2002, coal ash produced and landfilled during the early years of the Pleasant Prairie Power Plant operation has been excavated, crushed, and screened to meet the demand for use as base, subbase, and structural fill on several local projects including building pads, parking lots, and a major freeway upgrade. Availability of this stockpiled material enabled several projects to continue on schedule despite challenges related to weather conditions and poor-quality soils. Beyond supporting the construction schedules, the use of the locally sourced recovered ash enabled projects to achieve significant cost savings. Ultimately, through the removal and use of landfilled ash during the recovery process, We Energies has been able to upgrade the Pleasant Prairie landfill to include an improved liner and leachate collection system.

CONTINUOUS INNOVATION EFFORTS

In addition to the successful development of the patented coal ash recovery and reburn systems, We Energies has embraced an innovative spirit and developed and patented processes to beneficiate and use combustion products in other ways. Some examples include:

- **Electrically conductive concrete and controlled low-strength materials (CLSMs)** (Encourages the use of high-carbon coal ash in the production of concrete with the goal of enhancing electrically conductive properties of the final material)
- **Ammonia removal from fly ash** (Reduces the amount of ammonia on fly ash through the use of high-temperature air slide systems)
- **Mercury removal from activated carbon and/or fly ash** (Reduces the amount of mercury on fly ash and activated carbon through the use of high-temperature air slide systems)
- **Carbon dioxide sequestration in foamed CLSM** (Provides a means of sequestering carbon dioxide from flue gas while enhancing the production of lightweight aggregate materials)
- **Separation of cenospheres from fly ash** (Provides a dry separation technology for removal of cenospheres from fly ash)
- **Settable building material composition, including landfill leachate** (Provides a means of using leachate produced at landfills as the water source for concrete or settable building products)

With these patents in place and innovation as a goal, We Energies continues to be a leader not only in power production, but also in the production, beneficiation, and use of quality combustion products. The use of the combustion products provided by We Energies has enhanced multiple construction projects and products over the years, provided cost savings, and decreased the need for landfill space. ❖

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HOW PACT™ WAS USED TO AVOID 5 MILLION TONS OF LANDFILLED FLY ASH

By G. Craig Plunk, P.E.

Due to the Mercury and Air Toxics Standards (MATS) regulations as promulgated by the U.S. Environmental Protection Agency (EPA), coal-fired utilities are being required to comply with restrictions on mercury emissions. The current favored practice for mercury capture from flue gas is based on the injection of powdered activated carbons (PAC). In most cases, the carbon containing the removed mercury is captured along with the fly ash in the ash collection system (typically fabric bag filters or electrostatic precipitators).

Various fly ash beneficiation technologies exist for reducing the impact that residual and activated carbon has on air-entrainment performance; however, these technologies are typically based on removing carbon from the ash and are usually quite capital intensive. These carbon-removal technologies are most effective when applied to materials with relatively high carbon contents. PAC contents in fly ash are typically below 2%; therefore, traditional methods of beneficiation by carbon removal will be challenged to remove the PAC.

The challenges for the utilities to control mercury emissions is complicated by many other factors, primarily the fact that the quantity of mercury present in coal is very low. The Electric Power Research Institute (EPRI) has estimated that the quantity of mercury in coal ranges from 0.02 to 0.25 ppm (average 0.09 ppm). The uncontrolled mercury emissions from a typical 500 MW coal-fired plant would be less than 250 lb per year or less than 1 lb per day. Actual emissions are much lower because environmental control technologies that utilities use to control the emissions of several air pollutants, such as sulfur dioxide and particulate matter, also remove mercury. The annual mercury contribution of U.S. fossil fuel electric utility boilers with existing criteria pollutant control equipment in place has been estimated to be less than 16% of all U.S. manmade sources and less than 1% of worldwide manmade sources.[1]

Another challenge for the utility industry is the fact that mercury concentrations in the flue gas typically on the order of 1 to 10 micrograms per normal cubic meter (micrograms/Nm^3) present very difficult sampling and analytical challenges due to the extremely low concentrations.[1] Additionally, adding to the measurement challenge is that mercury will exist in several different forms, primarily metallic or elemental mercury. Sampling and analysis techniques to capture and measure these species individually have not yet been fully developed and verified.

The challenges of mercury control for the utility can contribute directly to the difficulty for a beneficiation system to mitigate PAC. Obviously, changes in coal sources, flue gas treatments, fuel blending, and load cycling all can affect the PAC contents in the ash. Utilities are of course economically motivated to inject the minimum quantity of PAC necessary to meet their mercury capture criteria. Economics, energy pricing (in particular natural gas), alternative energy sourcing (such as wind, solar, nuclear and hydro), and the requirement to meet emission regulations are forcing more and more utilities away from steady state operation.

This variability in plant operation contributes to a highly variable fly ash quality, both in terms of residual carbon (RC) and ash PAC content. Therefore, a chemical beneficiation system must be flexible enough to adapt to a very wide range of ash quality and also be able to respond quickly to changes in fly ash quality.

In addition to the variability in ash quality discussed previously, suppliers of PAC have been busy developing new, more effective types of sorbents to provide mercury control. In particular, sorbents have been developed that are more "concrete-friendly" with material characteristics that lessens the impact on concrete properties. Boral Material Technologies (BMT) has investigated these materials and found that, in general, the carbon-friendly PAC has less impact in air-entrained concrete, but results vary widely. Additionally, sorbents may also contain combinations of silicates, halogens, and bromides; these products are now in common use in coal-fired stations across the country.

BMT has many years of fly ash chemical beneficiation experience amending carbons (RC and PAC). BMT began developing the first chemical FACT™ (fly ash carbon treatment) in 2000. The first-generation FACT system was deployed for field use in 2003. FACT was originally developed to mitigate elevated RC caused by lower boiler combustion temperatures due to LoNOx burners. FACT was reformulated to keep pace with deteriorating ash quality caused by additional environmental regulations. BMT, aware that federal legislation would require utilities to remove mercury from flue gas, began development once again to further refine our chemical beneficiation system in anticipation of PAC. PAC is produced and manufactured to have an ultra-high specific surface area (A gram of activated carbon can have a surface area in excess of 500 m^2, with 1500 m^2 being readily achievable).[2] The SEM photograph shown in Fig. 1 of a PAC particle clearly illustrates the microscopic pores which contribute to the ultra-high specific surface area.

Air voids are intentionally formed in concrete (typically 5 to 7% by volume) during the mixing phase through the use of chemical admixtures (air-entraining admixtures [AEA]) added during the concrete batching process. These air voids provide protection from damage caused by freezing-and-thawing cycles in hardened concrete. Carbon contamination in fly ash (RC and PAC) can readily adsorb the AEA chemicals and prevent the formation of the air void system. PAC, due to its high adsorptive capacity for organics (surfactants used as AEA) at very low levels, can render fly ash unsuitable for use in air-entrained concrete unless beneficiated.[3] Because PAC is approximately 10 times more adsorptive than RC, AEA dosage demand with even a 1.0% contamination by PAC can increase three to six times depending on specific PAC and AEA products.

Figure 2 illustrates the impact of PAC on the ability to entrain air in concrete. Each of the four curves are represented by three data points representing four separate concrete mixtures. All concrete mixtures were prepared containing fly ash with varying quantities of PAC in the fly ash ranging from 0 percent (control) up to 3% PAC by weight. The same PAC was used in all mixtures. The control mixture indicates that air can be easily entrained by very small AEA dosage rates and that the air content can be dramatically increased with very small increases in dosage rate. The other three mixtures illustrate that as the PAC content is increased, the AEA dosage required was increased by several orders of magnitude.

In 2009, BMT's research and development efforts led to the selection of the preferred chemicals to use for PAC mitigation. The formulation was selected that best fit all the criteria reviewed for implementation. Additional characteristics reviewed and defined as significant were the relative safety of the selected chemical, availability, and of course economics. It was desirable that the chemical be safe to handle with normal personal protective equipment (such as gloves and safety glasses) and with properties that would not be marginalized by temperature extremes.

The selected chemicals (PACT™) are a formulation of liquid chemicals that mitigate against the negative impact of PAC, fundamentally performing as a "sacrificial admixture" although not as an AEA itself through a number of mechanisms including sacrificing to carbon and thereby satiating the carbon's adsorption capacity. The PACT chemicals have a high affinity for PAC, allowing the PAC to preferentially adsorb the PACT chemicals. PACT is well-suited for addressing carbon contamination levels that are too low for the more traditional beneficiation technologies to be effective.

It was recognized early on in the development of BMT's original FACT chemical beneficial system that a reliable and repeatable method of quantifying the predisposition of the residual and PAC to adsorb admixtures used by concrete companies must also be developed with as little subjectivity inherent to the method, as possible. The existing traditional methods for quantifying carbon such as loss on ignition (ASTM C618) and foam index (FI), simply put, were not good enough to reliably determine the effect of fly ash RC or PAC on concrete admixtures. After reviewing and testing many methods for determining the impact of RC and PAC on AEA, it was determined that by slightly modifying ASTM C185[4] would provide the reliability and degree of accuracy required. Essentially, ASTM C185 was modified for BMT purposes to allow for the introduction of fly ash (20% replacement by mass) as a partial cement replacement and compare the resultant mortar air content to that of a cement control. The results are expressed as a mortar air ratio (MAR) on a percent basis. As an example, after computing the ratio of a cement ash blend with that of a

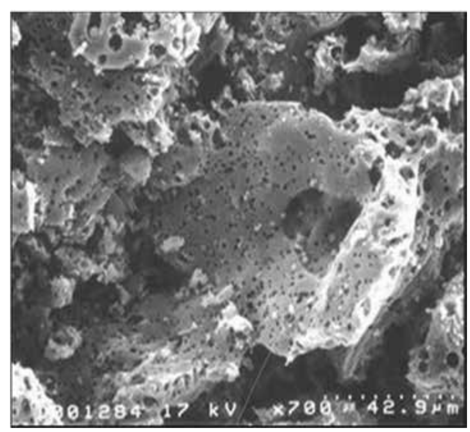

Fig. 1

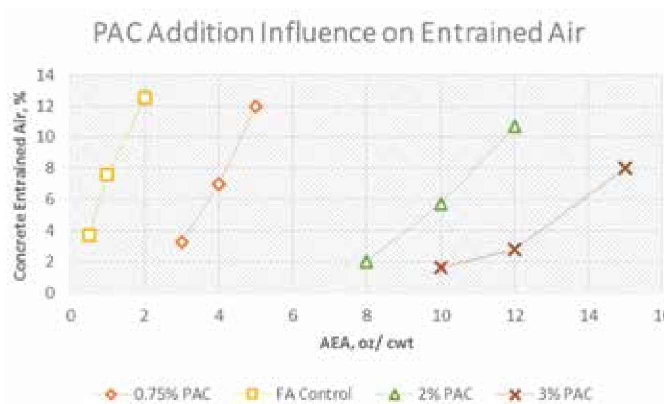

Fig. 2

control cement and the ratio is determined to be 80%, it can be reasonably concluded that a concrete mixture containing that specific fly ash would be only 80 percent as effective in entraining air, a value of 100 percent would indicate an ash with no effect on the concrete mixture. A standard cement, air entraining agent and silica sand are used throughout BMTs operations at all facilities that are required to perform MAR testing. The materials required to perform the testing are distributed to all on-site satellite laboratories from the BMT central laboratory to maintain consistency.

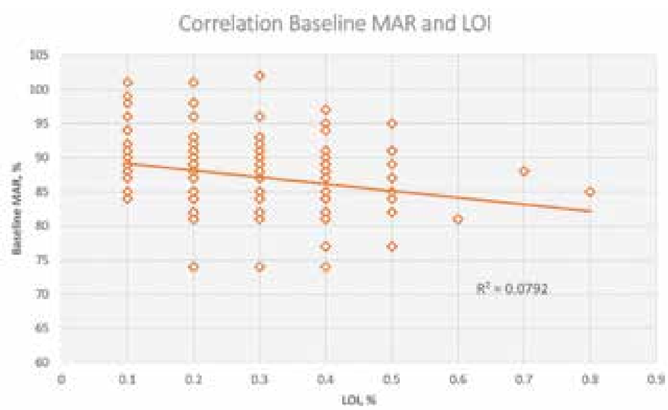

Fig. 3

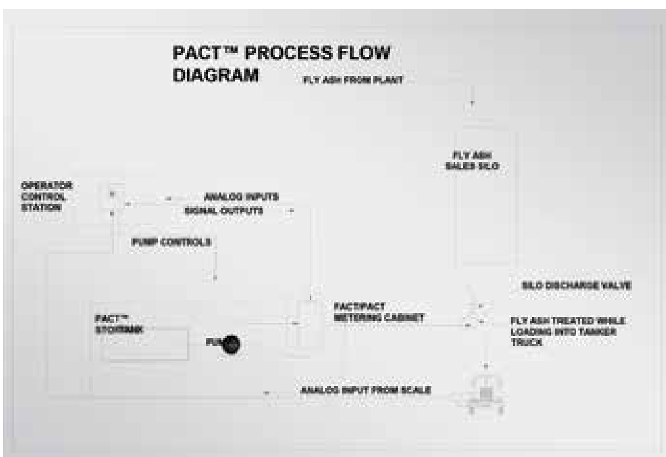

Fig. 4

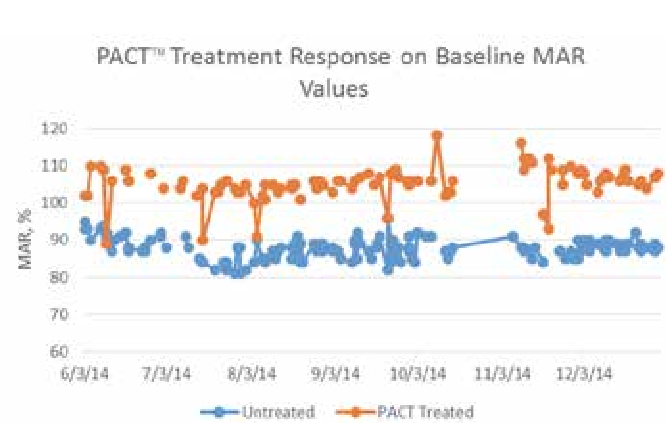

Fig. 5

The data shown in Fig. 3 was developed from a source that burns a blend of Texas Lignite and PRB fuel. The station also periodically injects PAC. As can be concluded from the data, there is no correlation between LOI and MAR, therefore supporting the premise that using LOI as a measure of carbon is outdated and unreliable.

Based on previous experience, BMT recognized that it was crucial to the success of a chemical beneficiation program that the chemical be applied uniformly on the ash. Therefore, our application system was designed and built around that premise. The chemical is atomized and applied directly to the ash through a series of atomizing spray nozzles as it is loaded onto a transport vehicle. Obviously, ash flowing from any loading system is not uniform. Therefore, any chemical application system must adjust the chemical flow continuously within a specific loading event. This challenge was solved by linking a programmable logic controller (PLC) to an electronic scale system. The PLC automatically adjusts the flow of chemical as the electronic truck scale senses load. BMT has successfully installed and operated such systems on weigh pod systems, air slides, and direct silo feed configurations.

The entire PACT application system is installed near the fly ash load-out silo and can be installed quickly—usually within 6 weeks. PACT can be applied on demand only as required. The PACT treatment process is non-intrusive to existing plant operations. The PACT system has a very small physical footprint with no modifications being required to existing equipment. Additionally, The PACT system does not interfere with the loading times of commercial delivery trucks. The diagram in Fig. 4 illustrates the application process of the PACT system.

As with any procedure, it is critical that methods be put in place to control such process. BMT has put in place standard operating procedures (SOPs) at each facility that operates a PACT system for beneficiation. PACT is applied to the ash depending on the underlying baseline quality as determined by MAR testing. Typically, to control the PACT process, samples are taken throughout a production cycle with the frequency determined by the variability of the underlying ash quality. For example, a uniform stable ash source may be tested twice per day, where a highly variable ash source may be tested as many as six times a day to maintain a good sense of the changing ash quality. After the baseline MAR value is determined, that baseline value is simply entered into the PLC and dosed at that rate until a new baseline MAR value is determined. The PLC that controls the PACT application is preprogrammed with a plant specific calibration curve that has been optimized for each plant.

Figure 5 clearly illustrates the effectiveness of PACT treatment and the ability of the PACT chemical beneficiation system to mitigate both residual and activated carbon over a very wide range of ash quality with quite different plant operating conditions. The data is sourced from a large coal-fired facility that has through the period shown burned coal blends ranging from 100% lignite fuel to 100% Powder River basin (PRB) fuel. The majority of the fly ash produced through this time period was produced with a fuel blend of 70% lignite and 30% PRB fuel. At various intervals, PAC was also injected at the facility depending on emission requirements. The chart directly compares MAR values of untreated fly ash with that of PACT-treated fly ash from July 1 through December 31, 2014. The untreated MAR values average 88%, with 169 data points, while the PACT-treated fly ash averages a MAR value of 103% represented by 137 data points. Put another way, ash treated with PACT and incorporated into concrete would result in no effect, while the untreated ash would reduce the ability to entrain air in the concrete by approximately 12%.

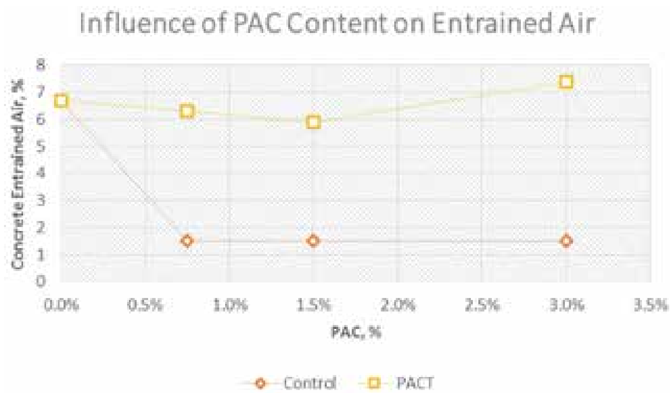

Fig. 6

Figure 6 indicates the ability of PACT treatment to minimize air fluctuations over a broad range of PAC contamination levels. Four concrete batches were prepared containing fly ash that had been PACT-treated to the appropriate level and four concrete batches containing the same porportion of fly ash that was not PACT-treated. As can be clearly seen, the PACT treatment essentially removed the effect of the PAC over a wide range of PAC contents, clearly when the PAC content exceeded 0.75% it was very difficult to generate air in the concrete containing untreated fly ash.

Fig. 7

PAC also has an effect on the ability of a concrete mixture to retain and stabilize entrained air once a specified target is achieved. Laboratory testing of all PACT-treated ashes are tested in concrete to determine optimum dosage so that the proper quantity of entrained air can be established in concrete. Additionally, air-retention studies (Fig. 7) are also conducted to ensure that once the correct amount of entrained air is achieved in concrete, the air will stay stable over time. Hardened concrete properties have been investigated as well to determine the effect if any on air void size and spacing, durability testing (sulfate and alkali-silica reactivity), compressive and tensile strength, plastic properties such as slump, entrained air, temperature, initial and final set times, and admixture compatibility.

Since 2003, BMT has successfully treated over 5 million tons of Class C, Class F, and Lignite fly ash collectively with FACT, FACT II™, and PACT chemical technologies. BMT is currently chemically beneficiating fly ash at seven utility locations and two rail terminals. The treatment process does not alter nor modify an ash's ability to meet the requirements of ASTM C618. In addition, BMT has been successful in obtaining and maintaining Department of Transportation approvals in all of BMTs market areas. BMT holds multiples patents on chemical beneficiation and system applications protecting the intellectual property related to the FACT, FACT II, and PACT technologies.

In summary, the benefits of a PACT chemical beneficiation system include:

- It is a low-capital installation
- It has a 5 million ton successful treatment history
- Installation does not interfere with plant operations or influence loading times
- It is a safe and non-hazardous chemical
- Dosage can be continuously adjusted to meet variable ash quality due to changes in fuel, combustion conditions, or additives
- It is approved for use by Departments of Transportation and many other state and federal specifying agencies
- It does not alter the ability of the fly ash to meet ASTM C618 specifications ❖

REFERENCES

1. Change, R., and Offen, G.R., "Mercury Emission Control Technologies: An EPRI Synopsis," *Power Engineering*, V. 99, No. 11, 1995, pp. 51-56.
2. "Value Added Products from Gasification—Activated Carbon," Combustion, Gasification and Propulsion Laboratory at the Indian Institute of Science, http://cgpl.iisc.ernet.in/site/Portals/0/Publications/Presentations/Bio-Energy/Value%20Added%20Products%20From%20Gasification%20%20-%20Activated%20Carbon.pdf. (last accessed Sept. 22, 2015)
3. Hill, R.; Zhang, Z.; and Shaw, B., "A Fly Ash Carbon Treatment for Producing a Marketable Product from Activated Carbon Contaminated Fly Ash" 2009 World of Coal Ash Conference, May 4-7, 2009, Lexington, KY, 10 pp.
4. ASTM C185-15, "Standard Test Method for Air Content of Hydraulic Cement Mortar," ASTM International, West Conshohocken, PA, 2015, 4 pp.
5. ASTM C618-12a, "Standard Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use in Concrete," ASTM International, West Conshohocken, PA, 2012, 5 pp.

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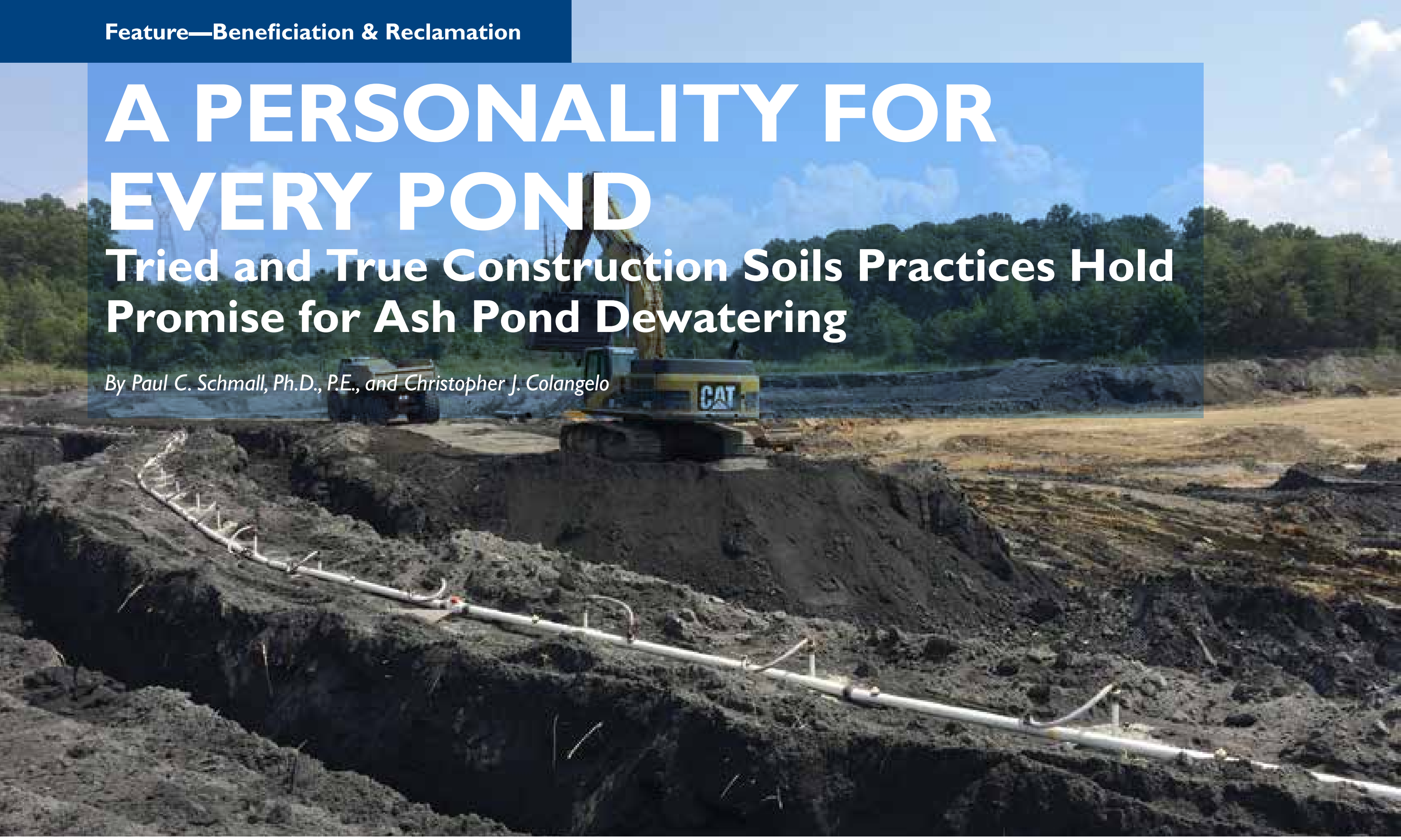
A PERSONALITY FOR EVERY POND

Tried and True Construction Soils Practices Hold Promise for Ash Pond Dewatering

By Paul C. Schmall, Ph.D., P.E., and Christopher J. Colangelo



As the clock ticks down toward mandatory compliance with the Environmental Protection Agency (EPA) coal combustion residuals (CCR) ruling, facility owners and their engineers must rapidly move ahead with developing plans for the closure of wet ash surface impoundments and landfills.

