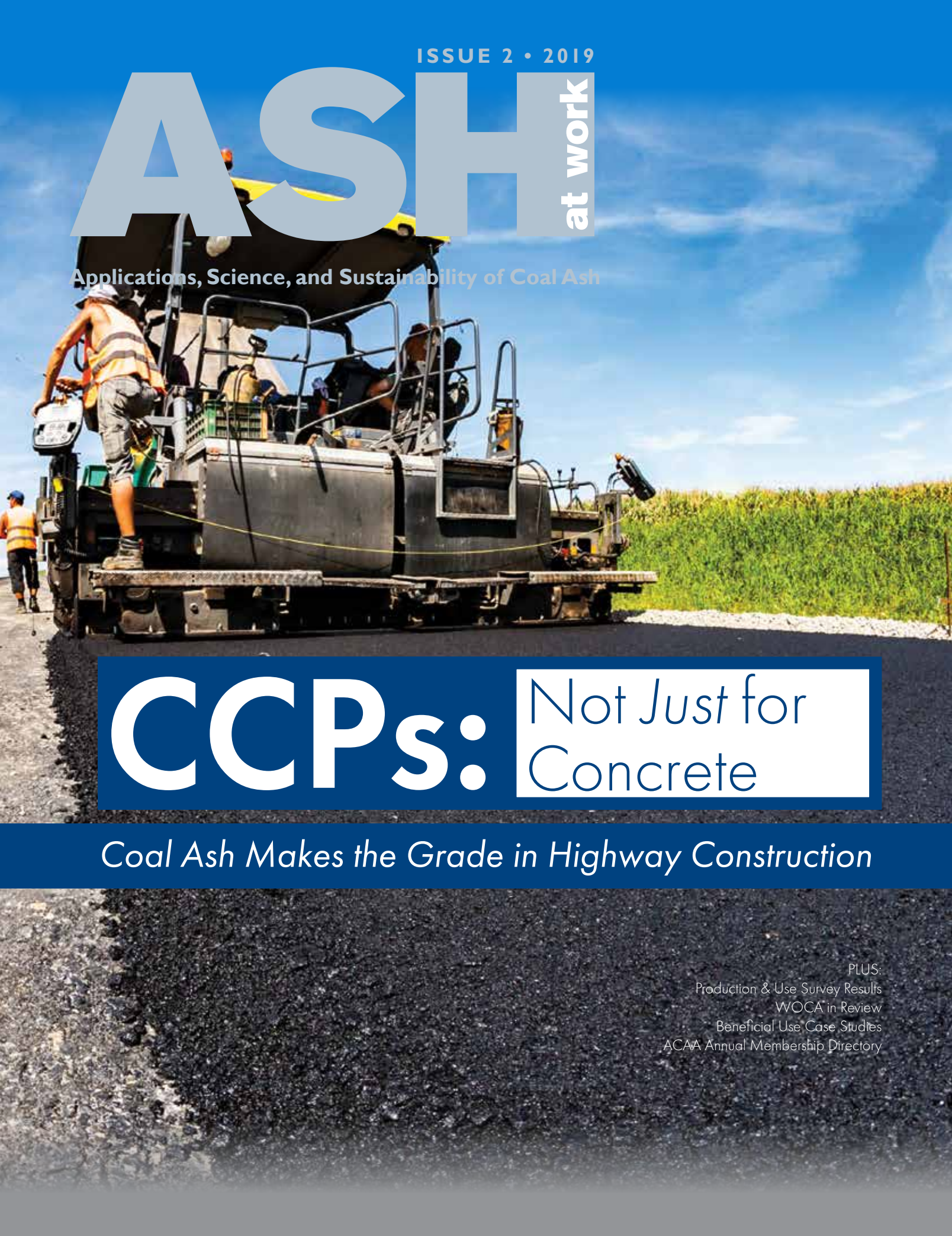
ISSUE 2 • 2019

ASH at work

Applications, Science, and Sustainability of Coal Ash



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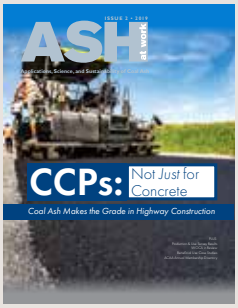
On the Cover

Coal ash is increasingly used in non-concrete applications from road construction to structural fill.