For decades, there has been no reason to physically perform work on the ponds, and the methods of doing so have remained rudimentary. Albeit slowly, the ash will drain with rim ditching and sumping. This will eventually provide enough "dry crust" on the surface of a pond to permit equipment use—typically low ground pressure or amphibious. The material consists microscopically of very fine ball-bearing-like spheres that are highly unstable when wet. Rim ditching is like digging a hole at the beach—you don't get too far below the water before the material runs and sloughs in. The rim ditches can incrementally lower the water table, like slowly peeling an onion.

The rate of draining or partially draining a pond with rim ditching may be very slow, but the greater concern is the compromise in safety. The rim ditching and sumping approach will always keep the equipment (and operators) just slightly above the water level in the ash. This is the place of greatest vulnerability. The ash may appear to be stable, but will completely give way under the vibration or motion of a piece of equipment. A more confident operator would consider it very unstable soil. But it's not soil. It doesn't behave quite like soil. It's ash. There needs to be a better, safer way, and there is—the installation of a pre-drainage dewatering system using wells or wellpoints. However, in the past, this has proven to be problematic with regard to ash, not because dewatering in and of itself is ineffective but because the approach and methodology used has been misapplied.

DEWATERING WORKS

The number of successfully pre-drained, clean-closed ash ponds can be counted on one hand. There are not enough fingers or toes to count the failed attempts to pre-drain ash, and failures are what people remember. Ash is peculiar. It's like soil in some regards, but very different in others. Building effective dewatering devices such as wellpoints or wells in ash is tricky. For example, the traditional well filter pack design used in conventional construction dewatering doesn't always apply when the particles resemble ball bearings. Previous use of fabric filters in lieu of conventional sand filters has proven to restrict water flow and resulted in plugging of the wells or wellpoints. In fact, traditional dewatering methods improperly applied have been problematic to the point where many people believe that pre-drainage techniques just don't work in ash. But with proper geotechnical analysis of the site-specific conditions, pre-drainage dewatering can, and does, work extremely well.

Moretrench has completely dewatered the ash for three full (and large) pond clean closures now, and numerous smaller-scale projects. We have gone through the learning curve(s). And it works, to the point where near-vertical cuts can be made in the ash. The transformation is astounding: the drained material can be cut vertically or near-vertically. Simply put, what occurs is this: when the "free" water is drained from the ash, it transitions from a soup to a very nice soil-like material with apparent cohesion and "stand-up time". Geotechnical engineers recognize that as the point where the pore water pressure goes from positive to

Fig. 1: Typical ash pond rim ditch construction. The shallow rim ditch permits slow drainage from the ash.

negative. It's the point where the water transitions from a lubricant into a glue. This apparent cohesion is what is needed to get equipment out on a pond, whether it is for excavation or regrading for a cap.

What makes pre-drainage dewatering so much more advantageous than the old-school method of rim ditching and sumping? First, by installing dewatering devices such as wells or wellpoints deeper into the ash, the water can be lowered a lot further than can be done with a rim ditch. Lowering the water further means that a higher gradient (groundwater pressure differential) can be created and thus induce a greater water withdrawal rate from the ash. This speeds up the process. Secondly, the water is lowered below the surface of the ash BEFORE excavation equipment sets out onto the pond (that is, PRE-drainage).

EVERY POND HAS ITS OWN UNIQUE "PERSONALITY"

Whether a site is slated to be clean-closed or capped, the goal is to execute the work plan safely and efficiently. And there is no "one-size-fits-all" solution. The more we work in the ash, the more we realize that every pond has a unique personality. And yes, some are better than others. The personality of the pond is built up from the source of the coal, the characteristics of the burner, the manner in which it was transported, the proportions and frequency of mixing bottom and fly ash, the shape of the pond, the location(s) of the sluice pipe(s), the thickness of the ash, and the pH of the water. The variables are seemingly endless. What ultimately matters is how the ash behaves under the tracks of an excavator. Every pond has a certain "dry crust" thickness needed for safe passage of equipment. We need to understand how all of the variables interplay to demand 5 ft of dry crust on one pond and 10 ft on another.

PILOT PUMPING TESTS ARE CRITICAL

The pervasive lack of geotechnical information on any of the ash ponds adds another level of uncertainty to the work. Most ponds are not stable enough to support even a small cone rig, so the data is more or less nonexistent. Historic knowledge of a pond is therefore extremely beneficial. This could be pre-ash topographical maps, perimeter borings, or knowledge of borrow sites for the construction of the perimeter embankments.

With or without geotechnical information, the key to effective "boots on the ground" stabilization of a pond lies in the ability of the dewatering contractor to thoroughly understand the behavior of the ash, the hydraulic connection to the soils below pond bottom, the groundwater conditions, and how both

Fig. 2: Stable, near-vertical cuts along a line of wellpoints illustrates the "apparent cohesion" that ash exhibits when it is pre-drained.
Courtesy of Glover Construction Company.

Fig. 3: Wellpoint pre-drainage dewatering. Ash removal began approximately 5 weeks after groundwater pumping was initiated and completed 5 weeks later.

ash and underlying soils react to dewatering. This knowledge can only be obtained from inside the pond itself. The degree of stratification and layering of the ash alone has proven to be highly influential to the ease or difficulty of draining ash. This is a condition that can only be evaluated in place.

It is therefore best practice to conduct pilot pumping tests to evaluate the hydraulic conductivity of the ash, the radius of influence, and the achievable well (or wellpoint) yield from properly built and representative production wells (or wellpoints). The hydraulic conductivity dictates the rate at which the pond can be drained. The spacing between devices is based on the radius of influence. And a representative dewatering device provides a good indication of how many of them will be needed for full-scale dewatering. The pilot pumping tests should be performed with multiple wells (wellpoints) because single borehole permeability tests can be highly misleading.

The ultimate demonstration with a pilot pumping test is to dig a test pit or walk a piece of equipment out onto the ash. Water levels, pore water suction, in-place shear strength, and so on, can be measured, but the successful use of a real piece of equipment is the proof of the pudding.

NEED TO MAP THE POND

The typical pond has a finer and a coarser end depending on the location of the sluice pipes and the outfalls. The coarse end is bottom ash, which may be drained simply with sump wells. The finest end will be so fine that the ash appears to be like clay with no “free” water, and cannot be improved by dewatering techniques. The bulk of the pond will be typically wet, runny, unstable fly ash. This material may be considered the problematic material, but the good news is that this material is typically highly responsive to dewatering techniques. The rule of thumb is if it will run, it will drain. It is key to map those transitions within the pond when evaluating what can be achieved and how.

Once the hydraulic conductivity, radius of influence, and yield of properly constructed dewatering devices can be determined, a more specific plan can be formulated. Wellpoints will typically be used when the thickness of the saturated ash is relatively thin or the ash is relatively fine and closely spaced; lower yielding pick-up points are warranted. Wellpoints are relatively inexpensive on a unit price basis, but they are limited by their suction lift or the depth to which they can lower the water beneath the surface header pipe.

Wells may be used when the ash is relatively thick and permeable and the dewatering devices can be spaced further apart. Wells are more expensive, but they can yield significant quantities of water. Where there may be coarser strata with depth, wells may be very effective in tapping those “sweet spots” to accelerate drainage of a deeper pond.

Ejector wells may be used for conditions somewhere in between. Ejector wells are appropriate where closely spaced dewatering devices are warranted, but the depth of groundwater lowering is beyond the suction lift capability of a wellpoint system.

Fig. 4: Installed pilot wellpoint system. Pilot pumping tests provide critical information pertaining to the hydrogeological behavior of the pond necessary for developing a pre-drainage plan.

Fig. 5: Typical runny behavior of wet fly ash. This behavior is actually a good sign. If the material behaves in this manner, it will be responsive to predrainage dewatering.

Fig. 6: Deep well installation from pond perimeter to provide deep pressure relief to sandy alluvial soil that immediately underlies the ash. If this source of recharge is not depressurized, it will result in resaturation and subsequent destabilization of the ash at depth.

Fig. 7: Excavation to natural pond clay bottom, achieved safely and on schedule with pre-drainage dewatering. Courtesy Glover Construction Company.

Regardless of the type of system used, variability of the ash conditions must be considered in the design. Ash varies from site to site, but also varies significantly within each pond. The dewatering devices must be built with the water transmitting capacity to pump whatever the ash will yield. On a recent clean closure, Moretrench installed wellpoints that yielded generally between 0.5 and 15 gpm. In coarser areas of the pond, where the ash will give up as much as 15 gpm, it is imperative to pump it. Time is of the essence. What that means in the context of pre-draining ash ponds is simply this: pump as much water from the ash as you can every day. Don't let the dewatering devices restrict you if the ash will release the water.

The excavation/grading plan must mesh well with the dewatering installation. The ultimate goal is not to dewater the ash, but to excavate or grade it. The dewatering system must conform to the bigger site picture. Plastic pipes and excavators don't coexist well. The best approach is to install the system, let it do its work, and remove it immediately prior to excavation. This approach needs time for the installation of the dewatering system, drainage of the ash, and excavation/grading of the ash to occur linearly, not coincidentally. If time is available, say, while the cap or closure plan is still under design, that is time when you could be draining water out of the ash. Use the time wisely.

CONCLUSIONS

With a properly conducted evaluation of the ash and the subsurface conditions and pilot testing, appropriately designed and installed watering devices, and comprehensive monitoring and evaluation of the results, pre-drainage dewatering works very well. If it can run, it will respond nicely to predrainage techniques. But while considerably faster than rim ditching and sumping, dewatering still takes time. As the clock continues to tick, plan early and use time to your benefit. ❖

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RESTOREAIR CARBON PASSIVATION TECHNOLOGY

Next-Generation Tools to Mitigate Impact of Sorbent Injection on Fly Ash Quality

By Rafic Minkara, Ph.D., P.E.

Residual unburned carbon in fly ash has long been the most common barrier to using ash in high-value concrete applications. Technologies to remove residual carbon or neutralize its effects have been developed and deployed for nearly two decades to provide fly ash that would not interfere with air entrainment in concrete.

Recent changes in environmental regulations have increased the need to deal with carbon in ash. The U.S. Environmental Protection Agency's Mercury and Air Toxics Standards (MATS) final rule was enacted in December 2011 and required coal-fueled power plants to control mercury emissions by April 2015. States were allowed to grant 1-year extensions until 2016 and certain critical units are allowed to delay compliance until 2017 by EPA administrative order.

Power plant owners have undertaken a variety of strategies for MATS compliance, including switching fuel and changing operations of existing emissions control equipment such as flue gas desulfurization scrubbers. A major compliance strategy involves the injection of powdered activated carbon (PAC) into flue gas streams. PAC acts as a sorbent to capture mercury. However, the addition of this highly reactive form of carbon with highly adsorptive surface area can create a barrier for fly ash use in concrete if PAC is collected with the ash in a common particulate collection system.

Headwaters Resources, America's largest manager and marketer of coal combustion products, is currently deploying RestoreAir®, the next generation of carbon mitigation technology. Developed to be economical and more precisely controlled than previous generations of carbon mitigation technologies, RestoreAir is already installed at 15 power plant locations, with 16 more in evaluation, design, or scheduled for installation. The technology's effectiveness derives from the use of an improved reagent, a robust reagent injection system and a new patent-pending ash activity sensor that represents a step change in how the negative effect of carbon in concrete-grade fly ash is measured and mitigated.

RESIDUAL CARBON MITIGATION VARIABILITY

There is no "one-size-fits-all" solution for mitigation of carbon in ash. Coal-fueled power plants consume a range of coal types in boiler and emissions control configurations that vary widely from facility to facility.

First-generation carbon mitigation strategies approached this variability in two ways. Carbon removal technologies addressed the problem by eliminating the residual carbon through separation or combustion. These technologies required high capital expenditures and were best suited for power plants with high levels of residual carbon in ash. Ash with lower carbon levels could be treated chemically at much lower expense, leaving the carbon intact but neutralizing its effects on air entrainment when used in concrete.

PAC now being added for mercury control presents different challenges when it is present in fly ash. Activated carbon is much more adsorptive than unburned coal with a high affinity to adsorb air-entraining agents (AEAs) that are used in concrete production. These characteristics are the result of activated carbon's complex pore structure (Fig. 1). Mercury is sequestered in

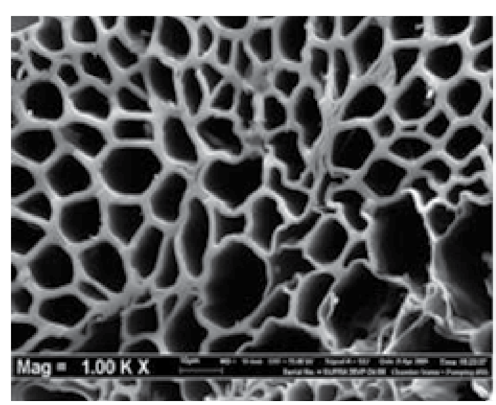

Fig. 1: Micrograph of PAC particle.

very small portions of the carbon structure, but there remain ample pores and surface areas available to adsorb other compounds, including AEAs from fresh concrete mixtures.

Additionally, PACs used for mercury control are not created equal. Figure 2 shows high variability in the impact of two different PAC samples on potential air entrainment demand as measured by foam index testing.

LIMITATIONS OF TRADITIONAL TESTING

Variability in plant configurations, ash composition, and PAC characteristics are not the only challenges facing first-generation carbon mitigation technologies. Imprecise and cumbersome test methods for determining carbon impact on ash complicate the day-to-day operation of ash treatment operations.

Traditionally, there are three methods of assessing residual carbon in fly ash and evaluating its impact when used in concrete. Loss on ignition (LOI) testing is used to determine the mass percentage of carbon that remains in an ash sample. But LOI testing provides no information regarding the form of the carbon or how reactive it will be in the presence of AEAs. A more comprehensive approach to evaluating the impact of carbon-containing ash on concrete mixtures involves preparing fresh mortar or concrete specimens with cement, fly ash, and aggregates then evaluating changes in their air content over an extended period of time. This process is more cumbersome and less suited to identifying the variability of ash performance day-to-day or even hour-to-hour in an operational setting. Also, cement hydration, mixture rheology, and the manual handling of the fresh mortar specimens affect air in mortar measurements for the purpose of evaluating the impact of carbon on air entrainment.

The most common method of determining carbon impact on ash destined for concrete use is the foam index test. This simple test involves placing 200 mL of water and 40 grams of ash in a blender or glass jar. An AEA preferred in the local market is added with a syringe or a dropper a few drops at a time. The solution is mixed for

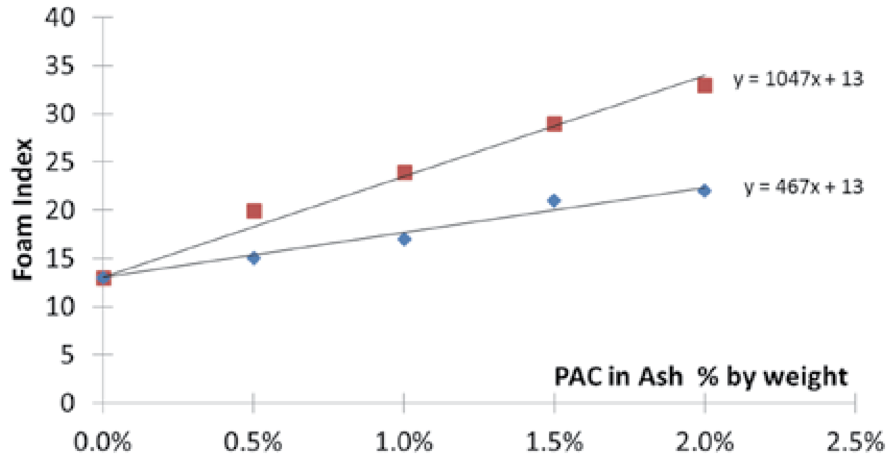

Fig. 2: Number of air-entrainment agent drops needed to create foam in ash/water slurry containing PAC.

10 seconds and the operator performing the test watches for foam development on the surface of slurry. The steps are repeated until a stable layer of air bubbles is formed and the number of "drops" required to allow air entrainment is noted.

Use of the foam index test frequently results in imprecise measurements due to its inherent variability and subjectivity, resulting in inadequate quality assurance and quality control practices.

RESTOREAIR'S THREE-PRONGED APPROACH

The next-generation RestoreAir technology makes significant improvements to all three of the key factors for effective carbon mitigation: the mitigation reagent itself, the inline ash treatment system, and the measurement method for determining reagent dosage and quality control.

RestoreAir's reagent has been reformulated to improve dispersion and create greater affinity to adsorb on activated carbon. When applied to fly ash, the reagent saturates the activated carbon surfaces with a sacrificial agent to prevent the carbon from attracting AEAs used in concrete. The reagent features a tamed dose-response function to accommodate variability in carbon levels.

An inline ash treatment system has been developed to provide accurate and uniform distribution of reagent as it is applied to fly ash. The next-generation system can also be fully automated, significantly reducing the potential for operator error.

Finally, a new patent-pending ash activity sensor has been developed to measure the adsorption potential of ash containing PAC. This sensor technology can be used for quality assurance (QA) to qualify ash for marketing, to determine reagent dosage, and for quality control (QC) of treated ash.

The RestoreAir system package is customizable to address specific power plant configurations and conditions. The system consists of ash handling components that can easily fit between the bottom of the ash silo and existing load-out. The RestoreAir ash handling system provides a consistent ash flow to assurance uniform distribution of reagent on treated ash. Ash handling equipment and components are customized to fit the silo space and match the site needs. Power plants that show low variability in fly ash carbon composition or that use PAC less aggressively can use basic off-the-shelf RestoreAir sytem components. Power plants using PAC aggressively or that have high variability in ash quality as a result of swings in plant load may require customization and a fully automated and robust treatment system.

RESTOREAIR SYSTEM FIELD RESULTS

A total of 15 RestoreAir systems will be in service at the end of 2015. Four systems are scheduled for installation during the winter of 2016 and a dozen more are in the evaluation and design stages. Reagent dosages on installed systems have been averaging between 1 and 2 lb/ton of ash and are expected to be less than 5 lb/ton for the most adsorptive fly ashes (see Table 1).

Improvements in ash characterization and flow control during reagent application have helped eliminate uneven treatment that was common in first-generation carbon mitigation systems. Figure 3 shows the consistency of RestoreAir system performance as measured by foam index testing, while Table 2 shows concrete testing results. RestoreAir treatment of ash containing PAC restored the AEA dosage to the same level expected with ash containing no activated carbon.

NEW SORBSENSOR—FLY ASH SORPTION TESTER

Headwaters Resources is now beginning deployment of the first automated instrumentation designed to provide more accurate and dependable measurement of ash quality than foam index testing. The patent-pending SorbSensor® uses well-understood adsorption principles and fluorescence spectroscopy to analyze ash samples and determine the adsorption potential for optimum reagent dosage rates.

This breakthrough technology overcomes the variability inherent in foam index testing by eliminating operator subjectivity and providing more accurate measurements of AEA adsorption potential. Like many surfactants, AEAs contain double conjugated bonds that get excited by ultraviolet light and fluoresce a different wavelength light that can be detected by optical sensors. The fluorescence intensity is proportional to the concentration of the compound.

Using fluorescence-sensing technology, SorbSensor can determine the adsorption potential of any ash sample using single-point isotherm measurement or breakthrough analysis to provide more accurate and repeatable characterization of adsorption potential than the traditional manual foam index testing. The SorbSensor outputs can be calibrated to calculate any of the traditional foam index numbers for user convenience.

The SorbSensor instrument now in production (see Fig. 5) can be used for quality assurance or for research activities. It can be semi-automated for quality assurance activities at power plant sites. It can also be integrated in an automated RestoreAir system for treatment process quality control.

TABLE 1: REAGENT DOSAGES FOR VARIOUS ASHES WITH POWDERED ACTIVATED CARBON (PAC) AND/OR UNBURNED CARBON (UBC)

Material	Carbon, %	Initial foam index	Reagent dosage, lb/ton	Final foam index
C-Ash (PAC)	0.1	37	0.4	9
C-Ash (PAC)	0.8	37	1.0	12
C-Ash (PAC)	0.5	27	1.9	7
C-Ash (PAC + UBC)	1.4	78	1.9	7
F-Ash (PAC +UBC)	2.9	28	1.0	15
F-Ash (UBC)	0.5	30	1.3	9
F-Ash (UBC)	1.8	25	1.9	7
F-Ash (PAC+UBC)	3.5	61	2.3	6

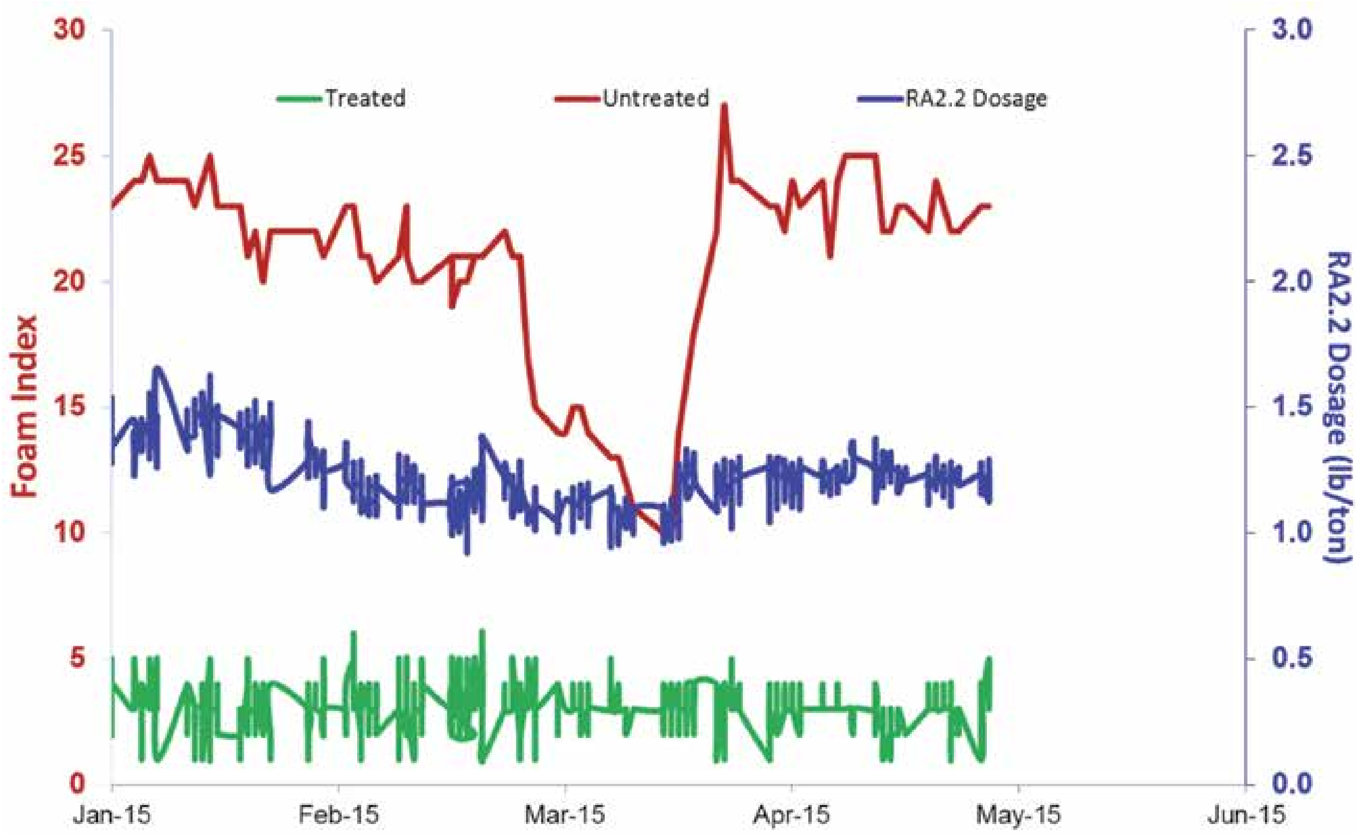

Fig. 3: RestoreAir system performance results

TABLE 2: RESTOREAIR CONCRETE TESTING RESULTS

Concrete testing parameter	Control	Ash	Ash with PAC	
	Cement	No PAC	Untreated	Treated RA 2.2
Foam index (MBVR)	—	3	18	5
AEA (MBVR) dosage (oz/cw)	1.2	1.4	4.2	1.7
Air content (6 ± 1%)	7.0	7.0	6.3	5.8
Water-cement ratio (*w*/*c*)	0.53	0.50	0.49	0.49
Slump, in. (6 ± 1)	6.25	6.0	6.25	5.75
7-day, psi	3433	3689	3592	3918
28-day, psi	4594	4802	4764	4908

CONCLUSIONS

The addition of PAC to fly ash has led to the development of next-generation carbon mitigation tools that will ensure continued availability of ash for concrete production. The associated improvements in reagent chemistry, material handing systems, and testing instrumentation represent a major step change in ash quality assurance for coal-fueled power plants everywhere. ❖

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TRIBO-ELECTROSTATIC BENEFICIATION OF LANDFILLED AND PONDED FLY ASH

By Lewis Baker, Abhishek Gupta, Stephen Gasiorowski, and Frank Hrach

The American Coal Ash Association (ACAA) annual survey of production and use of coal fly ash reports that between 1966 and 2011, over 2.3 billion short tons of fly ash were produced by coal-fired utility boilers.[1] Of this amount, approximately 625 million tons have been beneficially used, mostly for cement and concrete production. However, the remaining 1.7+ billion tons are primarily found in landfills or filled ponded impoundments. While use rates for freshly generated fly ash have increased considerably over recent years, with current rates near 45%, approximately 40 million tons of fly ash continue to be disposed of annually. While use rates in Europe have been much higher than in the United States, considerable volumes of fly ash have also been stored in landfills and impoundments in some European countries.