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Effort In, Value Out

By Kenny Tapp, ACAA Chair

It's an oft-repeated refrain: you get out of something what you put into it. That dictum is seldom more applicable than for associations, where personal involvement and effort can build knowledge, professional contacts, and leadership ability—all while benefiting a larger cause.

The American Coal Ash Association has long operated with a streamlined professional staff, aided ably by members at all levels of their respective organizations who have willingly volunteered their time and expertise to work on issues that are of importance to us all. In this way, ACAA's comparatively small membership has managed to project an outsized voice and influence policies at the federal, state, and local levels that have helped preserve the very existence of the coal ash beneficial use industry.

As on Capitol Hill, the committees are where the action is. ACAA has three standing committees—Government Relations, Technical, and Communications and Membership—all of which are "staffed" by ACAA members who have committed their time and services voluntarily. Collectively, these committees drive the work of the association and its value to the membership. Committee participation is open to employees of member companies in good standing. Consider this an open invitation to contact the Committee chairs listed below to ask how you may contribute.

- Communications and Membership, chaired by Travis Collins, of National Minerals Corporation, oversees all programs involving formal information dissemination on behalf of the association. The Committee reviews and makes recommendations for acceptance on all new applications for membership, as well as on membership classes and dues structure as warranted. Travis can be contacted at travis@nmcflyash.com.
- The Technical Committee, chaired by Rafic Minkara, of Boral Resources, oversees all programs of a technical nature. Its members serve on industry standards-setting bodies; generate technical commentary on agency rulemakings; and produce papers and conduct workshops and seminars to help members and external customers understand the practical implications of agency rulings and standards updates. Rafic can be contacted at rminkara@boral.com.
- Government Relations, chaired by John Ward, oversees all programs involving interface with federal, state, regional, and local government agencies. The Committee monitors regulatory and legislative developments concerning coal ash beneficial use; coordinates input from ACAA members for comment letters to regulatory agencies; and prepares and delivers testimony before governmental bodies. John can be reached at wardo@wardo.com.

The above are, in fact, just a partial description of the duties these committees carry out. The Technical and Government Relations Committees, in particular, liaise heavily with allied organizations to ensure that our messages are aligned and carry the most forceful impact.

Whether we like it or not, the coal ash beneficial use industry is under constant attack from an array of forces—some willfully uninformed, others merely ignorant. Environmental non-governmental organizations ("ENGOs"), the media, regulators, legislators, and the public all need to be constantly educated as to the science and the facts about coal ash beneficial use—or our industry could perish.

The American Coal Ash Association wants you to "ask what you can do for your association." Please consider stepping forward and volunteering to help ensure the future of our industry—truly one of the great environmental success stories of our time. I thank you in advance.












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Thanks a lot!

By Thomas H. Adams, ACAA Executive Director

BYLAWS OF THE AMERICAN COAL ASH ASSOCIATION INC.

Article I

Section 2. Mission. The Mission of the American Coal Ash Association is to advance the management and use of coal combustion products in ways that are environmentally responsible, technically sound, commercially competitive, and supportive of a sustainable global community.

I realize that the readers of *ASH at Work* understand this statement and may feel they need not be reminded. However, I wanted to call attention to one of the most important activities of the ACAA that supports this mission—the annual survey of the production and use of CCPs. In the late 1960s, as this association was born, the first attempt at a survey emerged. This first crude version of the survey attempted to discover what was being produced and used. It has since evolved and developed into a broad and detailed report that has served as the barometer for the beneficial use industry. The survey is not intended to detail the factors that cause changes within any specific product category or use. We do not have the resources required to make such in-depth analysis. The survey is intended to demonstrate trends over time. When we can tie these trends to major events such as the dramatic change in federal regulatory interest and anti-coal activism in 2009, we include evaluation of those factors into our analysis of beneficial use progress.

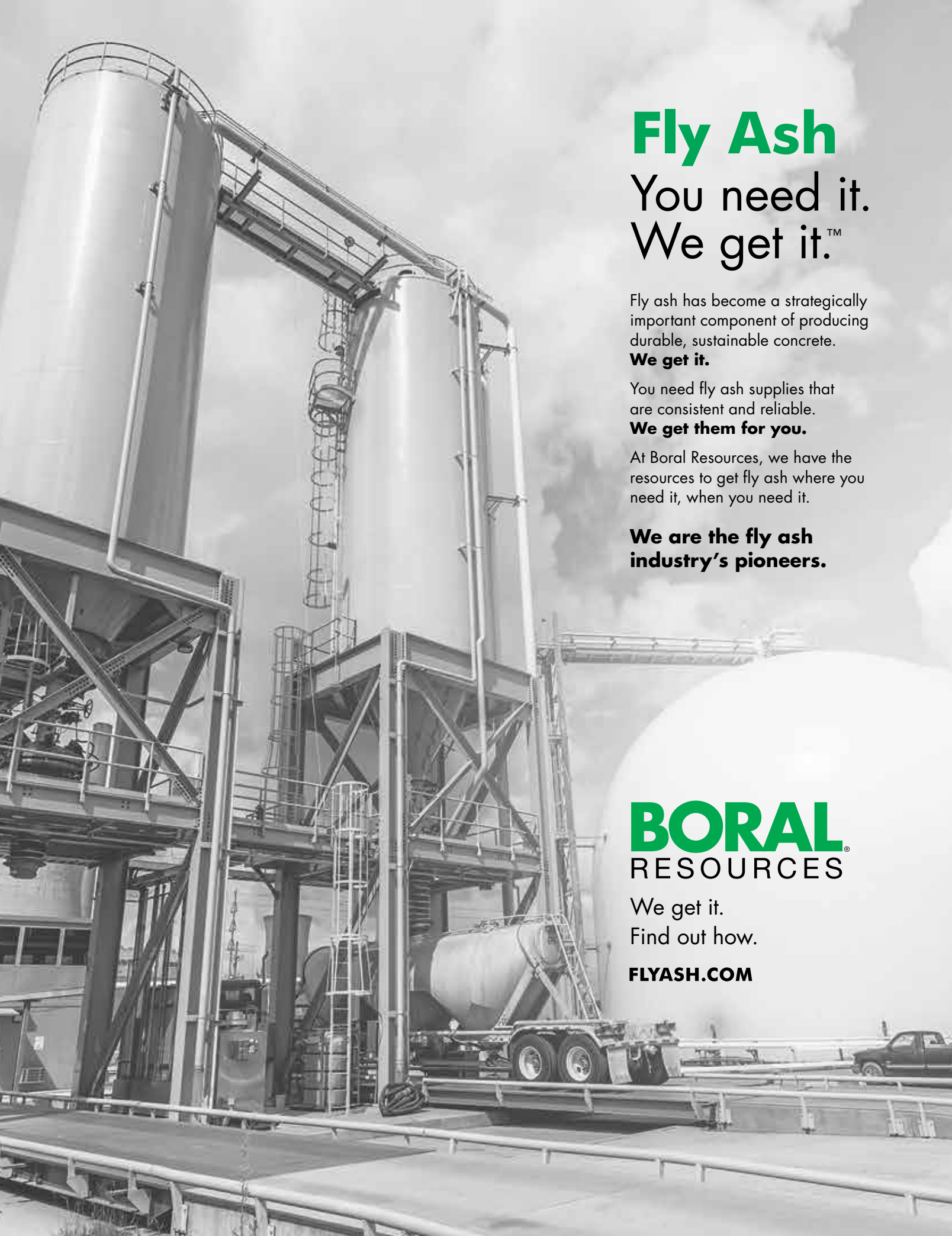
In order to create this report, we ask major generators of coal combustion products to report their data. Thankfully, most of the major generators respond positively to this request. Much of the data we seek is already collected and reported to the Energy Information Administration (EIA), an agency of the U.S. Department of Energy. *EIA 923: Power Plant Operations Report* is a mandatory report. Production and use is reported in Schedule 8 of that report. This data is eventually publicly available on the EIA website but can be delayed by as much as two to three years. Also, the data as presented does not clearly show the production and use according to material type and specific beneficial use. While individual states have their own reporting requirements, no state has a reporting that details production and use tied to beneficial use markets. Therefore, the ACAA report is regarded as the bellwether document on CCP production and beneficial use. It is regularly cited by a wide variety of organizations and groups, including regulators, researchers, environmental media, activists of all stripes, and the general public.