Recently, interest in recovering this disposed material has increased, partially due to the demand for high-quality fly ash for concrete and cement production during a period of reduced production as coal-fired power generation has decreased in Europe and North America. Concerns about the long-term environmental impact of such landfills are also prompting utilities to find beneficial use applications for this stored ash.

LANDFILLED ASH QUALITY AND REQUIRED BENEFICIATION

While some of this stored fly ash may be suitable for beneficial use as initially excavated, the vast majority will require some processing to meet quality standards for cement or concrete production. Because the material has been typically wetted to enable handling and compaction while avoiding airborne dust generation, drying and deagglomeration is a necessary requirement for use in concrete because concrete producers will want to continue the practice of batching fly ash as a dry, fine powder. However, assuring the chemical composition of the ash meets specifications—most notably the carbon content, measured as loss on ignition (LOI)—is a greater challenge. As fly ash use has increased in the last 20+ years, most "in-spec" ash has been beneficially used, and the off-quality ash disposed. Thus, LOI reduction will be a requirement for using the vast majority of fly ash recoverable from utility impoundments.

LOI REDUCTION BY TRIBOELECTRIC SEPARATION

While other researchers have used combustion techniques and flotation processes for LOI reduction of recovered landfilled and ponded fly ash, ST Equipment and Technologies (STET) has found that its unique triboelectrostatic belt separation system, long used for beneficiation of freshly generated fly ash, is also effective on recovered ash after suitable drying and deagglomeration.

STET researchers have tested the triboelectrostatic separation behavior of dried landfilled ash from several fly ash landfills in the Americas and Europe. This recovered ash separated very similarly to freshly generated ash with one surprising difference: the particle charging was reversed from that of fresh ash, with the carbon charging negative in relation to the mineral.[2] Other researchers of electrostatic separation of fly ash carbon have also observed this phenomenon.[3-5] The polarity of the STET triboelectrostatic separator can easily be adjusted to allow rejection of negatively charged carbon from dried landfilled fly ash sources. No special modifications to the separator design or controls are necessary to accommodate this phenomena.

TECHNOLOGY OVERVIEW—FLY ASH CARBON SEPARATION

In the STET carbon separator (Fig. 1), material is fed into the thin gap between two parallel planar electrodes. The particles are triboelectrically charged by interparticle contact. The positively charged carbon and the negatively charged mineral (in freshly generated ash that has not been wetted and dried) are attracted to opposite electrodes. The particles are then swept up by a continuous moving belt and conveyed in opposite directions. The belt moves the particles adjacent to each electrode toward opposite ends of the separator. The high belt speed also enables very high throughputs up to 36 tons per hour on a single separator. The small gap, high-voltage field, counter—current flow, vigorous particle-particle agitation, and self-cleaning action of the belt on the electrodes are the critical features of the STET separator. By controlling various process parameters, such as belt speed, feed point, and feed rate, the STET process produces low LOI fly ash at carbon contents of less than 1.5 to 4.5% from feed fly ashes ranging in LOI from 4% to over 25%.

The separator design is relatively simple and compact. A machine designed to process 40 tons per hour is approximately 30 ft (9 m) long, 5 ft (1.5 m) wide, and 9 ft (2.75 m) tall. The belt and associated rollers are the only moving parts. The electrodes are stationary and composed of an appropriately durable material. The belt is made of nonconductive plastic. The separator's power consumption is about 1 kilowatt-hour per ton of material processed with most of the power consumed by two motors driving the belt.

The process is entirely dry, requires no additional materials other than the fly ash, and produces no waste water or air emissions. The recovered materials consist of fly ash reduced in carbon content to levels suitable for use as a pozzolanic admixture in concrete, and a high-carbon fraction useful as fuel. Use of both product streams provides a 100% solution to fly ash disposal problems.

PROASH RECOVERED FROM LANDFILLS

Four sources of ash were obtained from landfills: Sample A from a power plant located in the United Kingdom and Samples B, C, and D from the United States. All these samples consisted of ash from the combustion of bituminous coal by large utility boilers. Due to the intermingling of material in the landfills, no further information is available concerning specific coal source or combustion conditions.

The samples as received by STET contained between 15 and 27% water, as is typical for landfilled material. The samples also contained varying amounts of large >1/8 in. (3 mm) material. To prepare the samples for carbon separation, the large debris was removed by screening and the samples then dried and deagglomerated prior to carbon beneficiation. Several methods for drying/deagglomeration have been evaluated at the pilot scale to optimize the overall process. STET has selected an industrially proven feed processing system that offers simultaneous drying and deagglomeration necessary for effective electrostatic separation. A general process flowchart is presented in Fig. 2.

The properties of the prepared samples were well within the range of fly ash obtained directly from normal utility boilers. The most relevant properties for both the separator feeds and products are summarized in Table 2, along with recovered product.

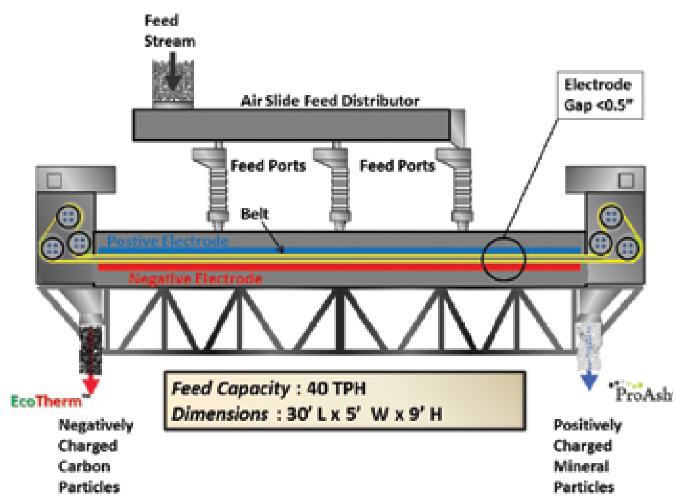

Fig. 1: STET separator processing dried, landfilled fly ash

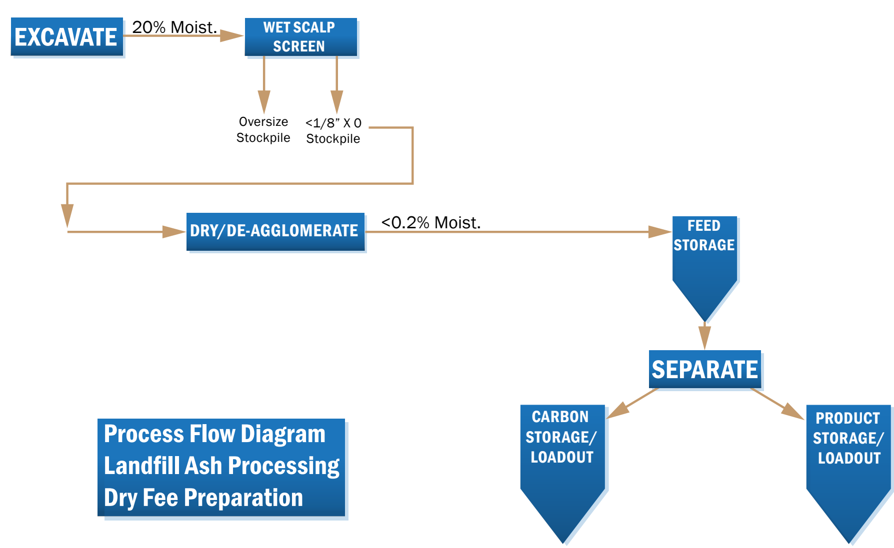

Fig. 2: Process flow diagram

CARBON SEPARATION

Carbon reduction trials using the STET triboelectric belt separator resulted in very good recovery of low-LOI products from all four landfill fly ash sources. The reverse charging of the carbon as discussed previously did not degrade the separation in any way as compared to processing fresh ash.

The properties of the low-LOI fly ash recovered using the STET process for both freshly collected ash from the boiler and ash recovered from the landfill is summarized in Table 1. The results show that the product quality for ProAsh® produced from landfilled material is equivalent to product produced from fresh fly ash sources.

PERFORMANCE IN CONCRETE

The properties of the ProAsh generated from the reclaimed landfill material were compared to that of ProAsh produced from fresh fly ash generated by the utility boilers from the same location. The processed reclaimed ash meets all the specifications of ASTM C618 and AASHTO M 250 standards. Table 2 summarizes the chemistry for samples from two of the sources showing the insignificant difference between the fresh and reclaimed material.

Strength development of a 20% substitution of the low-LOI fly ash in a mortar containing 600 lb/yd^3 cementitious material (see Table 3) showed the ProAsh product derived from landfilled ash yielded mortars with strength comparable to mortars produced using ProAsh from fresh fly ash produced at the same location. The end product of the beneficiated reclaimed ash would support high-end uses in the concrete industry consistent with the highly valuable position ProAsh enjoys in the markets it currently serves.

PROCESS ECONOMICS

The availability of low-cost natural gas in the United States greatly enhances the economics of drying processes, including the drying of wetted fly ash from landfills. Table 4 summarizes the fuel costs for operations in the United States for 15% and 20% moisture contents. Typical inefficiencies of drying are included in the calculated values. Costs are based on the mass of material after drying. The incremental costs for drying fly ash for STET triboelectrostatic separation processing are relatively low.

Even with the addition of feed drying costs, the STET separation process offers a low-cost, industrially proven process for LOI reduction of landfilled fly ash. The STET process for reclaimed fly ash is one-third to one-half of the capital cost compared to combustion-based systems. The STET process for reclaimed fly ash also has significantly lower emissions to the environment compared to combustion or flotation-based systems. Because the only additional air emission source to the standard STET process installation is a natural gas-fired dryer, permitting it would be relatively simple.

RECOVERED FUEL VALUE OF HIGH-CARBON FLY ASH

In addition to the low-carbon product for use in concrete—brand-named ProAsh—the STET separation process also

TABLE 1: PROPERTIES OF FEED AND RECOVERED PROASH

Feed sample to separator	LOI, %	ProAsh LOI, %	ProAsh fineness, % +325 mesh	ProAsh mass yield, %
Fresh A	10.2	3.6	23	84
Landfilled A	11.1	3.6	20	80
Fresh B	5.3	2.0	13	86
Landfilled B	7.1	2.0	15	65
Fresh C	4.7	2.6	16	82
Landfilled C	5.7	2.5	23	72
Landfilled D	10.8	3.0	25	80

TABLE 2: ASH CHEMISTRY OF LOW-LOI ASH

Material source	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	K_2O	Na_2O	SO_3
Fresh B	51.60	24.70	9.9	2.22	0.85	2.19	0.28	0.09
Landfilled B	50.40	25.00	9.3	3.04	0.85	2.41	0.21	0.11
Fresh C	47.7	23.4	10.8	5.6	1.0	1.9	1.1	0.03
Landfilled C	48.5	26.5	11.5	1.8	0.86	2.39	0.18	0.02

TABLE 3: COMPRESSIVE STRENGTH OF MORTAR CYLINDERS

	7-day compressive strength, % of fresh ash control	28-day compressive strength, % of fresh ash control
Fresh B	100	100
Landfilled B	107	113
Fresh C	100	100
Landfilled C	97	99

TABLE 4: DRYING COSTS ON BASIS OF DRIED MASS

Moisture content, %	Heat requirement KWhr/T wet basis	Drying cost/T dry basis (natural gas cost $3.45/mmBtu)
15	165	$ 2.28
20	217	$ 3.19

recovers otherwise wasted unburned carbon in the form of carbon-rich fly ash, branded EcoTherm™. EcoTherm has significant fuel value and can easily be returned to the electric power plant using the STET EcoTherm Return system to reduce the coal use at the plant. When EcoTherm is burned in the utility boiler, the energy from combustion is converted to high-pressure/high-temperature steam and then to electricity at the same efficiency as coal, typically 35%. The conversion of the recovered thermal energy to electricity in the STET EcoTherm Return system is two to three times higher than that of the competitive technology where the energy is recovered as low-grade heat in the form of hot water, which is circulated to the boiler feed water system. EcoTherm is also used as a source of alumina in cement kilns, displacing the more expensive bauxite, which is usually transported long distances. Using the high-carbon EcoTherm ash either at a power plant or a cement kiln maximizes the energy recovery from the delivered coal, reducing the need to mine and transport additional fuel to the facilities.

STET's Talen Energy Brandon Shores, SMEPA R.D. Morrow, NBP Belledune, RWEnpower Didcot, EDF Energy West Burton, RWEnpower Aberthaw, and the Korea South-East Power fly ash plants all include EcoTherm Return systems.

STET ASH PROCESSING FACILITIES

STET's separation process has been used commercially since 1995 for fly ash beneficiation and has generated over 20 million tons of high-quality fly ash for concrete production. Controlled low-LOI ProAsh is currently produced with STET's technology at 12 power stations throughout the United States, Canada, the United Kingdom, Poland, and the Republic of Korea. ProAsh fly ash has been approved for use by more than 20 state highway authorities, as well as many other specification agencies. ProAsh has also been certified under the Canadian Standards Association and EN 450:2005 quality standards in Europe. Ash processing facilities using STET technology are listed in Table 5.

CONCLUSIONS

After suitable scalping of large material, drying, and deagglomeration, fly ash recovered from utility plant landfills can be reduced in carbon content using the commercialized STET triboelectric belt separator. The quality of the fly ash product, ProAsh, using the STET system on reclaimed landfill material, is equivalent to ProAsh produced from fresh feed fly ash. The ProAsh product is very well-suited and proven in concrete production. The recovery and beneficiation of landfilled ash will provide a continuing supply of high-quality ash for concrete producers in spite of the reduced production of "fresh" ash as coal-fired utilities reduce generation. Additionally, power plants that need to remove ash from landfills to meet changing environmental regulations will be able to use the process to alter a waste product liability into a valuable raw material for concrete producers. The STET separation process with feed preprocessing equipment for drying and deagglomerating landfilled fly ash is an attractive option for ash beneficiation with significantly lower cost and lower emissions compared to other combustion- and flotation-based systems. ❖

REFERENCES

1. American Coal Ash Coal Combustion Products and Use Statistics, http://www.acaa-usa.org/Publications/Production-Use-Reports.

2. ST Internal Report, Aug. 1995.

3. Li, T. X.; Schaefer, J. L.; Ban, H.; Neathery, J. K.; and Stencel, J. M., "Dry Beneficiation Processing of Combustion Fly Ash," *Proceedings of the DOE Conference on Unburned Carbon on Utility Fly Ash*, Pittsburgh, PA, May 19-20, 1998.

4. Baltrus, J. P.; Diehl, J. R.; Soong, Y.; and Sands, W., "Triboelectrostatic Separation of Fly Ash and Charge Reversal," *Fuel*, V. 81, 2002, pp. 757-762.

5. Cangialosi, F.; Notarnicola, M.; Liberti, L.; and Stencel, J., "The Role of Weathering on Fly Ash Charge Distribution during Triboelectrostatic Beneficiation," *Journal of Hazardous Materials*, V. 164, 2009, pp. 683-688.

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TABLE 5: FLY ASH PROCESSING FACILITIES USING STET SEPARATION TECHNOLOGY

Utility and power station	Location	Start of commercial operations	Facility details
Duke Energy—Roxboro Station	North Carolina	Sept. 1997	2 separators
Talen Energy—Brandon Shores Station	Maryland	Apr. 1999	2 separators 35,000 ton storage dome Ecotherm Return 2008
ScotAsh (Lafarge / Scottish Power Joint Venture)—Longannet Station	Scotland, UK	Oct. 2002	1 separator
Jacksonville Electric Authority—St. John's River Power Park, FL	Florida	May 2003	2 separators Coal/petcoke blends Ammonia removal
South Mississippi Electric Power Authority R.D. Morrow Station	Mississippi	Jan. 2005	1 separator Ecotherm return
New Brunswick Power Company Belledune Station	New Brunswick, Canada	Apr. 2005	1 separator Coal/petcoke blends Ecotherm return
RWE npower Didcot Station	England, UK	Aug. 2005	1 separator Ecotherm return
Talen Energy Brunner Island Station	Pennsylvania	Dec. 2006	2 separators 40,000 ton storage dome
Tampa Electric Co. Big Bend Station	Florida	Apr. 2008	3 separators, double pass 25,000 ton storage dome Ammonia removal
RWE npower Aberthaw Station (Lafarge Cement UK)	Wales, UK	Sept. 2008	1 separator Ammonia removal Ecotherm return
EDF Energy West Burton Station (Lafarge Cement UK, Cemex)	England, UK	Oct. 2008	1 separator Ecotherm return
ZGP (Lafarge Cement Poland / Ciech Janikosoda JV)	Poland	Mar. 2010	1 separator
Korea South-East Power Yeongheung Units 5&6	South Korea	Sept. 2014	1 separator Ecotherm return
PGNiG Termika-Siekierki	Poland	Scheduled 2016	1 separator Ecotherm return
To Be Announced	Poland	Scheduled 2016	1 separator Ecotherm return

IMPROVING BENEFICIAL USE, ASH CONDITIONING, AND METALS STABILIZATION WITH HIGH-INTENSIVE MIXING

By Keith C. Day, Ethan G. Day, and Edwin C. Kercher

Coal ash and electricity generation: two terms that will remain inseparable for the foreseeable future. With coal remaining a primary American fuel source and new federal disposal guidelines setting a nonhazardous designation, now is the time to invest in new innovations for beneficial reuse of wet and dry fly ash, dry scrubber material, bottom ash, and gypsum, as well as ash conditioning and metals stabilization. The end of a long rulemaking process has provided much-needed stability for the coal combustion product (CCP) market. Coal-fired utilities that act now to establish new and more valuable reuse markets will have a head start and be promoting the sustainability of coal ash.

BENEFICIAL REUSE—PELLETIZATION

New to the utility sector but used for many years in industrial processes, high-intensive, counter-current mixing technology is quickly being revealed as a powerful tool in beneficial use processes, ash conditioning, and metals stabilization. The high-intensive mixer's pelletization capability makes a wide variety of materials more stable, transportable, and valuable in new and wider end-use markets. CCPs already boast a diverse list of markets, ranging from road base and asphalt applications to lightweight aggregates and agricultural placements. However, a changing regulatory landscape driving the closure of impoundments—moving from wet to dry unloading, and injecting sorbents for air pollution control that change ash characteristics—means that beneficial reuse must also adapt. Rule changes, coupled with a downturn in industries such as wallboard production, mean that utilities are fortunate just to avoid landfilling large quantities of material. Exploring new ways to modify raw products can make CCPs more marketable in areas of higher-tiered, more valuable, beneficial reuse.

Using the Lancaster® Products high-intensive mixer, powders, ashes, sludge, and dusts may become uniform, pelletized products designed to meet end-users' size, hardness, and dissolvability needs. The mixer's countercurrent mixing action is a highly effective method for producing consistent uniformity, thoroughness, and rapid mix time, with fewer moistures and additives. Simply stated, countercurrent action occurs when the pan rotates in one direction, while the fixed-position mixing tools rotate in the other. Processing times can be greatly reduced while providing a more homogenous batch. For the purposes of beneficial reuse, a very popular application of the Lancaster® K-Mixer is to first homogenize a mixture and then pelletize or agglomerate the material to form pellets—all in one machine. The rotational speed of the pan and countercurrent speed of the rotor can be varied in countless combinations, allowing for infinite mixing and pelletizing options.

The process of discovering what high-intensive mixing technology could make from a by-product is always interesting. No two fly ashes, bottom ashes, or gypsums are exactly the same. Depending on how a flue gas desulfurization (FGD) gypsum pelletizes, it may be fit for a traditional application, such as a soil amendment, or with the right design, a product for one of several lucrative private consumer markets may be attainable. Pelletizing fly ash, bottom ash, and boiler slag also improves the value of familiar end-use options such as aggregate, and adds new options such as products serving the oil and gas industry. Beneficiate: North America or "BNA"—a product development company that uses the Lancaster Products mixer line in reuse programs—has worked to develop both traditional and nontraditional markets for clients' materials. The first program using this technology, in which BNA has partnered with Kercher Industries, Inc., manufacturer of the Lancaster Products line, is expected to be operational by 2016 in the midwestern United States. The company has also developed a method for combining ponded fly ash with daily production fly ash to make a synthetic aggregate, noting that the future of beneficial reuse will focus on the recovery of coal combustion residuals (CCRs). Also in development, a proppant product made from—among other ingredients—fly ash is expected to be complete in late 2016 and will serve natural gas exploration.

ASH CONDITIONING

As with beneficial reuse, it is also important to consider new, more efficient ways to condition ash. High-intensive mixers have demonstrated the capacity to considerably reduce water use. In a 2013 study, ash produced at a BNA client's power plant was successfully conditioned with 7.6% less water and had a resulting 12% higher density. The industry-standard pug mill in use at the power plant could not compete with the Lancaster mixer, which produced a more uniform, dense and flowable mixture—all while using less water. Less water used means less money spent by the utility. If the ash is destined for a landfill or low-tier beneficial use placement such as mine reclamation, reducing the total tonnage with less water reduces costs and a denser product means less truck transportation and less air space required at the landfill (refer to Fig. 1 and 2). Using technology to find efficiencies like this supports the broader goal of sustaining coal ash as a resource, rather than a waste.

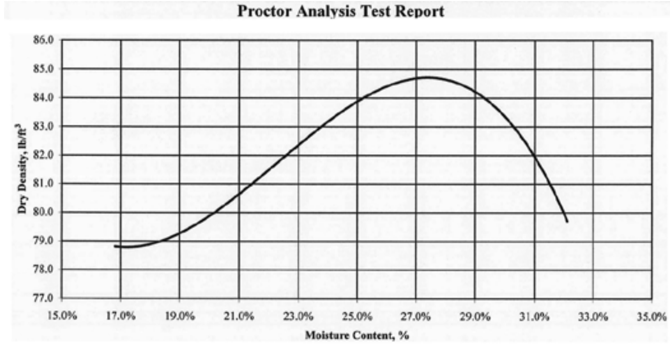

Fig. 1: Standard proctor test; maximum dry density 84.7 lb/ft³; optimum moisture 27.4%

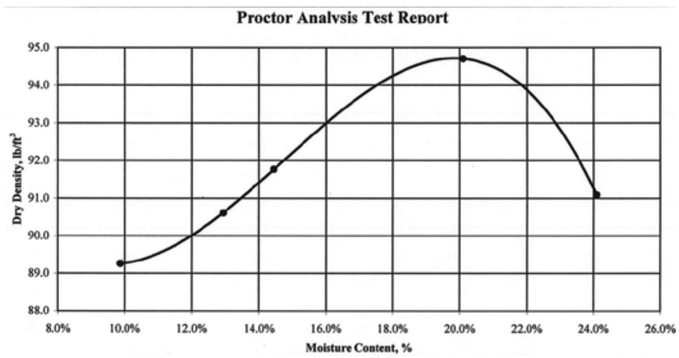

Fig. 2: Proctor with Lancaster Mixer; maximum dry density 94.7 lb/ft³; optimum moisture 19.8%

METALS STABILIZATION

A third way industrial sector technology may soon be benefitting utilities involves metals stabilization—specifically when sodium sorbents are used for controlling air pollutants. BNA's recent study for SOLVAir Solutions again shows the versatile uses of the Lancaster mixer. SOLVAir provided BNA with powder river basin (PRB) and eastern bituminous ash samples at two different dry sorbent injection rates. The sodium levels were found to be 12 and 21%. Using a Lancaster Products K-Lab high-intensive mixer, the ash samples were combined with two different stabilization materials: lime kiln dust (LKD) and sodium silicate. It was determined that two ratios of LKD would be evaluated—5% and 10% additions to the ash—and that two ratios of sodium silicate would also be evaluated at 2% and 5%. The results showed the PRB baseline ash had 0.021 mg/L of leachable arsenic. When mixed with 5% LKD, the leachable arsenic went down to 0.004 mg/L. When ash had 12% sodium in it, the level went up to 1.1 mg/L. When stabilized with 5% LKD, the level went back down to 0.73 mg/L and down to 0.45 mg/L when 10% LKD was used (Fig. 3).

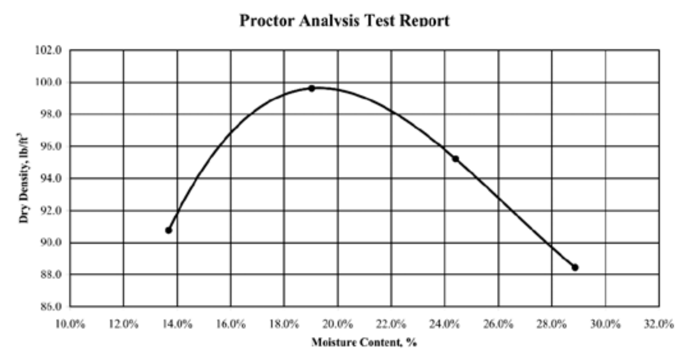

Fig. 3: Proctor density test on ash with 20% trona, 10% LKD; maximum dry density 99.6 lb/ft³; optimum moisture 19.3%

Comparing the same baseline material with 12% trona and using 2% sodium silicate, the 1.1 mg/L was reduced to 0.85 mg/L and at 5%, sodium silicate lowered down to 0.47 mg/L. Leachable arsenic was reduced to very similar levels for the eastern bituminous coal ash.

The way in which utilities interact with coal ash is advancing on two fronts: beneficial reuse and management efficiency. If innovation continues—if new ways to condition ash and stabilize metals are realized, and new markets for beneficial use are secured—coal ash will continue to be accepted and welcomed as a valuable product and a smart alternative to using natural resources. Implementing technologies such as high-intensive mixing will open up new markets for beneficial reuse, thereby integrating coal ash in more segments of industry. ❖

Keith C. Day is the President of Beneficiate: North America. He has worked in the utility sector for 35 years, with a focus on air pollution control and by-product management.

Ethan G. Day is the Vice President of Business Development for Beneficiate: North America.

Edwin C. Kercher is the President of Kercher Industries, Inc.

Fig. 4: Normalweight aggregate made from ponded and daily production coal ash

Fig. 5: Soil amendment made from pelletized FGD gypsum

Fig. 6: Proppants made from fly ash, multiple ingredients

Fig. 7: Soil amendment made from pelletized dry scrubber material (DSM)

CHALLENGES IN FLY ASH BENEFICIAL USE AND OPTIONS FOR INCREASING UTILIZATION

By Melissa Harrison and Christopher Poling

With Mercury Capture Systems, coal-fired electric utilities can eliminate mercury, ammonia, and moisture from their impounded coal combustion products (CCPs), making them safe and viable for use in cement and concrete. With specialized equipment, fly ash loss on ignition contents can be reduced to concrete standards without destroying its glass content. When applied to activated carbons, mercury can be fully removed and the carbon left behind intact. This process can prevent landfilling of these materials by making them suitable for beneficial use, which can exempt materials from regulation under the recently published U.S. Environmental Protection Agency (EPA) final rule, "Disposal of Coal Combustion Residuals from Electric Utilities."

The use of fresh ash or reclaimed impounded ash in these industries depends on its constituents. Moisture, ammonia, and high carbon contents represent obstacles for ready mixed concrete use. Mercury contents represent a challenge for use in cement manufacturing; fly ash that has been dosed with powdered activated carbon (PAC) or other sorbents to control mercury is almost never used in cement manufacturing. Typically, fly ash is more valuable if it meets ASTM requirements for inclusion in ready mixed concrete than when used as a raw material in cement manufacturing.

Rather than excavating impounded ash for landfilling, the impounded fly ash can be used as a raw material in cement manufacturing, assuming no sorbents are included. If sorbents are included, some type of mercury removal will be needed. Since 2005, over 500,000 tons of coal ash from utility impoundments have been recycled by SCB International within the cement industry as a beneficial use. Working with the utilities, we have been able to dewater the impoundments during the non-operational shoulder months. Specialized heavy equipment was used to excavate and stockpile the wet slurry material so that it could dewater and be suitable for hauling by truck or railcar (Fig. 1 and 2). In addition to the recovery of impounded ash, SCB has been able to use freshly generated ashes as part of the recycling process.

Older ash impoundments typically have the benefit of being relatively free of flue gas desulfurization (FGD) materials, activated carbon, or other additives for emissions control. When CCPs are comingled, it becomes very difficult to recycle fly ash economically, it eliminates a potential revenue stream or a cost avoidance, and increases costs as the CCPs accumulate over time. FGD materials mixed with fly ash and fly ashes with high sulfate contents are virtually unusable for cement or concrete. With advanced planning, the utility can handle the CCPs separately and recycle each stream for optimal revenue or cost avoidance.

Without some type of beneficiation, ash with high carbon (from PAC or unburned coal) and/or moisture contents cannot be used in ready mixed concrete. Several systems costing tens of millions of dollars have been installed or are planned to reduce the carbon and moisture contents of both recovered impoundment ashes as well as freshly generated ashes. While performing well, these systems require a very high capital investment and sizable operating footprint. With respect to moisture content of fly ash for concrete, ASTM C618 has begun the discussion of allowing impounded Class F ashes with moisture contents exceeding 3%, but it will take years for any specification modification.

SCB International has taken beneficiation one step further with 'Mercury Capture Systems' (MCS). Our patented system removes mercury while reducing the carbon, moisture, and ammonia contents of a coal ash stream. With careful balancing of our equipment, we can reduce the carbon content without vitrifying the ash to make it viable for concrete.

This same process can be applied to activated carbon, bottom ash, and other industrial dusts. For PAC, we are able to remove the mercury without destroying the activated carbon itself. This creates a viable fuel stream for cement and a potential for reuse as a sorbent at the utility. The equipment has relatively low capital cost and can be made portable.

During a recent demonstration on a granular activated carbon, the mercury reduction was over 99% with material concentration levels starting as high as 240 ppm. The concentrated gas stream, which was processed by our MCS gas reactor, measured up to 8388 ppm mercury at various times (Fig. 3). Also processed

Fig. 1: Impounded ash recovery and loading trucks

was a high-carbon fly ash with 9% loss on ignition (LOI); it was reduced to 1.4% LOI, making it suitable for concrete use.

Most importantly to SCB is that the MCS process produces a concentrated stream of heavy metal residue which is in particulate form. TCLP tests are underway and will confirm previous data sets which conclude the particulates are non-leachable even at these higher concentrations (Table 1).

The MCS gas reactor forces the heavy metals being carried by a gas stream to chemically react with and bond to a specialized chemical reagent. The result of this reaction is a solid particle, which is isolated and collected. The residue can then either be immobilized in concrete or sent for further recovery of the metals. Instead of generating thousands of tons of low-concentration sorbents which must be landfilled, MCS generates a few hundred pounds of concentrated residue. The process allows ash producers to generate a clean, saleable product that is effectively free of mercury and other contaminants.

Utilities can increase cement and concrete use of CCPs by keeping the CCPs separated and realizing the value of each product. Hopefully in the near future, ASTM will allow Class F ashes with higher moisture contents in ready mixed concrete. Until then, fly ashes containing mercury, high carbon contents, and ammonia can be beneficiated with MCS and recycled in greater volumes in cement and concrete.

Mercury Capture Systems is a subsidiary of SCB International providing specialized, full-service equipment design solutions for plant emissions from cement kilns and coal-fired power plants. We have a proven, patented process to remove mercury from dust-free gas streams generated through thermal desorption or from other sources. These solutions provide beneficial removal and isolation of heavy metals found in coal fly ash, activated carbon, clay, and other industrial dusts. SCB can provide proven expertise and unparalleled service to assist in compliance with mercury emissions limits and regulation compliance. ❖

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Fig. 2: Conditioned ash into railcars

Fig. 3: MCS gas reactor

TABLE 1: MCS CONCENTRATED RESIDUE

	MCS residue	
	Liquid	Solid, mg/kg
Total mercury	ND	2360
Metals SM 3120 B		
Arsenic	0.043	147
Barium	0.054	141
Cadmium	ND	49
Chromium	ND	166
Lead	ND	16
Selenium	ND	ND
Silver	ND	514

CARBONBLOCKER: WASTE MANAGEMENT'S PATENTED SOLUTION TO PRESERVING FLY ASH QUALITY AND USE

By Shrief Kabis

Over 15 years ago, FlyAshDirect, now a division of Waste Management (WM), launched an effort to develop a chemical solution that would protect fly ash quality from the negative impacts of carbon. Today, that solution is known as CarbonBlocker™, a patented fly ash chemical beneficiation system provided by WM to a number of utilities throughout the United States and Canada. With more than 12 installations, CarbonBlocker has enabled WM to recycle over 2 million tons of beneficiated fly ash for use in concrete, allowing this valuable resource to avoid disposal.

THE CHALLENGE OF NATURAL CARBON VERSUS POWDER-ACTIVATED CARBON

The challenges associated with fly ash containing elevated or inconsistent levels of unburned or "natural" carbon for use in air-entrained concrete are well-known and attributed to the adsorptive nature of such fly ash carbon to air-entraining admixtures. Natural carbon has been a common nemesis to the beneficial use of ash for many years and became especially apparent in the eastern regions of the United States when the Clean Air Act of 1990 and subsequent use of low-NO_x burners gave rise to some of the first fly ash beneficiation technologies. More recently, due to the EPA MACT rule, powdered activated carbon (PAC) injection systems have become a growing solution for utilities as a means to capture mercury. PAC injection, when used ahead of particulate control systems, cause mercury-laden carbon to comingle with the collected fly ash. PAC-contaminated fly ashes present a significantly more challenging situation than natural carbons for use in air-entrained concrete, as they are far more absorptive due to their extremely high surface area, designed specifically to capture oxidized mercury. Hence, even low concentrations of PAC can render an ash unsuitable for air-entrained concrete and consequently have caused large amounts of previously high-quality ash to be disposed of throughout various parts of the country. An example of this phenomenon has occurred in the state of Illinois, where millions of high-quality fly ash tons have been disposed of due to the effects of PAC.

THE EVOLUTION OF CARBONBLOCKER

Some of the first beneficiation systems in the East used either a form of carbon burnout or separation to remove carbon from the ash. These systems, while effective, often require significant capital, long ramp-up times, special permitting, and are limited in their ability to treat low levels of carbon—that is, less than 6% loss on ignition (LOI). Considering this, WM focused its attention to developing a beneficiation solution that would be relatively easy to implement in under 10 weeks, require very little capital, no permitting, and effectively treat a wide range of carbon levels from 0.5 to 14% LOI. After years of development, WM implemented the first two CarbonBlocker installations at American Electric Power's Clifty Creek Station in 2005 to address ash quality challenges associated with low levels of natural carbon. CarbonBlocker essentially is a two-part system, one of material handling and the other chemistry, where the application of chemistry, occurs in a bulk flow environment in "real time." Another unique aspect is the system imparts chemistry on to fly ash in the dilute phase, as opposed to the dense phase, significantly reducing the amount of chemistry needed relative to other available chemical beneficiation technologies.

The original systems at Clifty Creek imparted a first-generation chemistry developed by Cognis and since then, WM has collaborated with BASF through a joint development effort to develop two new chemical formulations that have expanded the technology's reach to both natural carbon and PAC applications. Illinois, being one of the first states to pass its own mercury control standards, provided WM and BASF an excellent testing ground to achieve this goal. Today, in addition to natural carbon, WM is actively treating and marketing several sources of fly ash negatively impacted by PAC. WM launched the first of these projects in 2012 at Dynegy's Joppa generating station in Joppa, IL—the first system in the United States to our knowledge to successfully beneficiate and market a Class C fly ash containing considerable amounts of PAC that was otherwise unmarketable. With the April 15, 2016, MACT deadline, WM believes several other utilities throughout the nation will continue to experience this challenge.

This article will share the technical benefits that CarbonBlocker has generated in both lab studies and active commercial projects. Test data will specifically demonstrate the ability of CarbonBlocker to treat various carbon-tainted fly ashes with BASF chemistry to deliver stable air performance in air-entrained concrete over extended mixing cycles of up to 60 minutes. Natural and PAC-contaminated fly ash samples used in the study were taken from active coal-fired energy generating stations. Such real-life fly ash samples were collected at power stations that have implemented some of the highest PAC injection rates currently used throughout North America, at 5 lb/MMacf (80 mg/acm).

EXPERIMENTAL

Materials and Methods

Mortar and concrete mixtures contained Type I/II cement and siliceous fine aggregate. A blend of No. 57 and No. 8 limestone was used as the coarse aggregate for concrete batches. Fly ash contaminated with either natural carbon or PAC originated from multiple locations. Table 1 describes some of the characteristics of the fly ashes used in the various studies.

Concrete Mixture Design, Mixing, and Testing

For testing fly ashes that contained natural carbon, laboratory concrete mixtures were designed with a total cementitious content of 564 lb/yd^3 (335 kg/m^3) that included 20% by mass fly ash. For testing with fly ashes containing PAC, laboratory concrete mixtures were designed with a total cementitious content of 600 lb/yd^3 (356 kg/m^3) that included 25% by mass fly ash. Initial slump of concrete was targeted at 5 to 7 in. (125 to 180 mm). Air-entraining admixture was dosed to produce an initial air content of 5 to 7%. Concrete mixing was performed in laboratory-scale rotating drum mixers that were equipped with a controller to adjust the drum speed from 0 to 20 rpm. The concrete mixing cycle was 3 minutes at 20 rpm followed by 3 minutes of rest, followed by 2 minutes at 20 rpm. After the initial mixing cycle, the speed of the mixer was reduced to 3 rpm for a 60-minute period to simulate transport of concrete in a ready mix truck. Slump and air content (pressure method) were measured. Unit weight measurements were performed with each air content measurement. In most cases, slump, air content, and unit weight of the concrete were measured after the initial mixing cycle, again following 30 minutes of slow agitation, and once more following a total of 60 minutes of slow agitation.

Chemical Treatment of Fly Ash

Treated fly ash used for the studies presented herein was prepared either with a lab-scale or pilot-scale treatment system or with the industrial treatment system in place at some power plants. Details of the treated fly ashes are shown in Table 2. Natural carbon Class F (ASTM C618) fly ashes were usually treated with CB chemistry, while PAC-contaminated Class C (ASTM C618) fly ashes were treated with ACB chemistry. Ash J was a PAC-contaminated fly ash that was treated with both CB and ACB chemistries.

Lower dosages of treatment chemistry are required with the natural carbon fly ashes due to the lower adsorption of natural carbon compared to PAC. Fly ash foam index values were reduced as a result of the treatment, and higher treatment dosages usually resulted in a lower fly ash foam index.

RESULTS AND DISCUSSION

Stability of Entrained Air: Fly Ash Contaminated with PAC

Ash J, a PAC-contaminated Class C fly ash, was treated with two dosage levels of either CB or ACB. The treated fly ash was tested for its influence on air stability using the mortar method described in this paper. A synthetic air-entraining admixture was used to generate air in the mortar. The test results for the fly ash treated with

TABLE 1: DESCRIPTION OF FLY ASHES USED IN EVALUATIONS

Identifier	Fly ash class (ASTM C618)	LOI	Fineness	Foam index	PAC injection rate
Ash A	F	2.87%	12.70%	130	Natural carbon
Ash M	F	5.52%	16.00%	50	Natural carbon
Ash C	C	2.36%	9.81%	130	5 lb/MMacf
Ash W	C	2.94%	10.60%	210	5 lb/MMacf
Ash N	C	0.80%	15.27%	135	2.5 lb/ MMacf
Ash J	C	2.70%	14.41%	320	5 lb/MMacf

Note: Chemical admixtures used for the mortar and concrete testing included natural and synthetic air-entraining admixtures (BASF Micro Air® air-entraining admixture, BASF MB-VR™ Standard air-entraining admixture, or Euclid Air Mix 200) and water-reducing admixtures (BASF Pozzolith® 80 water-reducing admixture or Euclid Eucon WR 91).

TABLE 2: FLY ASH TREATMENT

Identifier	Class	Foam index	Treatment chemistry	Treatment chemistry dosage (fl. oz/ton)
Ash A	F	120	CB	5
Ash A	F	45	CB	11.1
Ash C	C	0	ACB	37
Ash C	C	0	ACB	47
Ash W	C	0	ACB	93
Ash N	C	0	ACB	23
Ash J	C	80	CB	69
Ash J	C	0	CB	142
Ash J	C	190	ACB	66
Ash J	C	0	ACB	138

CB appear in Fig. 1 and for the fly ash treated with ACB in Fig. 2. A comparison of the plots indicates that with the use of treated Ash J, the ACB treatment allows for more of a linear response of air content in mortar compared with the CB treatment.

Ash C, a PAC-contaminated Class C fly ash, was treated with 52 oz/ton of CB and 47 oz/ton of ACB. Figure 3 shows the comparison of concrete air results using Micro Air® air-entraining admixture versus Fig. 4, which used MB-VR™ Standard air-entraining admixture. It is clear from these two plots that the concrete that contained fly ash treated with ACB showed a much more stable air content than the concrete that contained fly ash treated with CB, independent of the type of air-entraining admixture.

Petrographic analyses of concrete specimens were completed using methods described in ASTM C457. Values that are typically associated with concrete possessing adequate freezing-and-thawing durability exhibit an air content ≥4.5%, specific surface area ≥600 $in.^2/in.^3$ (24 mm^2/mm^3), and a spacing factor ≤0.008 in. (0.20 mm). The concrete that used for the air void analysis results contained in Table 3 match the concrete air content results in Fig. 3. The results in Table 3 show that treatment of Ash C with CB causes the air void system to become unstable with extended mixing of the concrete. The treatment of Ash C with ACB causes the air void system to improve (higher specific surface and lower spacing factor) with extended mixing of the concrete.

Based on these results, ACB was chosen as the treatment chemistry for PAC-contaminated fly ash. Also, the results from the mortar screening test for air stability correlated well with results from the air contents measured during the extended mixing cycle in concrete, which was considered to be a validation of the mortar screening method.

EFFECT OF TREATMENT CHEMISTRY ON MORTAR AND CONCRETE PERFORMANCE: FLY ASH CONTAINING NATURAL CARBON

Figure 5 shows the results from a study that included no fly ash, untreated Ash A, and Ash A treated with CB. The air content results show that in the presence of the treated fly ash, the air content is greater than that of untreated Ash A. The air content of the mixture containing Ash A treated with 4.9 oz/ton of CB was very similar to the mixture containing no fly ash. In the

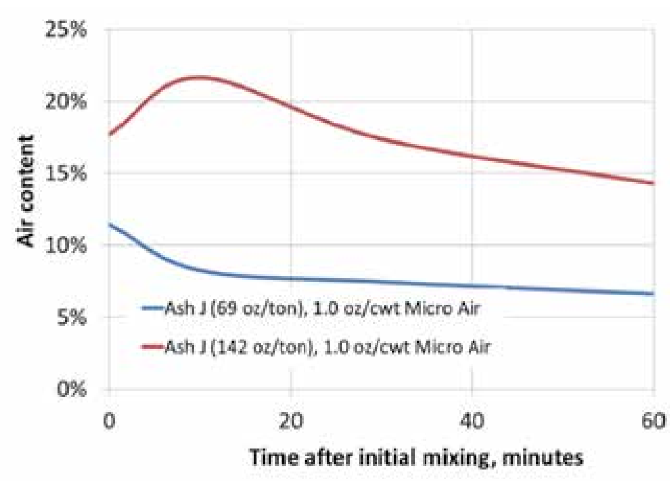


Fig. 1: Stability of entrained air in mortar—Ash J treated with CB (Note: 100 oz/ton = 3.26 mL/kg; 1.0 oz/cwt = 0.65 mL/kg)

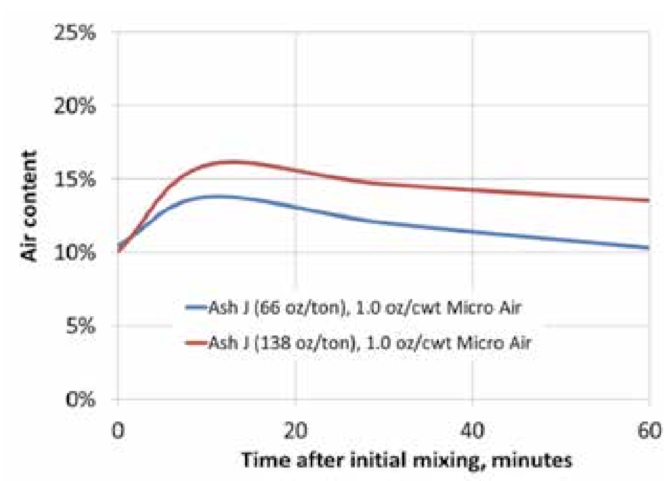


Fig. 2: Stability of entrained air in mortar—Ash J treated with ACB (Note: 100 oz/ton = 3.26 mL/kg; 1.0 oz/cwt = 0.65 mL/kg)

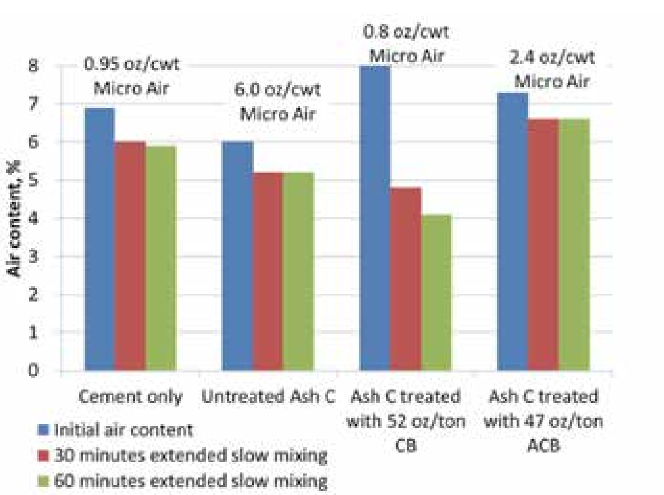


Fig. 3: Stability of entrained air in concrete—Ash C and Micro Air (Note: 100 oz/ton = 3.26 mL/kg; 1.0 oz/cwt = 0.65 mL/kg)

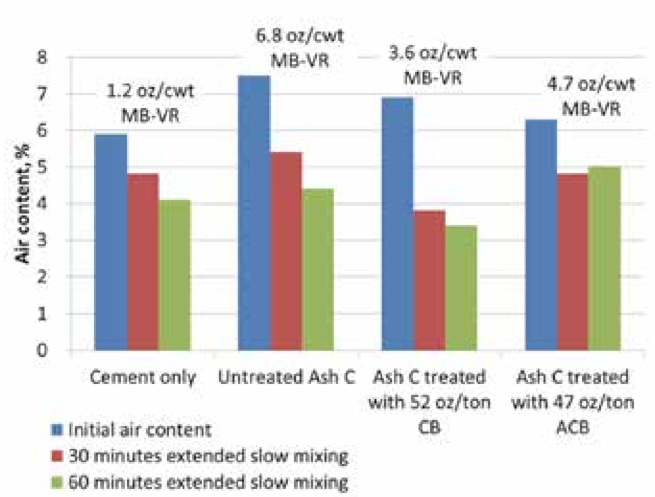


Fig. 4: Stability of entrained concrete—Ash C and MB-VR Standard (Note: 100 oz/ton = 3.26 mL/kg; 1.0 oz/cwt = 0.65 mL/kg)

TABLE 3: PETROGRAPHIC PARAMETERS OF HARDENED CONCRETE (CONCRETE MIXTURES FROM FIG. 3)

		After initial mixing			After 60 minutes agitation		
Concrete description	Micro Air dosage, oz/cwt (mL/kg)	Air content, %	Specific surface area, in.²/in.³ (mm²/mm³)	Spacing factor, in. (mm)	Air content, %	Specific surface area, in.²/in.³ (mm²/mm³)	Spacing factor, in. (mm)
Cement only	0.95 (0.62)	7.4	447 (18)	0.008 (0.20)	6.9	460 (18)	0.008 (0.20)
25% Ash C, untreated	6.0 (3.9)	7.5	614 (24)	0.006 (0.15)	4.2	625 (25)	0.008 (0.20)
25% Ash C, 52 oz/ton (1.7 mL/kg) CB	0.8 (0.5)	7.7	559 (22)	0.006 (0.15)	6.1	335 (13)	0.012 (0.30)
25% Ash C, 47 oz/ton (1.53 mL/kg) ACB	2.4 (1.6)	8.7	499 (20)	0.006 (0.15)	7.4	663 (26)	0.005 (0.13)

concrete mixture containing Ash A treated with 11.1 oz/ton of CB, more entrained air was generated and the trend of air over time was similar to the mixture that contained no fly ash.