ACAA takes great care to protect submitted data. We have engaged a trusted third party, the Brattle Group, to receive data. A memorandum of understanding containing strict confidentiality language is the cornerstone of this relationship. The ACAA never sees individual company data. Brattle receives and aggregates data. This data is organized into the format that we have used now for several years. Once this draft is generated, the ACAA works with Brattle to identify anomalies. We follow up with "sanity checks," where necessary, factoring in market activity within specific uses.

Periodically, we are asked to provide data broken down by state. We have elected not to do so as this might reveal activity that can be easily tied back to specific companies, violating confidentiality and creating anti-trust concerns. We only report on a national scale.

Without the data submitted for the annual ACAA survey, we would be unable to achieve our stated mission. How are we to speak up on behalf of beneficial use if we cannot obtain hard data to describe the scope of beneficial use activities?

To those generating utilities reporting to the survey, we thank you. Because of your contributions, we are able to speak confidently about the state of CCP beneficial use. To those who are not currently contributing, we urge you to participate when the 2019 survey begins in March of 2020. More than ever, we need to accurately portray trends in beneficial use if we are to preserve decades of progress and continue to fulfill our mission.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Sustainable Use of FGD Materials in Mine Reclamation: Research to Commercialization

By Tarunjit Singh Butalia, Ph.D., P.E.; Jason Cheng, Ph.D., P.E.; and Robert Baker

This article highlights the use of coal combustion residues, particularly flue gas desulfurization (FGD) materials, for sustainable reclamation of legacy abandoned coal-mined lands—from the research phase to demonstration scale to the commercialization of the technology.

During the 1950s and 1960s, America's post-WWII economic boom was in full swing without much regard for the environmental impacts associated with industrial activities such as coal mining and coal-powered generation. In this era, mine reclamation required only the planting of trees on impacted surface-mined lands, but not the elimination of pits and highwalls or addressing water quality concerns. Coal-fueled power plants were being constructed across Ohio to utilize its abundant coal resources for power production. During this time, power plants emitted many pollutants that may have contributed to acid rain and other local air quality problems. In the 1970s several landmark federal environmental legislative initiatives were passed, including the Clean Water Act, Clean Air Act, and Surface Mine Reclamation and Control Act. Over the next couple decades, measureable improvements on the ground, in the water, and in the air were achieved by the mining, power generation, and other industries.

Amendments to the Clean Air Act in the 1990s strengthened power plant emission standards, requiring many generators to adopt flue gas scrubbing technologies to improve air emissions. As a result of this legislation, coal-fueled power plants in Ohio equipped with scrubbers produced significant amounts of FGD material. By 2009, three power plants in eastern Ohio produced approximately 4.2 million tons of FGD materials per year using lime-infused wet and forced-air oxidation scrubber techniques to reduce SO2 emissions and comply with air quality regulations. Ohio State University (OSU) researchers determined that:

- By 2012, five power plants would annually produce approximately 10 million tons of FGD material as a result of amendments to the Clean Air Act mandating a reduction in SO2 emissions;
- During this period, 90% of Ohio's power generation was from coal-fueled power plants; and
- Landfilling the FGD material was expensive, at an estimated $20-$30 per ton for capital costs and $2-$3 per ton for operating costs.