Figure 6 shows the results of a concrete study that includes three samples of Ash A treated at the power plant during commercial loading on different days. The samples were treated with 4.2 oz/ton, 5.0 oz/ton, or 4.6 oz/ton of CB. A synthetic air-entraining admixture was used for this study. The results indicate that all three samples generated similar air results and stability.

CONCLUSIONS

Stable entrained air in concrete produced with fly ash that is contaminated with PAC or natural carbon may be difficult to achieve. This work has shown that the beneficiation of such fly ash with CarbonBlocker technology allows the fly ash to be effectively used in air-entrained concrete. For commercial applications, WM and BASF select the appropriate chemistry based on the character of the fly ash, and the treatment dosage can be determined using an analytical method.

CarbonBlocker has provided a commercially viable means to treat fly ashes at over 12 locations since 2005. This technology has been recently improved through the development of two new chemistries to provide a technically and economically viable fly ash beneficiation technology for fly ashes containing either natural carbon or PAC. For more information regarding the contents of this article, please visit **www.flyashdirect.com**. ❖

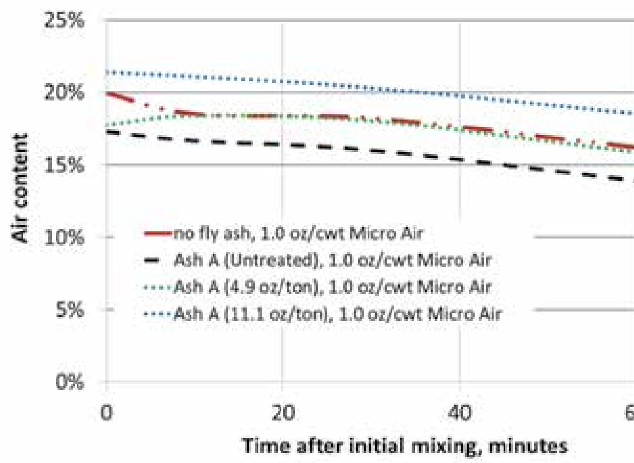


Fig. 5: Stability of entrained air in mortar—Ash A and Micro Air (Note: 100 oz/ton = 3.26 mL/kg 1.0 oz/cwt = 0.65 mL/kg)

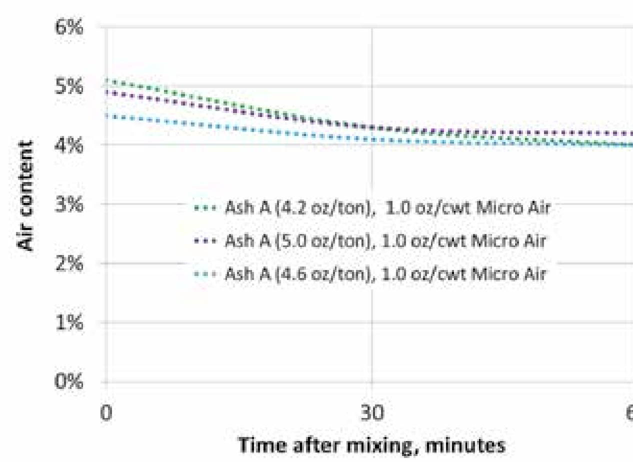
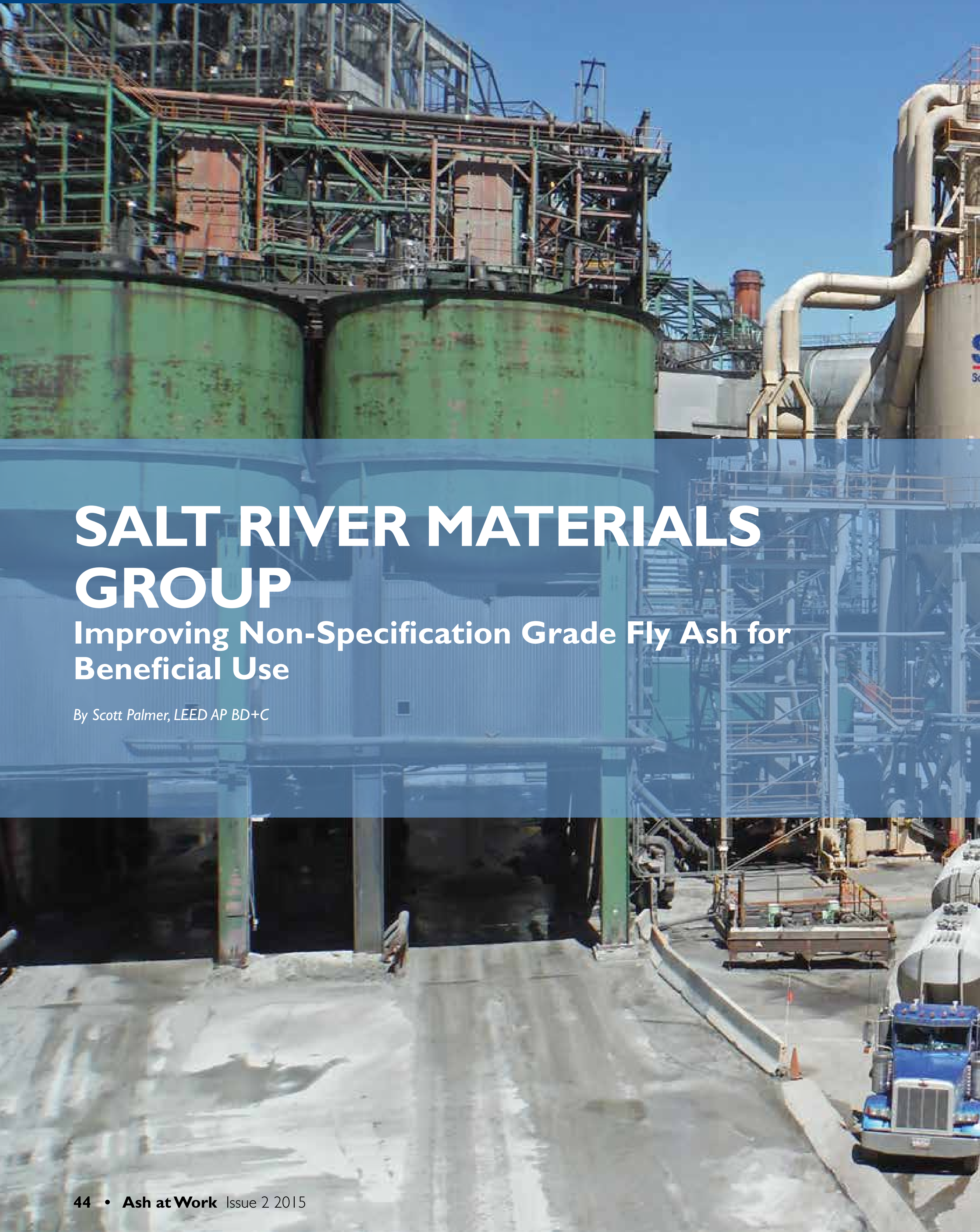


Fig. 6: Stability of entrained air in concrete—Ash A and Micro Air (Note: 100 oz/ton = 3.26 mL/kg; 1.0 oz/cwt = 0.65 mL/kg)

Shrief Kabis is Senior Business Development Manager, CCP Marketing, for Waste Management CCP Solutions. With degrees in both civil and environmental engineering, he has more than 18 years of experience serving the coal burning power industry, specializing in concrete, hydraulic binder and coal fly ash products, and related technologies. He currently oversees the development of new CCP marketing opportunities for WM and is responsible for the advancement of their fly ash chemical beneficiation technology, CarbonBlocker™.



SALT RIVER MATERIALS GROUP

Improving Non-Specification Grade Fly Ash for Beneficial Use

By Scott Palmer, LEED AP BD+C

Imagine for a moment a world without power. Every American and citizens of every modern city and beyond take for granted the ease and access of electricity. Our entire built environment, industries, product manufacturers, and the basis of society require the consistent and reliable distribution of electricity every minute of every day. But how does it happen so seemingly effortlessly? The answer: electric utility companies pulverize and burn coal to generate steam to power turbines that generate electricity. Once the coal is burned, the resulting residual by-product materials that do not combust (fly ash, bottom ash, and so on) must be moved to nearby landfills or disposal ponds unless they can be recycled and beneficially used. Disposal into landfills requires an increased footprint, additional investment and management by the utility, and could become targets for environmentally charged groups.

Alternatively and fortunately, there is a better way…BENEFICIATION! The textbook definition of fly ash beneficiation is the process of making the material more suitable for specific applications. Several companies specialize in beneficiation processes throughout the United States, but Salt River Materials Group (SRMG) is an expert in on-site collection and beneficiation of fly ash and other coal-combustion products (CCPs) within the utility locations where it operates. SRMG has developed long-term relationships with several utilities and over the years, the partnerships have led to extremely high beneficiated ash products' use and extremely little disposal. Additionally, SRMG continues to invest in large capital projects to improve beneficiation as well as the logistics of collecting and delivering quality ash products to the marketplace.

Back in 1985 at the Cholla Power Plant in Joseph City, AZ, SRMG installed the first of what would eventually be several beneficiation facilities in its fly ash supply network. Two more facilities would be added over the next 17 years: a facility at the Four Corners Power Plant in 1997 and another at the San Juan Power Plant in 2002. The installations of these beneficiation facilities, which are uniquely integrated within the power plants and located on-site, require large capital investments. For 30 years SRMG has committed not only to the capital dollars to construct these facilities, but also to the operation and maintenance. As a result, more than 12 million tons of non-specification fly ash, that would have normally been landfilled or sent to disposal ponds, has been recycled for beneficial uses in concrete, concrete products, soil stabilization, and other applications.

Twelve and a half million tons! That's 25,296,244,000 lb (25.3 billion lb) or 261 million ft^3…enough to fill the entire Superdome in New Orleans twice!

Fly ash can also make good concrete even better because pumpability, workability, and durability are improved with the incorporation of fly ash in concrete. Fly ash also makes concrete less permeable (more dense) and helps reduce moisture migration through concrete, as well as mitigating alkali silica reactivity and soluble sulfate deterioration. Virtually every dam construction project or mass concrete placement will be specified with fly ash by engineers because of the slower heat of hydration benefits that fly ash provides. In the recent "green building" movement and the organization of the U.S. Green Building Council and its famous LEED rating system and building checklist, fly ash use in concrete is encouraged and awarded points for its recycled content and ability to be blended with cement in high dosages in efforts to reduce the carbon footprint and life-cycle cost of a building.

Given the multiple benefits for the use of fly ash and the positive effects on the built environment, SRMG continues to invest in beneficiation along with strategically placed locations within its distribution network, in railcars to deliver the material throughout the region and in innovative products that could supplement the demand for fly ash in the future. ❖

Scott Palmer is Market Development Manager for Salt River Materials Group. He serves as a Board Director for Portland Cement Association and Chairman of its Sustainable Development Committee. He served as a Steering Committee Member for the Concrete Home Building Council and the Materials Selection Subcommittee from 2005 to 2009 and was appointed the Board of Trustees for the Building Systems Council of the National Association of Homebuilders. Palmer is also a Founding Board Member of the Green Builder Coalition.

MSW LANDFILLS CAN HELP UTILITIES AVOID LEGAL RISKS OF CCR RULE

By William F. Hodges, P.E.

This October, new federal regulations go into effect concerning the handling of coal combustion residuals (CCR). The new rule, published earlier this year by the U.S. Environmental Protection Agency (EPA), establishes disposal standards, monitoring obligations, and public reporting requirements for CCR, and primarily impacts utility companies that operate CCR landfills. However, the EPA has chosen to regulate CCR as a solid waste under Subtitle D of the Resource and Recovery Act (RCRA), meaning it will have no ability to actually enforce the rule. This is because the RCRA grants enforcement authority to citizens or states through lawsuits. As a result, interpretation and enforcement of the new coal ash rule will occur through civil litigation, most likely pursued by non-governmental organizations (NGOs). In other words, citizens will be able to sue owners or operators of CCR landfills to enforce any of the rule's requirements. It goes without saying that for utilities, this is a major concern.

While states cannot enforce the federal CCR rule, they can choose to add their own rule. However, even if a state chooses not to add its own CCR rule, utilities can still be held responsible for non-compliance because the regulations are self-implementing. The chances of civil litigation occurring under these circumstances are already high, but they are made even more likely by the rule's requirement that owners or operators of CCR landfills must post compliance data on a publicly accessible website. The EPA will require those websites to be up and running when the rule goes into effect in October.

It's safe to assume that utilities that operate CCR landfills are hard at work planning for ways to mitigate risk associated with unpredictable and expensive citizen lawsuits. But whether they know it or not, there is another tool at their disposal that would allow them to avoid that risk altogether. Municipal solid waste (MSW) landfills are exempt under the new CCR rule, and can

provide a sort of "safe harbor" solution for utilities with coal ash disposal needs. The following is from page 21341, Part VI.A.4. of the rule's preamble titled "Municipal Solid Waste Landfills":

"EPA recognizes that there are MSWLFs that either accept CCR for disposal, use CCR for daily cover, or both. Since the proposed and final RCRA subtitle D standards for CCR landfills are modeled after the standards for MSWLFs found at 40 CFR part 258, EPA has concluded that disposal of CCR in MSWLFs is as protective as disposal in a CCR landfill and that permitted MSWLFs are not subject to the requirements of this rule. Like the MSWLF requirements, the CCR technical criteria require new units to have composite liners or their equivalent, and all units are subject to location restrictions, run-on and run-off controls, fugitive dust controls, groundwater monitoring and corrective action, closure and post-closure care requirements."

And from the Final Rule itself (not the preamble), on page 21469, Section 257.50(i):

"This subpart does not apply to municipal solid waste landfills that receive CCR."

Of course, utilities could choose to permit and develop their own MSW landfills. But that can be a lengthy and complicated process, as MSW landfills are permitted and regulated at the state level and thus require local approval. Therefore, for most utilities, this is probably not an attractive option. In any case, it would not be an immediate solution, as permitting can take years, and the CCR rule will be in effect in a few short months. A potentially wiser and timelier strategy would be to simply contract with an existing MSW landfill—one that is already permitted to receive coal ash and equipped to handle it, and where coal ash disposal is not subject to any further interpretation or dispute. In a best-case scenario, such a facility would have access to rail, the ability to accommodate a large number of rail car units, and the capacity to place a utility's CCR into its own discreet monofill so that it is segregated from other utilities' CCR. Separating CCR into separate monofills is crucial, as it allows utilities to monitor their own CCR so that they can assure that it is being disposed of properly.

Today, there are very few MSW landfills that meet all of these criteria. Arrowhead Landfill, located in Uniontown, AL, is one of the few that does. In December 2008, more than a billion gallons of coal fly ash slurry was released at the Tennessee Valley Authority's Kingston Fossil Plant in Roane, TN, after an ash dike ruptured. As part of the remediation effort, the Arrowhead Landfill was chosen to receive more than 4 million tons of TVA coal ash for disposal. Based on lessons learned from that event, the landfill's operators chose to completely redesign the facility, and I was tapped as the principal designer and project manager for the redesign. The project included expanding the facility to include discreet monofills for CCR, which means Arrowhead can now provide utilities with their own designated CCR disposal areas, separate from the CCR of other utilities, with their own environmental monitoring network and leachate management systems. Other aspects of the redesign project included optimizing liquid management of both the leachate and the storm water, and developing methods to dewater CCR in the event it arrives at the facility in a wetter state than what is considered optimum. At the height of the TVA Kingston disposal effort, more than 10,000 tons of coal ash per day were arriving by rail, so the landfill operators also learned a great deal about traffic flow and materials management.

There is no question that the EPA's new CCR rule has changed the landscape for utilities, which now must assess their options and act quickly. MSW landfills can provide a clean transfer of obligation for utilities that wish to shield themselves from the threat of citizen lawsuits and, in the case of a facility such as Arrowhead Landfill, could do so almost immediately. This also makes more sense from a broader industry perspective, as state regulation of CCR disposal at MSW landfills is much more simple and efficient than enforcement by civil litigation. ❖

William F. Hodges, of Hodges, Harbin, Newberry & Tribble, Inc., is a licensed professional engineer with specialized experience in civil and environmental engineering. A recognized expert in solid waste and coal ash management, he has provided engineering consulting services to a multitude of public and private organizations throughout the United States for more than 37 years. Hodges is the engineer of record for Arrowhead Landfill.

ASH CLASSICS

Seminars Laid Foundation for Coal Ash Beneficial Use

"Ash Classics" is a recurring feature of **ASH at Work** *that examines the early years of the National Ash Association (NAA) and issues and events that were part of the beneficial use industry's defining years.*

Long before the World of Coal Ash began attracting scholars, marketers, and ash users to an international symposium, the National Ash Association took its educational show on the road. This issue of ASH at Work *from 1970 shows the high level of interest in ash technology from the earliest days of the beneficial use industry.*

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Seminar Anticipates Utilization Symposium

First in Series Tells Story to Large Crowd in St. Louis

A group of approximately 100 men from the St. Louis area, representing engineering and construction firms, general contractors, ready mix and concrete product manufacturers, and state and local government, recently gathered at the Executive Inn near the St. Louis Airport to hear 3 widely recognized experts discuss the applications of coal ash. The seminar, first in a planned series, was sponsored by the National Ash Association in cooperation with the Union Electric Co. of St. Louis. Other NAA members represented included Illinois Power, Public Service Co. of Indiana, Peabody Coal Co., Interstate Power, and Central Illinois Public Service Co.

Edward Hyland, Sales and Service Engineer, Chicago Fly Ash Co., traced the history of flyash as a building material from Roman times to the present day. Hyland discussed in detail the use and advantages of flyash in mass and structural concrete and provided a summary of major concrete construction in the Chicago area in which flyash has been used to considerable extent.

Joseph Belot, Jr. of Arrow Block Co., Bellaire, Ohio, related that company's experience with the use of flyash in concrete block and brick. Arrow, and its parents, the Delta and Belot Concrete Companies, have used flyash for almost 10 years. Belot described Arrow's new product, Brik-Blok, a flyash concrete module incorporating the features of both concrete block and brick in one unit. Robert Heyl, the firm's treasurer, followed Belot's remarks with comments on the economics of flyash utilization and a description of the value of flyash used in conjunction with carbon dioxide curing of concrete block.

Ronald E. Morrison, Ash Research, Sales and Development Engineer, AEP Service Corp., described the several applications of boiler slag, the black glassy material produced in cyclone and wet-bottom pulverized boiler furnaces. Slag is being successfully employed as aggregate in bituminous highway surfacing, roofing granules, safety and blasting grit, fill and ballast, decorative aggregate facing, aggregate in pozzolanic pavement, and skid retardant.

The speakers' presentations were preceded with remarks by Pat Harrington, Union Electric, and John H. Faber, NAA. Similar seminars are being planned for several centralized locations throughout the country.

John Faber, NAA Executive Vice President, provided introductory remarks at the St. Louis Seminar. Shown beside Mr. Faber, seated, are the principal speakers (left to right): P.D. Harrington, Union Electric; Ed Hyland, Chicago Fly Ash Co.; R.E. Morrison, AEP Service Corp.; Robert Heyl and Joe Belot, Jr., both of Arrow Block Co.

Remember the '67 meeting? Two guys who do are Roy C. Kurtzrock, right, of the Pittsburgh Coal Research Center, and Frank Cronin, National Coal Association. They discussed the success of plant propagation in flyash-soil mixtures.

Planners of Ash Symposium Expect Winner

Technology and utilization of fly ash and bottom ash will be featured at a symposium to be held March 10-11, 1970, in Pittsburgh, Pa., at the Pittsburgh Hilton Hotel.

Co-sponsors of the symposium are the Interior Department's Bureau of Mines, National Coal Association, Edison Electric Institute, American Public Power Association, and National Ash Association, Inc.

Production of fly ash, the powdery solid material removed from power-plant stacks, is approaching 30,000,000 tons a year and will continue to grow with increased consumption of coal to meet burgeoning demands for electrical energy. Ash utilization in tonnage quantities is essential to help alleviate the cost and problems of ash disposal and achieve fuller utilization of this natural resource.

United States and European experts at the symposium will cover a broad range of subjects including fly ash specifications and properties, advancements in established uses for fly ash, and new applications, such as fly ash brick, soil conditioning, and water purification.

Fly ash utilization in concrete, bituminous fillers, and mine-void filling will be among topics highlighted at the symposium which is expected to attract upwards of 1,000 representatives of government, universities, and industry, particularly coal companies, coal-based utilities, concrete and cement manufacturers, and construction companies. A condensed program is shown on page 4.

Further details on the symposium can be obtained from Neil H. Coates, General Chairman, U.S. Bureau of Mines, P.O. Box 880, Morgantown, West Virginia 26505, or John H. Faber, Executive Director, National Ash Association, Inc., Suite 650, 1819 H. Street, N.W., Washington, D.C. 20006.

Exhibit of Morgantown Coal Research Center was manned, in 1967, by Lester E. Adams, Rex S. Wolfe, W.C. Smith and John H. Faber.

Highway Experts Told of Fly Ash Advantages

During the Highway Research Board's 49th Annual Meeting at the Sheraton Park Hotel in Washington, D.C., Dr. Ernest J. Berenberg, University of Illinois, and Dr. L. John Minnick, G. & W. H. Corson Co. presented papers on recent developments in two areas which are expected to be of increasing importance to flyash utilization.

Dr. Berenberg, a leading authority on pavement design, described the results of recent laboratory studies on the leaching of lime from lime-cement-flyash-aggregate mixtures. The work was conducted in conjunction with the Port of New York Authority's current Newark Airport Redevelopment Program.

Minnick's paper, "Lightweight Concrete Aggregate from Sintered Flyash", described the state-of-the-art in the manufacture of sintered flyash aggregate, and sketched the future role of flyash in the total lightweight aggregate picture. Lightweight aggregate is the fastest growing segment of all rock products and demand for the material is expected to expand at a very high rate.

France Keeps Working to Expand Utilization

For over ten years, technicians of the Nord and Pas-de-Calais coalfields of the French Ministry of Works in cooperation with private road builders in the country have been working on the utilization of coal flyash in the construction of stabilized road bases. A notable example is the Armentieres-Nieppes section of the new B 25 Lille-Dunkirk Motorway.

Authorities say more than 3.5 million tons of flyash have been used during the past decade in the construction of French roads. France leads the world in its use of flyash in the manufacture of portland-pozzolan cement. French consumption has increased markedly in recent years, from less than 20% in 1959 to over 50% last year; current utilization is well over 2 million tons per year annually.

French research on flyash is continuing in the laboratories of the Ministry of Works, C.E.R.I.L.H. (the cement industry research organization) H.B.N.P.C. (Nord and Pas-de-Calais coalfields research group), Electricite' de France, and individual cement plants.