A limited quantity of this material was being beneficially used in the production of wallboard, agricultural applications, and mine reclamation. In 2012, about 5% of the FGD material generated in Ohio was used for reclamation applications.

Use of FGD Materials at Ohio Coal Mine Sites

To address this increase in the FGD residual material and the cost of landfilling in Ohio, OSU researchers completed a Phase I study titled *FGD By-Product Utilization at Ohio Coal Mine Sites: Past, Present, & Future* in collaboration with state and federal agencies, utilities, marketers, and trade groups. OSU researchers advanced the idea of providing a high-volume beneficial use of solid products generated from SO2 control technology to reclaim nearby abandoned mined lands as an option in place of expensive landfilling. The overall objective of the initial research was to increase the high-volume utilization of FGD material for reclamation at Ohio coal mine sites in a manner that was economically viable and beneficial to the environment, the public's health and safety, and the generating companies. In this Phase I study, OSU reviewed the existing information, conducted FGD material and site characterizations, gathered stakeholder inputs, and made recommendations for carrying out two full-scale demonstration projects. The use of FGD materials at mine sites became a strategic focus area of research and development for the Ohio Air Quality Development Authority's Coal Development Office (OCDO) for the next few years, and OSU was the recipient of Phase I, Phase II, and Phase III research grants from the agency.

According to the Ohio Department of Natural Resources - Division of Mineral Resources Management (ODNR-DMRM), Ohio has over 200,000 acres of unreclaimed strip-mined lands that contribute as much as 250 tons of sediments per acre per year into streams and lakes. OSU researchers determined that hundreds of miles of potentially dangerous highwalls (heights ranging from 50 feet to 100 feet) in close proximity to coal-fueled power plants remained unreclaimed, and reclamation funds from the state to address these sites were very limited. The end user of mined land reclamation resulting from this beneficial use could realize a savings of $10,000-$20,000 per acre. In most cases this would be Ohio's coal mine regulatory authority, ODNR-DMRM.

OSU researchers used a site selection matrix and chose two mining sites for the large-scale FGD placement demonstration projects, one near the Conesville Power Plant in Coshocton County and the second near the Cardinal Power Plant in Jefferson County. The sites that rated highest in the matrix criteria were in close proximity to the power plant (less than two miles), located on private property owned by the utility company, used existing haul roads for site access, and were environmentally isolated. Laboratory testing found that coal combustion residues (CCRs) such as fixated FGD, fly ash, and FGD gypsum in various combinations had relatively high shear strength and could be used as backfill for reclamation of unreclaimed highwall/pit complexes, providing stable slopes regardless of the combinations used. The data collected from a series of leaching tests to evaluate the release of environmentally concerned constituents from the material also confirmed that these CCR materials could be used safely as backfill material in a beneficial use application in coal mine reclamation. Both demonstration sites were fully instrumented with monitoring wells to capture background water quality data prior to construction, and monitoring continued during construction and for a period of five years following completion of the construction.

The Cardinal Star Ridge site located in Jefferson County had an active mine permit that included legacy mined land (see Figure 1). Approximately 500,000 tons of FGD gypsum was placed at the site, which reclaimed 10 acres of legacy highwall/pit complexes, augmented by backfilling of the active mine highwall to meet the approximate original contour requirements. The site was completed in 2015 (see Figure 2).

The Conesville Five Points site is located in Coshocton County at an abandoned mine land site near the AEP Conesville Power Plant, which contained several miles of unreclaimed highwalls and pits (see Figure 3). Approximately 1.6 million tons of coal combustion residues (primarily stabilized sulfite FGD and FGD gypsum) were placed at the site, which reclaimed 22 acres of legacy pit complexes and eliminated 2,400 linear feet of unreclaimed highwall, returning the legacy mined area approximately to its original contours.

Figure 1. Cardinal Star Ridge site prior to and during FGD placement.

Figure 2. Cardinal Star Ridge site final reclamation.

Figure 3. West portion of Five Points prior to and during FGD placement.

The site was encapsulated with low-permeability sulfite FGD and soil material (see Figure 4) and reclaimed following the Appalachian Regional Reforestation Initiative. This forestry reclamation approach is characterized by the use of local end dumped spoil piles placed in an interlocking manner to encourage saturation, limit off-site erosion, and provide a medium that promotes tree survival and growth (see Figure 5).

In 2016 tree-compatible grasses were planted to prevent erosion, along with a mixture of deciduous trees and conifer seedlings (see Figure 6).

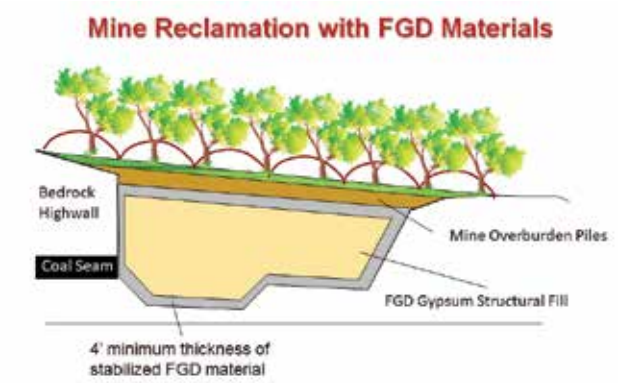

Figure 4. Encapsulation.

After the first growing season, survivability of the planted trees was calculated at 73%. A second tree survey at the site was completed in 2018. Based on the 2018 stem counts, the estimated density of live trees across the site (including any volunteers) was approximately 488 trees per acre. Survivability of the planted trees increased to 89% after the second growing season as a result of the volunteer trees, which is attributed to natural succession (see Figure 7).

Environmental monitoring has led to observations of short-term water quality impacts. However, further analysis has shown these impacts are primarily the result of modified groundwater paths due to backfilling and not the FGD material used for the backfill. None of the constituents monitored have exceeded the upper limit set by regulatory authorities in Ohio for the beneficial use of CCRs in mined land reclamation.

These projects have now progressed from the research and demonstration phases to a viable commercialization phase implemented by the local utility company at two additional sites near the Conesville Power Plant to eliminate an additional 5,000 feet of highwall and reclaim 100 acres of abandoned mined land. This approach has proved to be economically advantageous compared to the capital costs associated with building a landfill and the high costs for traditional mine land reclamation. More information can be obtained at the OSU Coal Combustion Products Program website at https://ccp.osu.edu/.

Figure 5. Interlocking spoil piles.

Figure 6. Forestry reclamation approach.

Figure 7. Evidence of volunteer black walnut trees in background.

Dr. Tarunjit Butalia is Director of the Coal Combustion Products Program at The Ohio State University. A registered professional engineer, he has provided leadership to several CCP research and demonstration projects and has authored, presented, and/or published more than 150 technical papers and book articles. He serves on the Advisory Board of the International Pittsburgh Coal Conference and is a member of the Editorial Board of *Coal Combustion and Gasification Products*.

Dr. Jason Cheng is Senior Research Engineer at The Ohio State University, where he earned both his Ph.D. and MSc. in civil engineering, with a specialization in environmental engineering and water resources. He is a registered professional engineer whose research interests include applying principles of geochemistry in exploring the beneficial use of industrial wastes and assessing the associated environmental responses.

Robert Baker is a graduate of the School of Natural Resources at The Ohio State University and has over 40 years' experience in the field of coal mine reclamation. After retiring from the Ohio Department of Natural Resources, Division of Mineral Resources Management in 2005, where he served in several managerial positions, he has been working as a consultant to OSU since 2009. He has been involved in coal mining and reclamation research projects and field demonstration projects that beneficially use coal combustion products for reclamation of coal mine sites.

EPRI Researches Emerging Beneficial Uses

By Ben Gallagher, P.E.

The power industry has a long history of investigating beneficial uses of coal combustion products (CCPs). Industry research traditionally has looked at the largest-volume applications because avoided cost of disposal has been a top consideration. While research into large-volume uses is still important, recent research also has focused on smaller streams of CCPs, such as spray dryer absorber materials, that are considered "off-spec" for concrete use and for which other beneficial uses are not available.