North Dakota Pushes Study of Lignite Ash

The acceptance of lignite flyash as mineral filler by the North Dakota Department of Highways was reported in the last issue of "Ash At Work." The utilization of lignite flyash has been the object of research being conducted for four years by Oscar E. Manz, Associate Professor of Civil Engineering at the University of North Dakota, Grand Forks. This last year he has directed his efforts to making full size brick from mixtures of water, flyash and bottom ash or sand. Since the flyash is extremely fine, like portland cement, it is necessary to add some coarser material to prevent cracking. A final mixture of 65% flyash and 35% bottom ash produced the best brick. With a 12% addition of water it required a forming pressure of 2,300 psi to produce bricks. After drying for 24 hours at 230° F the bricks were fired in an electric kiln to a temperature of 2100° F. The total linear shrinkage after firing was 1½% and the compressive strength was 5,200 psi.

Another phase of the brick project has been applications of ceramic glazes. Professor Manz and his assistants, Robert Benson and Dennis Hoffarth, Civil Engineering seniors, have produced very attractive brick with gold, white, orange, and red glazed surfaces.

In order to properly evaluate the flyash brick, several test panels have been laid up and placed on the roof of Leonard Hall on the North Dakota University campus, for exposure tests.

John Faber, center, discusses lignite use with Dr. Alan Fletcher, left, Dean of Engineering at North Dakota University, and Professor Oscar Manz, during Mr. Faber's recent trip to Grand Forks.

Glimpses of the St. Louis seminar: at top, a portion of the crowd. Below: Jim Wobbe, left, Union Electric, discusses concrete block with George Johnson, Frazier Davis Construction Co.

People In The News

D.E. Wooldridge was recently elected a Vice President of Ohio Edison Co. Wooldridge joined Ohio Public Service Co. in 1947 and moved to Edison's Akron headquarters after it merged with Public Service in 1950. He successively became production maintenance engineer in 1956, Superintendent of the Burger Power Plant in 1959, and General Superintendent of Power Production in 1964. In 1966 he accepted the additional responsibility of power transmission. Wooldridge has served as a director of NAA since its formation in 1968.

Gerald J. Krozel has joined the technical staff of the Chicago Fly Ash Co. and its Protex Mid-America Division as a service engineer. A Civil Engineer, Mr. Krozel was formerly associated with General Dynamics' Material Service Division as a quality control engineer.

Oscar Manz, Associate Professor, Civil Engineering, North Dakota University, was elected to membership in the National Ash Association at a regular meeting of the Board of Directors on January 14. Professor Manz has been active in research on lignite ash utilization for several years and is currently directing projects involving brick, mineral filler, and road base.

Fly Ash Utilization Symposium

PROGRAM
TUESDAY, MARCH 10

9 a.m. to 9:10 a.m.

OPENING REMARKS: *John A. Tillinghast, Executive Vice President, Engineering & Construction, American Electric Power Service Corp., and President, National Ash Association, Inc.*

9:10 a.m. to 12 Noon

A. ASH UTILIZATION
Chairman: C. E. Brackett
Southern Electric Generating Company

A.1 PRODUCTION AND UTILIZATION OF ASH IN THE U. S.: C. E. Brackett, Southern Electric Generating Company

A.2 INHIBITORY EFFECT OF FLY ASH ON STEEL IN CONCRETE: Antoni Paprocki, Economic Commission for Europe Group of Fly Ash Experts

A.3 A CONSULTING ENGINEER'S VIEWS ON ASH UTILIZATION: John P. Kothe, Consulting Engineer

COFFEE BREAK

A.4 A REVIEW OF ASH SPECIFICATIONS: Ronald E. Morrison, American Electric Power Service Corporation

A.5 COMPUTER PREDICTIONS OF FLY ASH BEHAVIOR: Edmund J. Purdy, Jr., Philadelphia Electric Company

12:15 p.m. to 1:30 p.m.

LUNCH

S. R. Jewell, Special Assistant to the President, Peabody Coal Company

2 p.m. to 4:50 p.m.

B. FILLERS
Chairman: Representative of the Bureau of Mines, U. S. Department of the Interior

B.1 FLY ASH AS A BITUMINOUS FILLER: Franklin V. Zimmer, Detroit Edison Co.

B.2 MISCELLANEOUS FILLER APPLICATIONS: M. Jack Snyder, Battelle Memorial Institute

B.3 FLY ASH UTILIZATION FOR REMOTE FILLING OF MINE VOIDS: M. O. Magnuson and Wilbert T. Malenka, Bureau of Mines, U. S. Department of the Interior

COFFEE BREAK

B.4 NEW USES AND APPLICATIONS: Joseph W. Leonard, Coal Research Bureau, West Virginia University.

B.5 PFA UTILIZATION IN THE UNITED KINGDOM: Alex Wilson, Central Electricity Generating Board.

6:30 p.m. to 7 p.m.

SOCIAL HOUR

DINNER *7:15 p.m.*

Representative of the U. S. Department of the Interior

PROGRAM
WEDNESDAY, MARCH 11

8 a.m. to 12 Noon

C. POZZOLANS AND CERAMICS
Chairman: Bryant Mather
U. S. Army Corps of Engineers

C.1 QUALITY CONTROL AND BENEFICIATION: Robert W. Styron, Southern Fly Ash Company

C.2 LIME-FLY ASH AGGREGATE: Frank Savage, Chicago Fly Ash Company

C.3 AUTOCLAVING OF POZZOLANS: Rudolph C. Valore, Valore Research Associates

COFFEE BREAK

C.4 AN INDUSTRIAL EVALUATION OF FLY ASH BRICKS: John A. Reidelbach, Jr., Housing Consultant

C.5 LIGHTWEIGHT AGGREGATES IN THE UNITED STATES: Griffith R. Morris, Stone & Webster Management Consultants

C.6 TECHNICAL ASPECTS OF FUSION FORMING OF FLY ASH CERAMIC STRUCTURES: Dr. William H. Bauer, Rutgers University

C.7 PRACTICES IN FRANCE: A. Jarrige, Houillères de Bassin Du Nord et du Pas de Calais

12 Noon to 1:30 p.m.

LUNCH

Bart Thomas, Dayton Fly Ash Company

1:45 p.m. to 3:45 p.m.

D. RESEARCH
Chairman: James R. Garvey
Bituminous Coal Research, Inc.

D.1 FLY ASH UTILIZATION IN THE TREATMENT OF POLLUTED WATERS: Dr. Mark W. Tenney and Dr. Wayne F. Echelberger, Jr., University of Notre Dame

D.2 "NEW" FLY ASH: Dr. L. John Minnick, G. & W. H. Corson, Inc.

D.3 ASH FROM LIGNITE: Oscar E. Manz, University of North Dakota

COFFEE BREAK

D.4 BENEFICIATION OF FLY ASH: Harold T. Stirling, Stirling Sintering Company

D.5 FLY ASH AS A FERTILIZER: Dr. David C. Martens, Virginia Polytechnic Institute

BULK RATE
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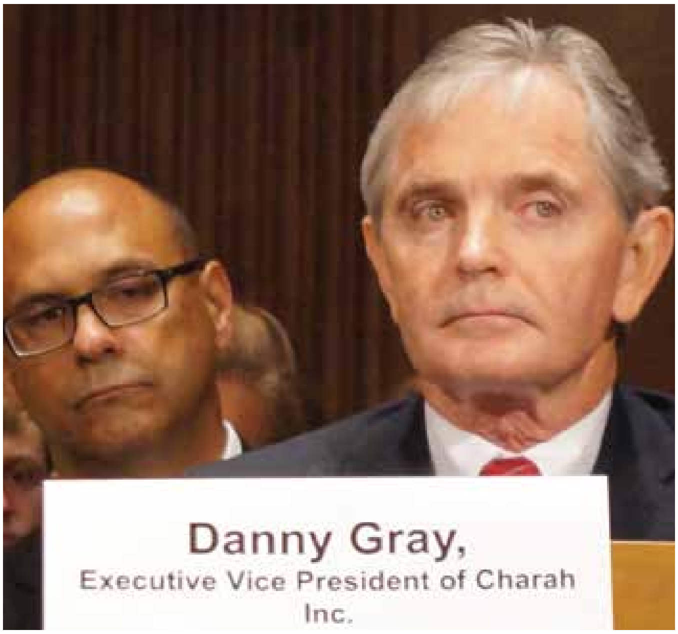
IN & AROUND ACAA



WASHINGTON, DC

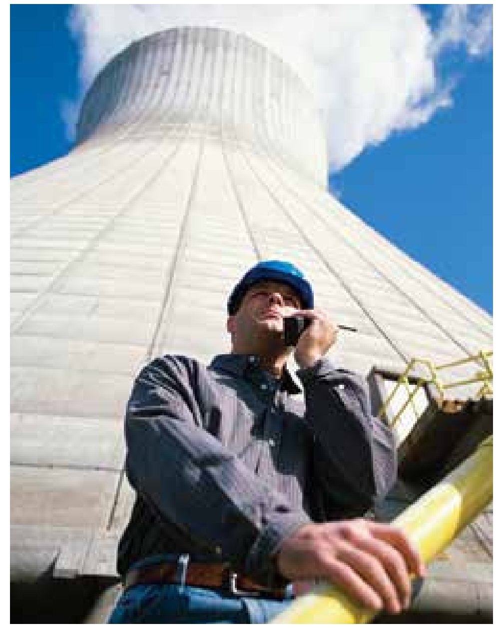
Danny Gray, Executive Vice President of Governmental & Environmental Affairs for Charah, Inc., testifies before the U.S. Senate Committee on Environment and Public Works on June 17, 2015, as ACAA Government Relations Committee Chairman John Ward looks on. Gray was one of five witnesses appearing before the Committee to discuss the U.S. Environmental Protection Agency's recently finalized coal ash disposal regulations. He stressed the importance of regulatory certainty in increasing beneficial use as a preferred alternative to disposal.

EAST SPENCER, NC

John Scoggan, Vice President of Utility Relations for Boral Material Technologies, and Ken Bruns, Plant Manager for Boral Composites, provide a tour on August 25, 2015, to U.S. Congresswoman Alma Adams and East Spencer Mayor Barbara Mallett. Boral's facility in East Spencer manufactures TruExterior trim board, which contains high volumes of coal fly ash.

RALEIGH, NC

Attendees at the ACAA Women's Leadership Forum luncheon heard remarks by Erin Culbert, communications manager for Duke Energy. Culbert provided insights about the challenging news media environment affecting Duke's operations in North Carolina.



RALEIGH, NC

The ACAA Educational Foundation conducted a workshop for these ACAA members serving as judges for the Foundation's college scholarship competition. Separately, the ACAA Board of Directors also elected three new directors for the Educational Foundation. New Educational Foundation Board members include Dawn DeJardin, Wisconsin Public Service; Jorge Tercero, Separation Technologies; and Dale Diulus, Salt River Materials. Continuing Board members include Thomas Adams, ACAA; Hollis Walker, Southern Company; Mark Bryant, Ameren; Kenny Tapp, LG&E and KU Services Company; and Willie Mills, Consumers Energy.

RALEIGH, NC

A standing-room-only crowd at the ACAA Fall Meeting luncheon heard a pair of keynote speakers from the North Carolina Department of Environmental Quality. Chief Deputy Secretary John C. Evans (left) and Assistant Secretary for Environment Tom Reeder (right) discussed their state's actions on coal ash regulation and Clean Power Plan carbon regulations.

Editor's Note: "Six Questions for…" is a regular *ASH at Work* feature in which leaders with unique insight affecting the coal ash beneficial use industry are asked to answer six questions.

Richard G. Stoll is a partner in the Washington, DC, and Milwaukee, WI, offices of Foley & Lardner LLP, where he concentrates his practice on federal administrative and environmental law matters. Stoll has been practicing environmental and administrative law since the 1970s, when he joined the U.S. Environmental Protection Agency's Office of General Counsel. He was involved in the development of regulations under the Clean Air, Clean Water, and Resource Conservation and Recovery Acts, and with the interpretation and application of those rules. Upon leaving the EPA, Stoll was Deputy General Counsel of the Chemical Manufacturers Association (now the American Chemistry Council) for 3 years. He currently represents Lafarge in litigation over EPA's recently finalized RCRA coal ash disposal rule.

Ash at Work (AW): You've written a book about how to communicate with federal regulatory agencies. What are the most important points for people to keep in mind when communicating with regulators regarding a rulemaking under development?

Richard Stoll (RS): A really critical point: *start early*. As discussed in my book, it usually takes a few years for the EPA to take a rule from initial concept to finalization. There are plenty of opportunities for interested parties to weigh in before a proposed rule is developed, and it is smart to do this. Because once a proposed rule hits the Federal Register, the options the EPA may be left with before it goes final often become quite limited.

And like Chicago, where you should vote early and often, you should at least try keep communicating with the agency personnel as often as you can as the process moves along. Remember, this is officially "informal" rulemaking, so communicating with agency personnel both before and after a proposal is issued (in addition to your all-important written comments) is appropriate and usually allowed by agency staff.

And in any communications—whether related to rulemakings or not—another key point is to back up your requests/arguments/advocacy with *credible facts and/or data*. EPA people are always hearing that some proposal or policy is misguided, stupid, and/or counterproductive. If you have any chance of getting them to take your concerns seriously, you need to support your points with real facts/data. And don't use misleading facts/data, because there is a good chance that will eventually be discovered. Then your credibility will be called into question—never good when dealing with the EPA.

AW: In what ways has the EPA changed over the years in which you have practiced environmental law?

RS: Let me try a few quick points:

a. The rulemaking process has become much more time-consuming and complex. Back in "my day" at EPA (late '70s), we could issue an ambient air quality standard under the Clean Air Act (CAA) with a proposed rule followed by a final rule only a few months later—and the proposed and final Federal Register notices might run for fewer than 10 pages!
b. EPA keeps having more things to do with fewer resources to do them. The statutes Congress has passed give the EPA a mind-boggling number of rules to issue and update, and citizens groups keep bringing a mind-boggling number of lawsuits to force the EPA to do this. One good current example: the EPA has issued CAA "CISWI" rules for non-hazardous waste combustors. The rules—as usual—are quite ambiguous and confusing on many critical points. In past rules, the EPA has issued under the same CAA section; the EPA has issued follow-up guidance to clarify the EPA's intent. But the EPA now has so many pending mandates under court orders, statutory deadlines, and Obama climate initiatives that its staff doesn't have the time or resources to issue guidance for the CISWI rules.
c. One thing that has not changed: the EPA is staffed by a great number of high-quality professionals who take their jobs very seriously.

AW: What are the odds that the next presidential administration will roll back many of the environmental regulations promulgated by the Obama EPA?

RS: I presume you are speaking of a scenario in which a Republican becomes President. I would assume that for any *new* regulations, the agency would give far greater weight to realistic assumptions about costs and benefits than we have seen under the Obama EPA. I would also assume the agency would be more respectful of the limits of its statutory authority than we have seen under the Obama EPA. The Obama "Clean Power Plan," for instance, is a prime example of an earthshaking rule based on highly questionable statutory authority.

The "roll back" issue is more difficult. Plenty of recent DC Circuit and Supreme Court precedents allow a new administration to revoke or revise rules from a prior administration based on the new administration's policy preferences, so long as the reasons for the revocation or revisions are adequately explained.

But as a practical matter, such revocations or reversals could take time because of the need to go through notice-and-comment rulemaking. So some rules may already have been implemented or be well on their way to implementation by the time the new administration can finalize any revocations/reversals.

This would have to be assessed on a rule-by-rule basis depending on how fast the rule in question is required to be implemented and the nature of the rule. Under the Clean Power Plan (CPP), for instance, many of the emission reduction goals are not required for many years, so a new administration could have success in rolling back key elements of the CPP if it wants to do so (assuming the DC Circuit or the Supreme Court will not already have done so). And under the "Clean Water Rule," (or "WOTUS" to some) because of its "jurisdictional" nature, it would be easy for a new administration to roll it back to something more rational.

AW: What are the odds that major parts of the EPA's Resource Conservation and Recovery Act final rule for coal ash disposal will be overturned by litigation?

RS: Tough question, because these days especially, the way the DC Circuit may approach an EPA rule challenge can depend on the composition of the three-judge panel that is chosen (by lot) to hear the case. Some of the judges tend to sympathize with the EPA and/or citizens' groups, while other judges tend to be more supportive of regulated parties' views—especially when it appears there is little benefit for great costs.

Because I am participating as counsel in that litigation, I hesitate to handicap the success of any particular challenges. But I can pass on some good news for industry parties. The greatest fear for both electric utilities and beneficial use interests in the CCR rulemaking was that the EPA would choose to regulate CCRs under RCRA Subtitle C. Once the EPA chose to stick with Subtitle D in the final rule, the greatest fear for the utilities and beneficial use interests has been that the environmental group petitioners would convince the DC Circuit that the EPA should have regulated CCRs under RCRA Subtitle C, and that the Court would order the EPA to issue Subtitle C regulations for CCRs. The good news: in preliminary filings with the Court, the environmental parties have committed to the Court that they will not seek to raise the Subtitle C versus D issue.

AW: By the time litigation over coal ash disposal regulations is complete, utilities will likely be far along in implementing compliance. Has litigation become a less potent tool in combating overreaching regulations?

RS: Good question. Based on the proposed briefing schedule the parties have presented to the DC Circuit, it appears that oral argument on the case will not be held until fall 2016 at the earliest. And that means there is a very good chance we won't have a court decision until late 2016 or more likely early 2017.

Some parts of the CCR rule require early actions and capital expenditures—once those actions are taken and the money is spent, a court reversal of those parts of the CCR rule wouldn't be of much use to the victorious litigants. But other parts of the CCR rule may require significant longer-term annual operating expenses or may prohibit or restrict certain types of actions (such as placing more than 12,400 tons of CCR on the land). A court victory relating to those parts of the rule would still be a great benefit to the challenging parties, so I would still say litigation can be a "potent tool."

AW: If you could choose one thing that would improve environmental regulation in the United States, what would it be?

RS: Can I please have two?

a. Amend the EPA's basic organic statutes (CAA, RCRA, CWA, and so on) to take away the ability of parties to sue the EPA to undertake rulemakings. These "citizens deadline suits" allow citizens groups to set the EPA's agenda and the court-ordered deadlines force sloppy rulemakings that are in constant need of cleanup. Congress has not saddled any other federal agency with such a regime. Please see my piece in *Politico* for more on this (**http://www.politico.com/story/2012/01/do-we-still-need-epa-rule-deadlines-071300**). Back in the early 1970s, when we had really dirty air and burning rivers, these deadline suits might have had a place—no more please!
b. Amend the EPA's basic organic statutes to include—for all major rules going forward—a requirement that costs must be shown to be justified by the benefits. And this would have to be based on an honest, unbiased assessment of costs/benefits performed by some agency or board wholly independent of the EPA. Back in the early 1970s, when we had really dirty air and burning rivers, a regime allowing or requiring EPA to ignore or downplay costs might have had a place—no more please!

Ad Index

New Ponded Ash Workshop Slated for February

The American Coal Ash Association has joined with the Center for Applied Energy Research at the University of Kentucky and the Electric Power Research Institute to host a new workshop on "Current Issues in Ponded Coal Combustion Products." The workshop will be held February 3-4, 2016, at the Hilton Tampa Downtown Hotel immediately following the conclusion of ACAA's winter membership meeting.

A full slate of expert speakers has been secured for the event, with topics including Nature of Ponds; Sediments; Structure of Ponds; Utilization of Ponded Ash and Chemistry; Geotechnical Considerations in Pond Closure; Structure and Stability of Ponds; Pond Failures; Relative Risk Assessment Framework for Pond Closures; Groundwater Monitoring and Corrective Action; In Situ Solidification and Stabilization; and much more.

Cost of the workshop is $595. Sponsorships are available.

Coal Ash Disposal Regulations Finally in Place

After more than 6 years of rulemaking activities, the U.S. Environmental Protection Agency has finalized a suite of regulations governing the disposal of coal ash.

On October 19, 2015, regulations for "Disposal of Coal Combustion Residuals from Electric Utilities" took effect under the Resource Conservation and Recovery Act (RCRA). (The RCRA is the section of federal environmental law governing solid waste.) On September 30, 2015, the EPA issued its Final Rule updating Steam Electric Power Generating Effluent Limitation Guidelines (ELGs) under the Clean Water Act. (ELGs regulate the discharge of water that was used in handling ash on power plant sites.)

Under the RCRA rules, which affect all power plants consuming coal to generate electricity, the EPA chose to regulate under the "non-hazardous" Subtitle D of RCRA. Beneficial use remained exempt from regulation, but the Agency established four "legitimacy criteria" to define beneficial use.

The ELG rule affects 134 of approximately 1,000 power plants. Plants must comply between 2018 and 2023, depending on when they need a new Clean Water Act permit.

In issuing the RCRA rule, the EPA reiterated support for beneficial use by saying: "Beneficial use of coal ash can produce positive environmental, economic and performance benefits such as reduced use of virgin resources, lower greenhouse gas emissions, reduced cost of coal ash disposal, and improved strength and durability of materials."

Although the final rules are now in place, litigation over their make-up will be on going. Seven petitions for review were filed in the RCRA matter addressing a host of issues, including an apparent mathematical error made by EPA in establishing a 12,400-ton threshold for conducting evaluations of non-transportation fill activities. (At press time, it was not determined whether any parties would sue over the ELG rule.) However, environmental groups indicated that they do not plan to challenge EPA's Subtitle D "non-hazardous" determination.

ACAA Champion Award: USDA Agricultural Research Team Honored for Synthetic Gypsum Work

The U.S. Department of Agriculture's Agricultural Research Service (ARS) was selected as the fourth recipient of the American Coal Ash Association Champion Award. Research team leader and Supervisory Soil Scientist Dr. H. Allen Torbert accepted the award at ACAA's Fall 2015 meeting on behalf of a team of ARS scientists for their work in advancing the use of synthetic gypsum from coal-fueled power plant scrubbers as soil amendments.

ACAA established the Champion Award in 2012 to recognize extraordinary contributions to the beneficial use of coal combustion products. The recipient is selected exclusively by the Chair of the ACAA Board of Directors and is known only to the Chair until the moment the presentation is made. The recipient may be an individual or individuals, an institution (private or public), a member of ACAA or a nonmember, living or deceased.

ACAA Chairman Hollis Walker praised the ARS team for its work beginning in 2007 to scientifically evaluate the risks and benefits of synthetic gypsum use in agriculture, as well as significant efforts to promote the practice. Those efforts have included multiple refereed journal articles and presentations at scientific meetings, establishment of a "By-product Gypsum Uses in Agriculture" Community of Interest within the American Society of Agronomy (ASA), organization of two symposia at the ASA meetings; ongoing development of an ASA monograph on gypsum uses in agriculture, and development of a new national Conservation Practice Standard for use of gypsum products titled "Amending Soil Properties with Gypsum Products Code 333" (finalized in June 2015).

The award noted the special contributions of eight USDA ARS researchers: Dr. Ray Bryant, Dr. Rufus Chaney, Dr. Dinku Endale, Dr. Michael Jenkins, Dr. Martin Locke, Dr. Harry Schomberg, Dr. Allen Torbert, and Dr. Dexter Watts.

The 2015 Champion Award marked the first time a group was recognized by ACAA. What constitutes extraordinary contributions to the beneficial use of coal combustion products (CCP)? In this case, beauty is truly in the eye of the beholder. Over the decades of beneficial use, many, many important contributions have come from a wide range of sources. Advances in research, innovative use of CCP, extraordinary marketing efforts, educational leadership, leadership for the industry through participation in technical organizations, involvement in regulatory activities, and protecting beneficial use from assaults by outside interests are examples of worthy contributions.

The biggest challenge for the initial awards is to sort through the myriad of worthy recipients and select just one. In 2012, Mark Bryant concluded his 4 years as Chair of the ACAA Board of Directors by presenting the very first ACAA Champion Award to Government Relations Committee Chairman John Ward for his exceptional work in providing leadership in meeting challenges from the U.S. Environmental Protection Agency and environmental groups following the Kingston, TN, ash spill in December 2008. Bryant noted that the immediacy and intensity of the assault on beneficial use by those opposed to coal-fueled generation of electricity challenged the very survival of the beneficial use industry. With his deep experience in the machinations of Washington, DC, Ward was able to provide top-notch advice and guidance to the association.

One year later in Pinehurst, NC, Chair Lisa Cooper bestowed the second award to retired ACAA Executive Director Dave Goss. While Goss has continued to manage special projects for ACAA since his “retirement,” he really did want to retire. Chair Cooper thought it was time to recognize Goss for his service to the ACAA over more than a decade. During his tenure as COO of the association, ACAA came back from a very fragile financial condition, carefully grew the services provided, increased membership, and improved the reputation of the ACAA to outside organizations. Goss also brought ACAA together with the Center for Applied Energy Research at the University of Kentucky to create the highly successful World of Coal Ash. Working with leaders from the ACAA membership, Goss nursed ACAA back to health.