In addition, research has expanded to include complementary uses that exist alongside large-volume applications. Complementary uses are likely to become more important in cases in which fresh or harvested CCPs are processed for use; multiple products can be produced, each for a different beneficial use. Complementary uses can reduce the reliance on one or two critical CCP markets and might improve the overall value of a beneficial use program.

Asphalt Binder

As much as 500 million tons of asphalt pavement is produced each year. One of the asphalt industry's major objectives is to increase the sustainability of asphalt pavements, and part of that vision involves increased use of "perpetual pavements." Perpetual pavements limit damage to the top surface and require only infrequent resurfacing, making durability a primary concern.

Fly ash collected in systems with direct sorbent injection (DSI) and spray dryer absorber materials (SDAMs) tend to contain alkaline sorbent reaction products and activated carbons that limit their application in beneficial uses such as ready-mix concrete. Research by Temple University and the University of Wisconsin-Milwaukee, supported by EPRI, is investigating pavement durability when off-spec fly ash containing DSI and SDAMs is used as replacement for a portion of the asphalt binder.

Results to date suggest certain fly ashes with DSI and SDAMs may improve the durability of asphalt binders. This is a promising finding because commercial mineral fillers don't necessarily contribute to pavement durability. The improvement in durability might be related to the round shape of fly ash as well as the chemical properties of the sorbent injection byproducts. Ongoing research is exploring the mechanisms responsible for improved durability.

In addition to increasing durability, another asphalt industry focus is increasing the recycled content of pavements. The quality of reclaimed asphalt generally limits its inclusion in new pavements. Ongoing research is exploring the properties of reclaimed asphalt containing fly ash. Preliminary results suggest reclaimed asphalt containing certain fly ashes with DSI or SDAMs may exhibit reduced aging of asphalt binder at the end of pavement life. This could help support incorporation of larger volumes of reclaimed asphalt in new pavement, reducing life-cycle costs and increasing the sustainability of the pavement.

Ash-Polymer Composites

Polymer composite materials have been used for decades in a wide range of applications. Probably the most widely recognized are fiberglass-reinforced composites, which make up products as diverse as pleasure boats and FGD scrubbers. A key advantage of composite materials is the ability to engineer properties

to suit the application through selection of raw materials and manufacturing techniques.

Fly ash can play a role in polymer composite materials. North Carolina A&T University studied fly ash-polymer foam composites and found the ash's rounded shape and resistance to environmental degradation can be useful properties in engineering composite products. Benchtop research at the university has produced utility pole cross arms, precast vault covers, and other products (see Figure 1). In these foam composite applications, the fly ash used may be the coarse fraction and can contain unburned carbon, making it a complementary use to fly ash in concrete, in which finer, low-carbon ash is most valued.

The process used to manufacture composite materials can determine the commercial success or failure of these materials. EPRI is in discussion with North Carolina A&T to investigate the ash polymer foam composite technology at EPRI's Ash Beneficial Use Center (ABUC), described in "EPRI and Georgia Power Team Up on Harvested Ash Use Research" in Issue 1, 2019, of *ASH at Work*. One of the objectives of the ABUC is to provide the infrastructure to test production processes at a size that could be reasonably scaled to full scale. Should EPRI test a technology like North Carolina A&T's ash-polymer foam composites, the ABUC would supply ash meeting the technology's specifications and host a pilot-scale flexible production facility where the technology provider would develop their manufacturing process and manufacture the composite products. Finished products would be lab tested by EPRI for conformance with specifications and also could be distributed for field testing. Collaboration on such a pilot production facility ideally would include one or more commercial entities interested in full-scale implementation.

Industrial Minerals/Critical Materials

The past 50 years of CCP use includes numerous attempts to develop technologies to economically extract valuable metals, such as iron or aluminum, from coal ash. Recent research in the U.S. has focused on so-called critical materials, such as rare earth elements (REEs), that are considered important to strategic industries and/or have geopolitical considerations.