The third ACAA Champion Award was presented in Pittsburgh, PA, to Congressman David B. McKinley, representative of the first Congressional district of West Virginia and a licensed professional engineer with a deep knowledge of beneficial use of CCP. Rep. McKinley became the elected voice for beneficial use in the U.S. Congress in his very first month following his election in 2010. Within 30 days of being sworn into office, McKinley authored a bill preventing the EPA from creating hazardous waste regulations for the management of CCP. That one-paragraph bill was the first in a series of bills passed by the House of Representatives with bipartisan support.

USDA’s Agricultural Research Service was selected for the fourth award in recognition of its multi-year efforts to qualify flue gas desulfurization (FGD) gypsum as a useful and desirable soil amendment. Because FGD gypsum is comparable to mined gypsum and more readily available in many parts of the country, there is significant potential to increase its use in agricultural settings. However, available research documenting the effects of FGD gypsum on plants, soils, and the environment was limited prior to ARS’s activities.

Dr. H. Allen Torbert of the USDA Agricultural Research Service receives the fourth ACAA Champion Award from ACAA Chairman Hollis Walker.

Beginning in 2007, a number of projects were undertaken by scientists from the USDA-Agricultural Research Service locations in Auburn, AL; Beltsville, MD; Oxford, MS; and Watkinsville, GA, to study the agricultural effectiveness of FGD gypsum as a soil amendment and determine safe levels for FGD gypsum application. Of particular interest to this group was reducing the transport of soluble P contamination from areas receiving applications of poultry litter and evaluating the potential for loss of contaminants (for example, microorganisms, Hg, As, and other heavy metals) into the environment. Experiments demonstrated that water quality could be greatly improved with the use of gypsum to decrease both P and microorganisms in runoff from poultry litter applications. FGD gypsum also improved soil quality, increasing the amount of rainwater infiltrating into the soil. In addition, trace elements in runoff were shown to be below EPA water quality standards.

ACAA maintains a plaque with the names of the recipients of the ACAA Champion Award. It is on display at every ACAA meeting. Who will be the fifth recipient? We will find out at the ACAA 2016 fall meeting.

2015 WORLD OF COAL ASH CRUSHES ATTENDANCE RECORDS

The 2015 World of Coal Ash symposium in Nashville, TN, May 4-7, 2015, shattered all previous attendance records.

Approximately 870 people from around the world attended, compared to a previous high of 590. Attendees took advantage of a sold-out exhibit hall, dozens of high-quality presentations and poster sessions, and a lively schedule of social events.

Proceedings papers from the symposium are available at **www.worldofcoalash.org**.

The next World of Coal Ash will be held in Lexington, KY, in 2017. World of Coal Ash is co-sponsored by the American Coal Ash Association and the University of Kentucky Center for Applied Energy Research.

WORLD OF COAL ASH WINNERS

The World of Coal Ash symposium in Nashville was not without a little friendly academic competition.

The winner of the 2015 Barton A. Thomas Memorial Award for Best Technical Paper was Angela Pakes Ahlman from the University of Wisconsin – Madison. Her paper was titled "System-Wide Life Cycle Benefits of Recycled Materials."

The award for Best Technical Poster went to Asokan Pappu of Washington State University for a poster titled "Recent Advances on Coal Ash Particulates' Fortified Glossy Finish Polymer Composites."

The Most Outstanding Student Poster presentation award went to Jenet Hattaway of the University of North Carolina at Charlotte for a poster titled "Practical Leaching Procedure Recommendations for Coal Ash Treatment Evaluation." Most Outstanding Student Oral presentation awards went to Ali Kiani of the University of Newcastle (Australia) for a presentation titled "Upgrading of Cenospheres in Fly Ash Using a Series of Inverted Reflux Classifiers," and Maria Amaya of The Ohio State University for a presentation titled "Beneficial Utilization of Chinese Dry FGD Materials for Stabilization of Weak Soils."

Additionally, since 2009, the Midwest Coal Ash Association has provided support (including $500 scholarships) to students who present either a paper or poster at the WOCA conference. The 2015 awardees are: Maria Amaya of The Ohio State University, Sarah Dillon of Tennessee Technical University, Madison Hood of the University of Kentucky Center for Applied Energy Research, and Qian Zhang of Indiana University.

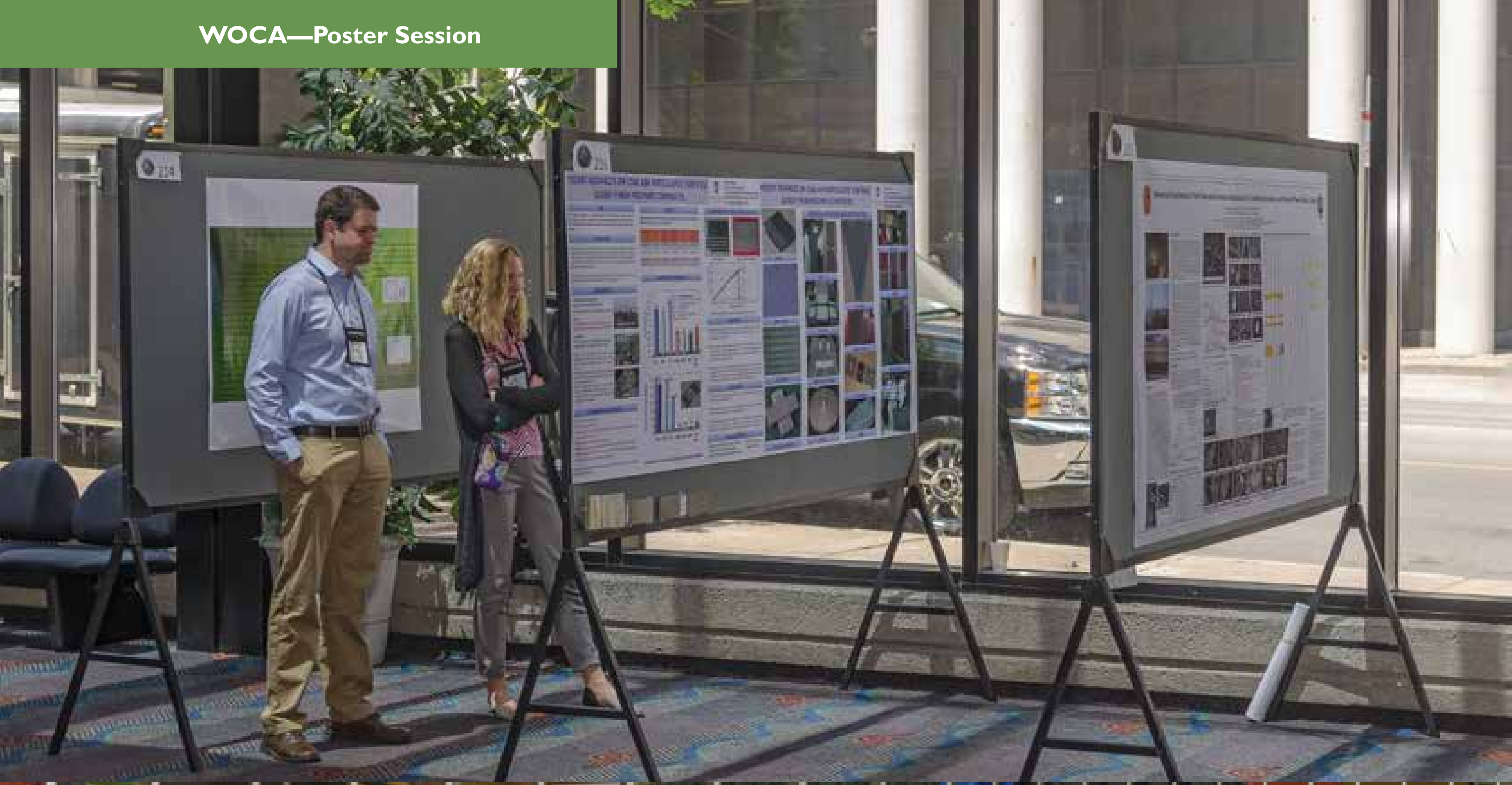
Photos above courtesy of Nashville Convention & Visitors Corporation

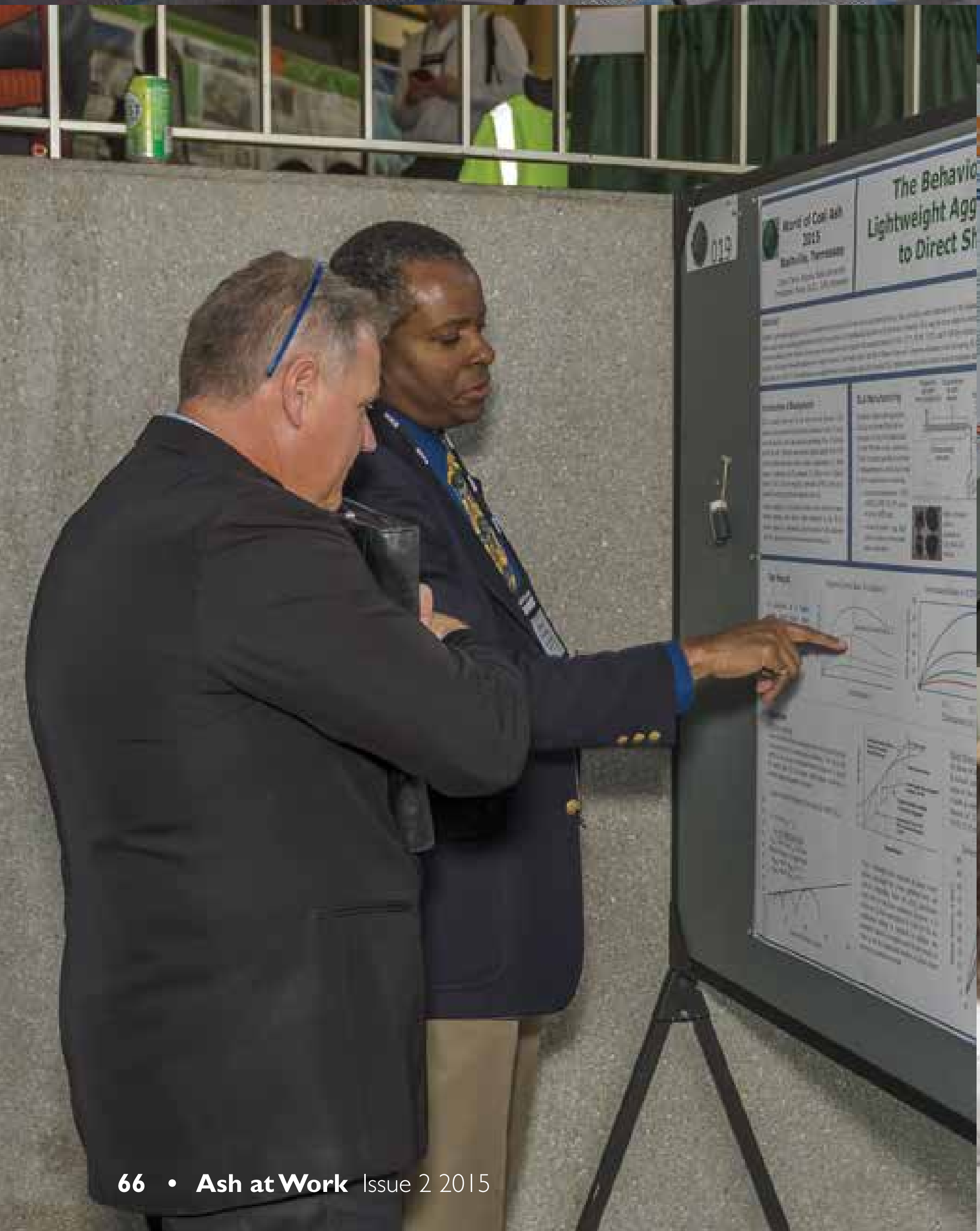

HEADWATERS
RESOURCES
America's Largest Manager and Marketer of Coal Combustion Products
HEADWATERS
RestoreAir
Fly Ash for Sustainability


LANCASTER PRODUCTS


World of Coal Ash
Lisa
World of Coal Ash


RENAISSANCE

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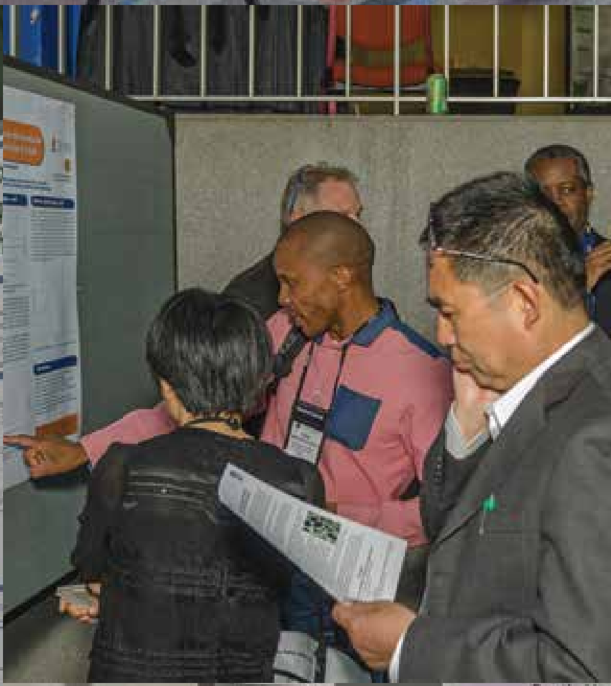
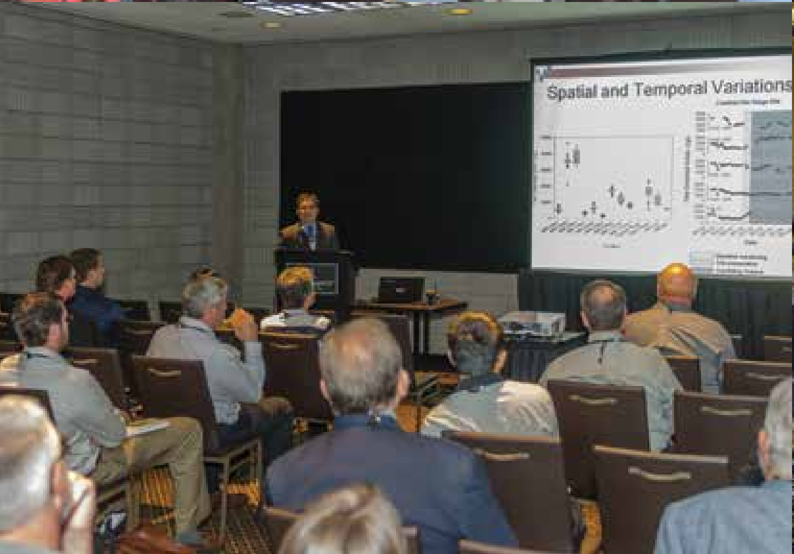



Phased Approach Design


Spatial and Temporal Variations

ACAA

Key Findings 2015

Coal Combustion Products Utilization

U.S. Historical Perspective and Forecast

Produced by the American Coal Ash Association (ACAA)

Building a Sustainable Future: Coal Combustion Products Utilization in the United States

The history of coal combustion products (CCPs) utilization is a success story of economic productivity, technical innovation, and environmental sustainability. CCPs have been used for decades to build the infrastructure of the U.S. – our highways and roads, bridges and tunnels, tallest skyscrapers, commercial structures, and residential buildings. Products containing CCPs can be found in nearly every American home, from the fly ash in concrete foundations and driveways to the to the synthetic gypsum in wallboard to the boiler slag in shingles on rooftops.

This report looks back at the economic and policy factors that influenced CCP production and utilization over the past 40 years, and looks ahead to the availability and demand for CCPs over the next 20 years. This look forward is based on econometric models of historical CCP data, projections for coal-fueled electric generation, and U.S. economic factors to forecast CCP production and utilization over the next two decades.

CCP production has increased 93 percent since 1974, growing at an average annual rate of 1.7 percent. The Clean Air Act (CAA) amendments accelerated CCP production, as coal-fueled utilities installed emissions control equipment to comply with the regulations. As more CCPs were produced, markets for their beneficial use emerged. CCPs were recognized as cost-competitive materials with distinct advantages over other materials commonly used in construction, agriculture and mine reclamation. Engineering standards were developed to guide CCP utilization in technically- sound, environmentally-protective ways.

CCP utilization has dramatically increased since 1974, growing by 500 percent to 51.6 million (short) tons beneficially used in 2013. This quantity represents materials diverted from disposal that enhance product performance and reduce impacts to our land, air, and water resources.

Coal will continue to account for a significant percentage of U.S. electric generation during the next two decades. As a result, CCP production is expected to remain steady, increasing by five (5) percent through 2033. The future of CCP utilization is equally bright. Growing demand in construction markets is expected to increase CCP utilization by over 48 percent. Forecast models project that CCP utilization rises to 63 percent of production by 2033. Even under alternative scenarios of accelerated coal-fueled electric generating unit retirements, CCP production is still expected to exceed overall demand.

40 Years of Innovation and Sustainability

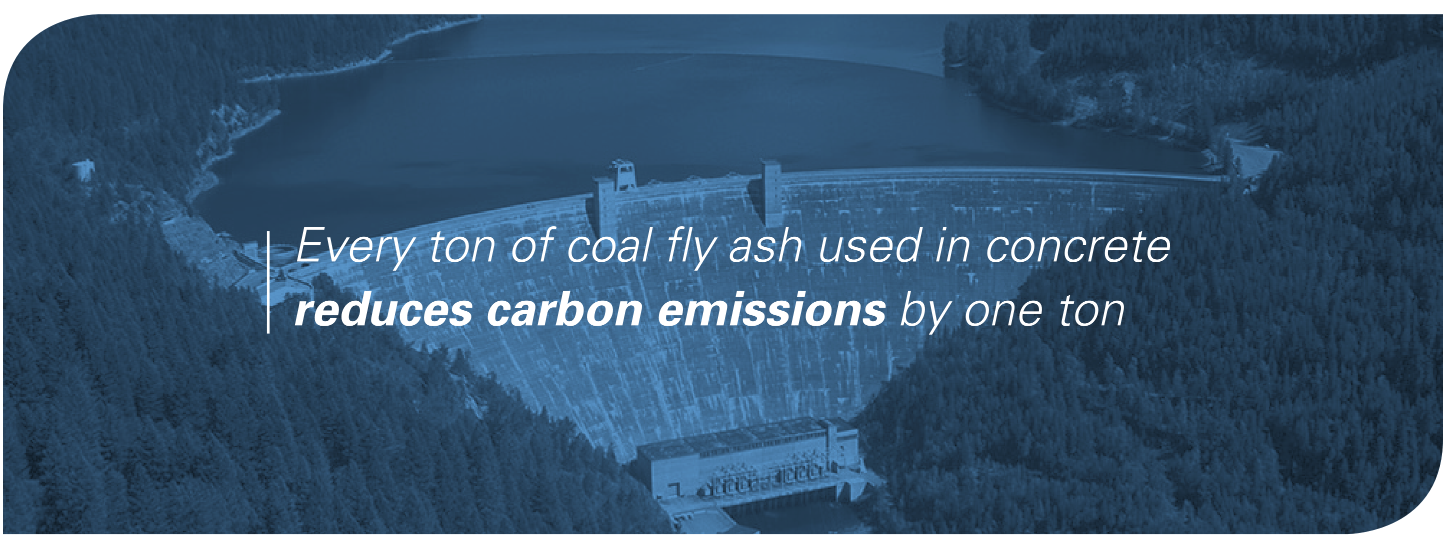
The use of CCPs as a substitute for mined or manufactured materials lowers construction costs, decreases water and energy use, and results in substantial carbon emissions reductions. For every ton of coal fly ash used as a replacement for portland cement in concrete, approximately one ton of carbon emissions are avoided. Using CCPs in place of mined materials reduces the land use impacts associated with extraction.

Equally important, products made with CCPs typically perform better and have greater longevity than non-CCP products. For example, concrete made with fly ash is less permeable and more resistant to acid, sulfates and other destructive chemical reactions than concrete made with portland cement alone. Reusing CCPs is environmentally responsible and supportive of a sustainable economy.

Since 1974 the American Coal Ash Association (ACAA) has tracked the production and use of CCPs in the U.S. Statistics are derived from a voluntary annual survey of the coal-fueled electric utility industry to track quantities of CCPs produced and beneficially used. ACAA's annual Production & Use Survey Report has been used by government agencies such as the Environmental Protection Agency (EPA) and the Department of Energy (DOE), and is considered the authoritative source for CCP production and use data in the U.S. Recent ACAA Production and Use Reports are available at: http://www.acaa-usa.org/Publications/Production-Use-Reports. ACAA commissioned the American Road and Transportation Builders Association (ARTBA) to conduct an economic analysis of historical CCP production and use data, and the linkages to construction markets and regulatory policies. Historical data and economic linkages were used to construct econometric models that forecast CCP production and use through 2033. The historical and forecast studies are presented in two separate reports:

- Production and Use of Coal Combustion Products in the U.S.: Historical Market Analysis[1]
- Production and Use of Coal Combustion Products in the U.S.: Market Forecast Through 2033[2]

This report is a synopsis of those two studies, providing key findings for CCP market participants, builders and architects, permitting authorities, and policymakers.



[1] *ARTBA. 2015. Production and Use of Coal Combustion Products in the U.S.: Historical Market Analysis. American Road and Transportation Builders Asssociation.*
[2] *ARTBA. 2015. Production and Use of Coal Combustion Products in the U.S.: Market Forecast Through 2033. American Road and Transportation Builders Asssociation.*

Clean Air Act Compliance Increased CCP Production

CCPs are produced as a byproduct of coal-fueled electric generation. Coal accounted for 44 percent of U.S. electric generation in 1974, climbing to a peak share of 57 percent in 1988. Since 1988 the use of coal for electric generation has declined, to 40 percent in 2013. However, due to increasing electric demand over time, overall coal consumption for electric power generation has remained higher than 1988 levels.

The production of CCPs has grown from 59.5 million tons produced in 1974 to 114.7 million tons in 2013. This volume represents the second largest industrial byproduct stream in the U.S. In comparison, 254 million tons of municipal solid waste was generated in the U.S. during 2013.

The increase in CCP production over the last four decades is due to a combination of regulatory and market factors, reflecting the reliance on coal for a significant percentage of the country's electric power generation and capital investments undertaken to comply with environmental regulations. The Clean Air Act (CAA) and amendments in 1970, 1977 and 1990 set national air quality standards for criteria pollutants, including particulate matter, sulfur dioxide (SO_2) and nitrogen oxides (NOx). In response to these regulations, emissions control equipment installed at coal-fueled electric power plants has resulted in larger quantities of CCPs being generated and captured. CCPs have varied chemical and physical characteristics, and include fly ash, bottom ash, flue gas desulfurization materials, boiler slag and fluidized bed combustor (FBC) ash.

The production of fly ash, which is captured from the exhaust flue gases, increased as emissions control equipment has been deployed at more power plants. Fly ash production increased from 40.4 million tons in 1974 to 53.4 million tons in 2013. Production of fly ash increased by 2.2 percent annually between 1990 and 2008.

Synthetic gypsum, a high-value byproduct formed in flue gas desulfurization (FGD) systems known as scrubbers, increased significantly as these systems have been installed to reduce SO_2 emissions. Scrubbers capture sulfur emissions using a calcium-based reagent, producing synthetic gypsum that is typically higher purity than mined natural gypsum. Gypsum is the primary ingredient used in wallboard manufacturing.

Of the operational scrubber units in 2012, nearly 70 percent went into service after 1990. The production of FGD materials (which

Clean Air Act Compliance Increased CCP Production

includes synthetic gypsum, wet scrubber, and dry scrubber materials) has increased 148 percent since 1987, rising to 35.2 million tons in 2013. This represents an annual average growth rate of 3.5 percent, far outpacing the 0.3 percent growth in coal-fueled electric generation during this same period. This growth is due to increased production of synthetic gypsum, accounting for over 70 percent of total FGD materials production.

Together, fly ash and FGD materials now account for 77 percent by weight of total annual CCP production. Bottom ash, the heavier CCPs collected at the bottom of coal-fueled boilers, increased one percent annually to 14.5 million tons in 2013.

Ash produced from fluidized bed combustors (FBC), which can burn coal with lower energy content, increased from 1.2 million tons in 2002 to 10.3 million tons in 2013. The only category of CCPs for which production has decreased is boiler slag, which is produced in cyclone boilers, many of which are being retired. Boiler slag production has declined by 72 percent since 1974 to 1.4 million tons in 2013.

The growth in CCP production over the last 40 years relative to major air regulations is shown in Figure 1.

Production of CCPs has grown at an average annual rate of 1.7 percent

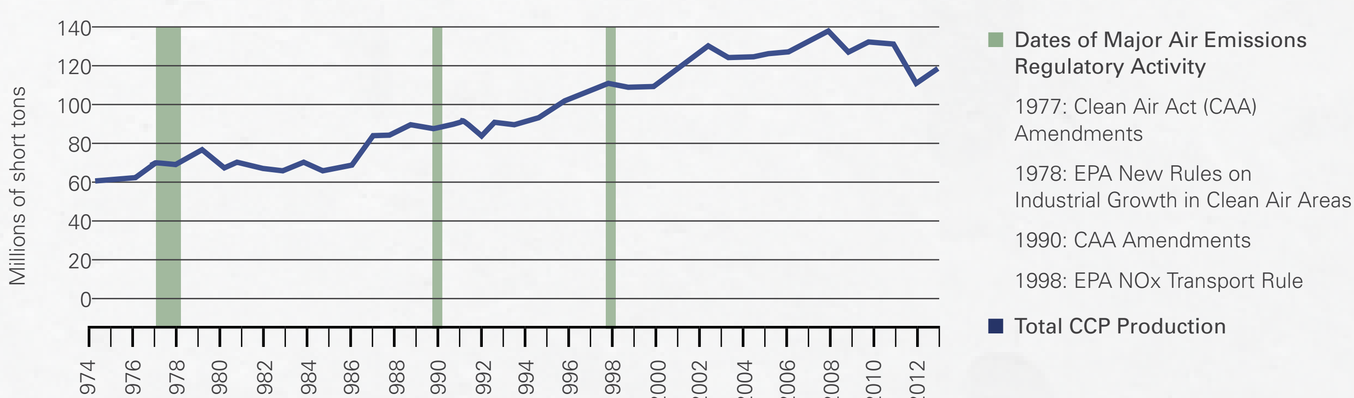


Figure 1. CCP production has increased due to coal consumption for electric power and installation of emissions control systems

As CCP Production Grew, Standards and Markets Emerged

CCPs are used in a number of construction-related products and applications. CCPs are used as supplementary cementitious materials (SCM) in concrete and cement products, in gypsum panel products, and as a replacement for aggregates in structural fills and embankments. Nearly two-thirds of CCPs are used in construction-related markets. Significant quantities of CCPs are also used in mining applications such as reclamation, as the alkaline nature of some types of CCPs mitigates the effects of acid mine drainage.

Overall CCP utilization has increased from 8.7 million tons in 1974 to 51.6 million tons in 2013 – a cumulative increase of nearly 500 percent. Over the history of ACAA recordkeeping, 1.2 billion tons of CCPs have been reused, rather than disposed.

CCP utilization has evolved as markets for CCPs matured and standards governing use have been implemented. Numerous technical and engineering standards for CCP utilization have been developed by federal and state agencies. Standards for CCP use have been developed by ASTM International, American Concrete Institute (ACI), American Association of State Highway and Transportation Officials (AASHTO), Federal Highway Administration (FHWA), Army Corps of Engineers (ACE), Federal Aviation Administration (FAA), National Ready Mixed Concrete Association (NRMCA), American Society of Civil Engineers (ASCE) and numerous state departments of transportation (DOTs).

Because CCPs improve the strength and durability of concrete, demand for ready mixed concrete is a primary driver for CCP utilization, particularly for fly ash. The demand for ready mixed concrete is closely correlated with construction markets and overall U.S. economic growth. Highway construction is also a major end market, as CCPs are used in pavements and bridges, and provide stability benefits in road base, structural fills and embankments.

The utilization rate of fly ash has grown from 8.4 percent of production in 1974 to 43.7 percent in 2013, when 23.3 million tons were beneficially used.

Technologies to improve ash quality, logistics and infrastructure to transport CCPs efficiently and wider recognition that CCPs are high-value materials have contributed to utilization. Demand for synthetic gypsum has been supported by the commercialization of wallboard manufacturing and market preference for the uniformity and lower cost of FGD gypsum compared to virgin (mined) gypsum. Wallboard manufacturers have co-located production facilities adjacent to coal-fueled power plants to streamline manufacturing.

Currently about 50 percent of the gypsum panel products manufactured in the U.S. are made with synthetic (FGD) gypsum. In 2013, 7.4 million tons of synthetic gypsum were utilized for wallboard products. FGD materials are also used in mining applications and as an agricultural amendment to improve soil quality, reduce nutrient run-off and boost crop yields. Overall, 12.9 million tons of FGD materials were utilized in 2013, with synthetic gypsum accounting for 92 percent of reuse.

CCPs are usually less expensive than the materials they replace, and the utilization of CCPs has increased, rather than decreased, during recessions. Fly ash utilization has increased during three of the last five recessions, while bottom ash utilization has increased following the beginning of every U.S. recession since 1973. Notably, CCP use increased steadily even when the real value of pavement work and new housing starts declined between 2000 - 2008.

Regulatory Uncertainty Hinders CCP Reuse

While CCP utilization has grown by an average 5.1 percent annually, total utilization as measured in tons has fallen since 2008. CCP utilization had increased to an all-time high of 60.6 million tons in 2008 – after the start of the most recent recession that began in December 2007. That peak was followed by six years of downturn in CCP utilization, where overall use declined by 15 percent.

This downturn occurred after the Environmental Protection Agency's (EPA) decision to reconsider the classification of CCPs as hazardous waste following the coal ash storage pond failure at Tennessee Valley Authority's Kingston power plant.

In June 2010, EPA proposed regulating CCPs as either solid waste under Subtitle D of the Resource Conservation and Recovery Act (RCRA) or as a hazardous waste under Subtitle C of RCRA. The final rule was published on April 17, 2015 – more than six years after the Kingston release.[3]

This period of regulatory uncertainty had significant implications for CCP utilization. Regulation of CCPs as a hazardous waste under Subtitle C would require expensive changes to CCP management and transport. In addition, the label of hazardous waste could impact consumer acceptance of building materials made with CCPs. As a result, CCP markets were negatively impacted.

While the downturn in CCP utilization coincided with the recession from December 2007 to June 2009, economic analysis has shown that the contraction in construction market activity was not solely responsible for the sharp decline in CCP utilization. Bottom ash utilization – which had previously increased following the start of the last five recessions – declined at an average annual rate of seven percent between 2008 and 2013. Fly ash utilization fell to 23.3 million tons in 2013, a decline of 18 percent from 2008 levels

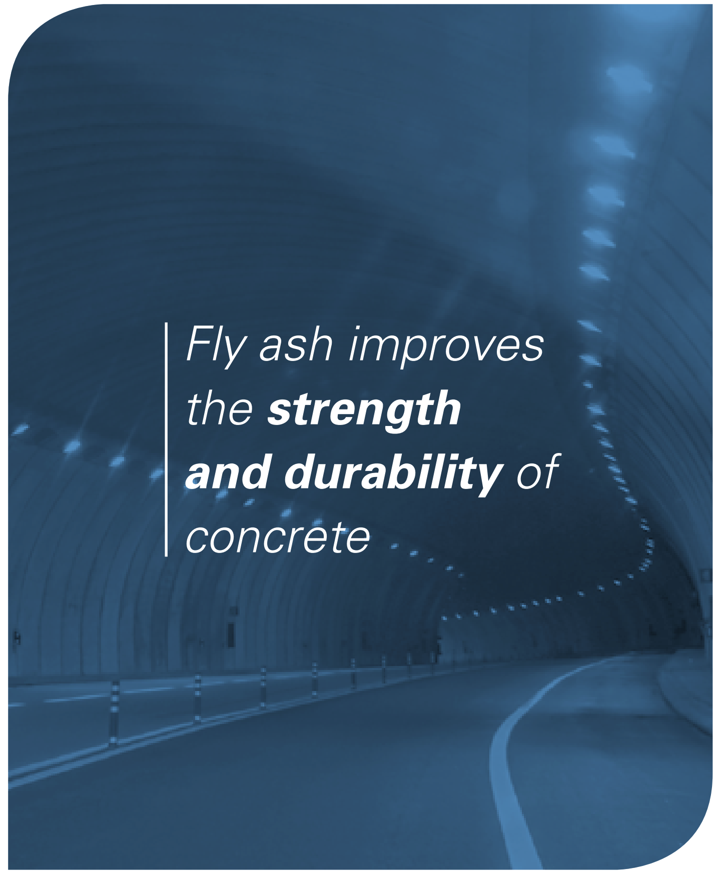
Although production of ready-mixed concrete in 2013 was still below pre-recession levels, the market bottomed out in 2010 and demand has increased annually since that time. Meanwhile, fly ash utilization had continued to remain depressed.

[3] *80 Fed. Reg. 21301. Hazardous and Solid Waste Management System; Disposal of Coal Combustion Residuals From Electric Utilities.*

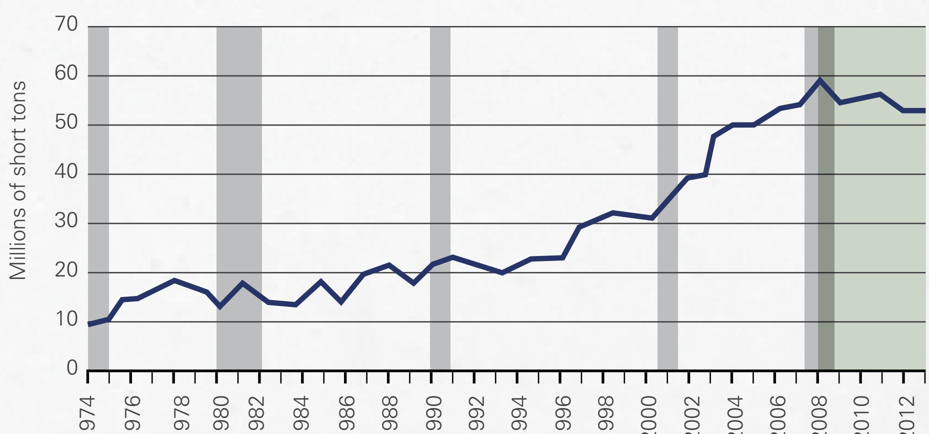
Regulatory Uncertainty Hinders CCP Reuse

The 2015 final rule regulating CCPs as nonhazardous and retaining the Bevill exemption for CCPs that are beneficially used restores certainty to markets. In addition, in 2014 EPA affirmed the safety of using fly ash in concrete and FGD gypsum in wallboard using a risk-based scientific methodology. EPA found that the environmental performance of fly ash concrete and synthetic (FGD) gypsum wallboard were comparable to non-CCP products and concluded "these beneficial uses provide significant opportunities to advance Sustainable Materials Management."[4] As a result, EPA "supports the beneficial use of coal ash in an appropriate and protective manner, because this practice can produce positive environmental, economic, and product benefits."[5]

The regulatory certainty provided by these two EPA actions is important for investment in CCP markets, and for CCP beneficial use to recover and surpass 2008 levels. The utilization of CCPs during recessions and the period of regulatory uncertainty is shown in Figure 2.



Utilization of CCPs has increased during recessions, but dropped during a period of regulatory uncertainty



- U.S. Recessions
- CCP Regulatory Uncertainty
- Total CCP Utilization

Major U.S. Recessions

November 1973 to March 1975
January to July 1980
July 1981 to November 1982
July 1990 to March 1991
March to November 2001
December 2007 to June 2009

CCP Regulatory Uncertainty:

December 2008 to April 2015: EPA decision to reconsider the classification of CCPs as a hazardous waste

Figure 2. Regulatory uncertainty led to a decline in CCP markets

[4] *U.S. EPA. 2014. Coal Combustion Residual Beneficial Use Evaluation: Fly Ash Concrete and FGD Gypsum Wallboard. Available at:* http://www.epa.gov/waste/conserve/imr/ccps/pdfs/ccr_bu_eval.pdf

[5] *U.S. EPA. 2014. Coal Ash Reuse. Available at:* http://www2.epa.gov/coalash/coal-ash-reuse

Steady Production Will Support Future CCP Market Growth

Coal once accounted for 50 percent of electric generation in the U.S., but declined to a low of 37.4 percent of in 2012. With 40 gigawatts (GW) of coal-fueled electric power capacity projected to retire through 2040, coal's role in the U.S. power system continues to evolve. The availability of CCPs for beneficial use and the potential for utilization over the next two decades was forecast using a series of econometric models using Box-Jenkins methods. These models were based on historical relationships between coal-fueled generation, construction market demand, and CCP production and utilization.

Despite the retirement of coal-fueled capacity, power generation from coal is expected to remain relatively steady through 2033 due to electric demand growth, according to the U.S. Energy Information Administration (EIA). As a result, CCP production is forecast to increase by five (5) percent over the next twenty years, from 114.7 million tons in 2013 to 120.6 million tons in 2033. Figure 3 shows the forecast utilization with 95 percent confidence intervals from the model results.

Fly ash and bottom ash production are each projected to increase annually by 0.1 percent over the next 20 years. Fly ash production is forecast to reach 54.6 million tons in 2033, and bottom ash production is projected to increase to 14.7 million tons. The production of FGD materials will not be significantly impacted by coal unit retirements, as most of these retiring units are older and lack scrubber systems. For units that will continue to operate, scrubbers have already been installed or are planned, reflecting investments already committed to comply with the Mercury and Air Toxics (MATS) rule. These new and planned scrubbers will increase the supply of FGD materials – particularly gypsum. Production of FGD materials is expected to surge 10 percent over the next 20 years under the baseline scenario, increasing to 38.8 million tons by 2033.

CCP utilization has ***increased 500%*** *since 1974*

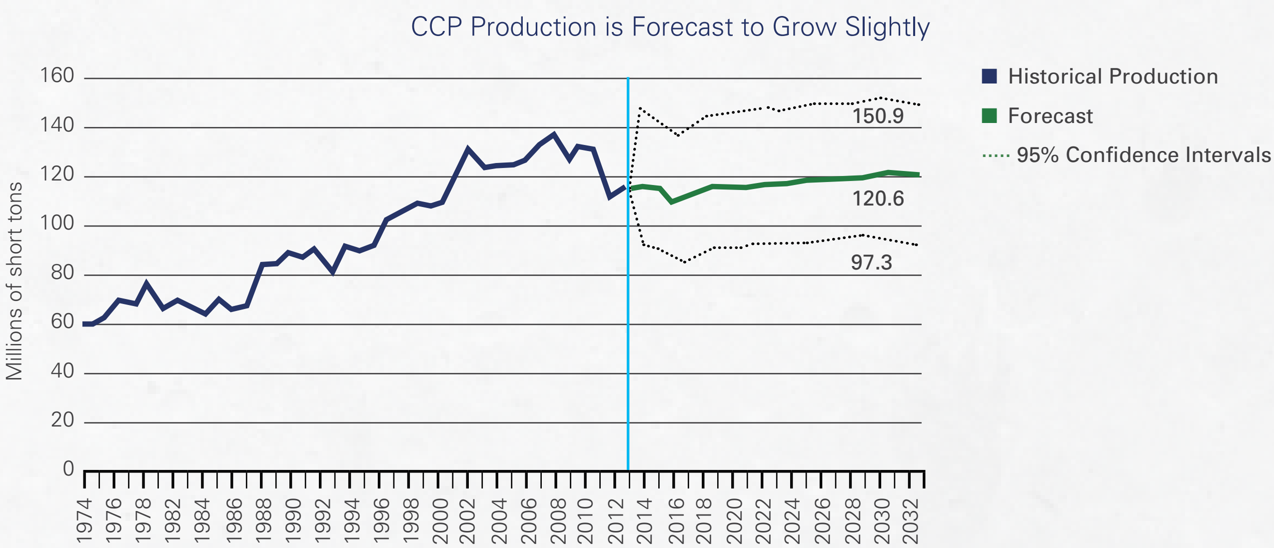


Figure 3. CCP production will increase 0.3 percent annually as coal demand for electric generation remains steady

Ready Mixed Concrete Demand and U.S. Economic Growth Drive Future Beneficial Use

Total CCP beneficial use is forecast to increase 48 percent from current levels to 76.5 million tons in 2033. As a result, overall utilization of CCPs is forecast to grow to 63 percent of production, as shown in Figure 4. Drivers of CCP utilization over the next two decades are growth in the U.S. economy, new housing starts, and increased demand for ready mixed concrete. Historically, ready mixed concrete demand has grown at an average annual rate of three percent.

Based on ready mixed concrete market projections, fly ash utilization is forecast to increase to 35.7 million tons in 2033 – a 53 percent cumulative increase over the next two decades.

FGD materials utilization is forecast to grow at three percent per year, to 22.3 million tons by 2033. It is expected that most of the materials utilized will be synthetic gypsum, consistent with historical reuse patterns and active markets for gypsum. Significantly, the overall FGD material utilization rate is projected to grow from 37 percent currently to 58 percent by 2033. Bottom ash utilization is forecast to increase 28 percent to 7.2 million tons in 2033, tied to demand from construction markets.

FBC ash utilization is projected to increase from 8.8 million tons in 2013 to 10.6 million tons in 2033, maintaining the average historical utilization rate of 89 percent of production. FBC ash has been used extensively for mine reclamation to mitigate acid mine drainage and restore landscapes.

It is important to note that the forecast models assume regulatory certainty based on the final EPA rule – that CCPs will be regulated as nonhazardous materials.The forecasts for each category of CCPs compared with 2013 production and utilization are shown in Table 1.

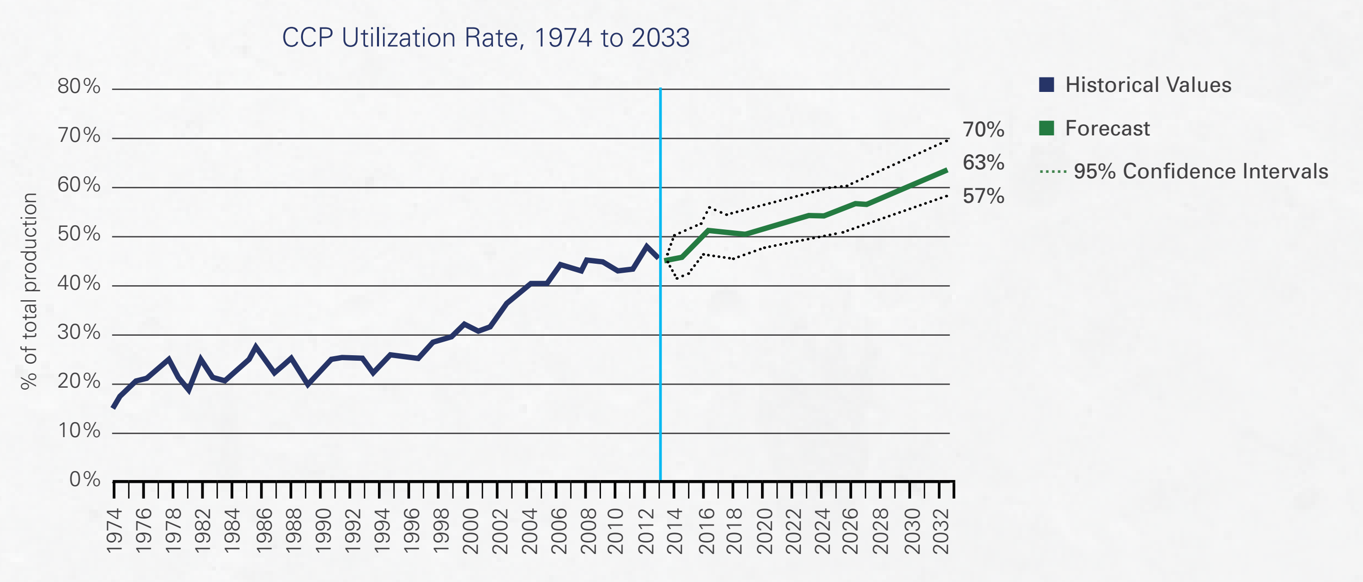


Figure 4. The percentage of CCPs utilized is expected to increase due to strong end market demand

Ample CCP Supplies Will Support Future Utilization

Alternative scenarios for "low growth" and "high growth" in fly ash, FGD materials and total CCP production were also modeled based on historical production patterns and different modeling techniques. Under the low growth scenario, which represents accelerated retirements of coal-fueled electric generating units, CCP production is forecast to drop 0.9 percent to 94.8 million tons in 2033. Fly ash production under the "low growth" scenario would decrease to 44.5 million tons in 2033. FGD materials production under this scenario would decrease by 2.1 percent annually to 23.0 million tons. Fly ash and FGD materials production for the "low growth" scenario would still exceed forecast utilization.

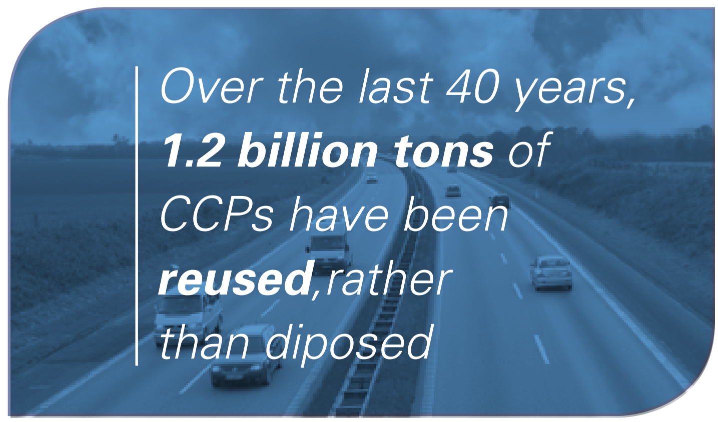
The "high growth" scenario is based on higher production growth for fly ash and FGD materials following the enactment of CAA regulations. Under this growth scenario, total CCP production is projected to grow 1.7 percent annually to 161.5 million tons in 2033. Fly ash production would grow by 0.9 percent annually, to 64.5 million tons. FGD production under the "high growth" scenario would reach 69.7 million tons in 2033.

Table 1. Forecast CCP production and utilization by category

	2013 Volume (million short tons)	2033 Forecast Volume (million short tons)	Projected Total Growth	Projected Average Annual Growth
PRODUCTION				
Fly Ash	53.4	54.6	2.2%	0.1%
FGD Materials	35.2	38.8	10.1%	0.5%
Bottom Ash	14.5	14.7	1.2%	0.1%
Boiler Slag	1.4	0.8	-43.2%	-2.8%
FBC Ash	10.3	11.8	14.5%	0.7%
Total Production	114.7	120.6	5.2%	0.3%
UTILIZATION				
Fly Ash	23.3	35.7	53.1%	2.2%
FGD Materials	12.9	22.3	72.9%	2.8%
Bottom Ash	5.6	7.2	28.4%	1.3%
Boiler Slag	0.9	0.8	-16.1%	-0.9%
FBC Ash	8.8	10.6	20.2%	1.0%
Total Utilization	51.6	76.5	48.3%	2.0%

Technologies and Logistics Enable New CCP Supplies

In addition to new production, ample supplies of CCPs are available from surface impoundments and landfills. Beneficiation technologies that treat CCPs for residual carbon, moisture and other undesirable properties are used to create ash that meets technical specifications, such as ASTM standards for use in concrete. These technologies have been successfully commercialized and are used throughout the U.S.



EPA regulations establishing disposal standards for CCPs as well as steam electric effluent limitations guidelines (ELG) will result in some CCP impoundments and landfills being closed. Beneficiation technologies provide an opportunity to reclaim materials that had been previously disposed. Further, as more utilities convert to dry CCP handling to comply with these environmental regulations, the quality and quantity of CCPs suitable for beneficial use will increase.

Engineers, planners, architects and construction professionals recognize the strength, durability and sustainability benefits that CCPs deliver. With demonstrated excellent technical performance of CCPs in various applications from construction to mine reclamation to agriculture, CCPs have become a high-value material resource. Forecast models project that sufficient quantities of CCPs will be available for beneficial use over the next two decades. Given regulatory certainty, CCP markets will continue to grow this recycling success story.

2015 American Coal Ash Association (ACAA)

DELIVERING INDUSTRY LEADERSHIP

When producers and users of Coal Combustion Products work with Headwaters Resources, they get more than access to the nation's largest manager and marketer of CCPs. They get a partnership with the unparalleled leader in building and protecting beneficial use practices in the United States.

Increasing the beneficial use of CCPs requires a sustained commitment to engaging in regulatory affairs, developing technologies and technical standards, ensuring ash quality, and providing logistics to reliably supply ash to end users. Headwaters Resources maintains the industry's most comprehensive program to address those needs.

From building CCP management infrastructure nationwide to defending our industry in Washington DC, count on Headwaters Resources to deliver.

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