Unlike iron or aluminum, in many cases, the critical materials of recent interest represent a very small fraction of the bulk material. If a fly ash contains 400 ppm of REEs, and all of the REEs are extracted, 99.96% of the fly ash remains for other use or disposal. EPRI research has focused on understanding the value of critical materials in CCP and on holistic methods for obtaining critical materials that also include a valuable use for the remaining material.

Figure 1. Engineered composite cross arm with ash-polymer foam fill.

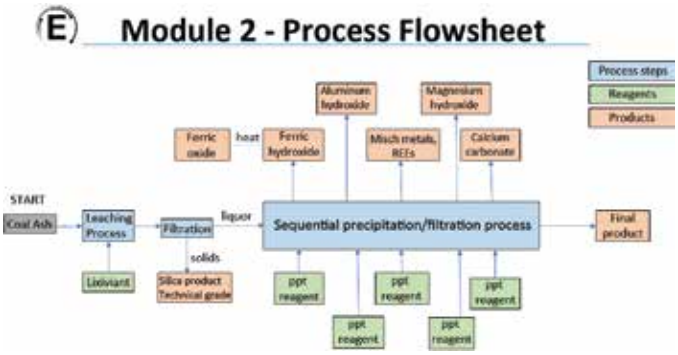

Figure 2. Simplified block diagram of an Elixsys module (courtesy of Elixsys Inc.).

One commercial entity working in this space is Elixsys Inc., which is developing a modular approach to refining CCPs into several different industrial products. Elixsys envisions modules that accommodate both FGD products and fly ash and uses a hydrometallurgical approach to separate the CCPs into seven or more mineral and chemical products, including one that contains REEs. Their process is claimed to utilize 100% of the CCP feedstock with a "near-zero waste stream" (see Figure 2).

Elixsys reports having successfully tested each of its major process steps at kilogram scale. EPRI is in discussion with Elixsys regarding hosting an integrated pilot test of its process at the ABUC. Since the ABUC includes several collaborating utilities, testing could include CCPs of varying compositions harvested from different ponds and landfills across the country. Ideally, collaboration would also include entities concerned with strategic access to materials as well as commercial parties interested in using the finished products.

Conclusion

The last two issues of *ASH at Work* (Issue 2, 2018 and Issue 1, 2019), covering the history and future of beneficial use, have clearly illustrated the challenges of developing and maintaining beneficial use markets for CCPs. Collaborative research played an important role in that history. As industry transition continues, including an increasing emphasis on the use of harvested CCPs, non-traditional beneficial uses are likely to expand, supported by research by EPRI and others.

Ben Gallagher is Senior Technical Leader at the Electric Power Research Institute (EPRI). Prior to joining EPRI, he worked as an engineer for Southern Company for over 10 years, where he directed and completed geotechnical engineering studies for clean air improvements, CCP storage, and new generation sites. Gallagher holds a bachelor's degree in civil engineering from the University of Toldeo, a master's degree in geotechnical and geoenvironmental engineering from the University of Missouri–Rolla, and an MBA from the University of Alabama at Birmingham.












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Sintered Lightweight Aggregate: A Host of End-Use Applications

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

Lightweight aggregates (LWA) are an increasingly popular construction material, specified across a range of projects for their low density and durability benefits to concrete products. A variety of raw materials can be used in the manufacture of LWA—including coal ash, pumice, shale, clay, and slate—producing aggregates of differing strength/density profiles suited to diverse end-use applications. Lightweight aggregates manufactured from coal combustion products are now proving their utility not only in concrete applications, but also in markets ranging from road construction to horticulture.

A pilot plant in Sowlany, Poland, produces 50,000 metric tons of lightweight aggregate annually.

Since 2018, Boral Resources has owned the commercialization rights in the U.S. for a technology that manufactures ceramic LWA from high-carbon fly ash. Ash sourced either from current coal-fueled electricity production or recovered from landfills or ponds can be used as feed material to manufacture the aggregate. With an estimated 1.5 billion tons of coal combustion products currently stored in landfills and surface impoundments throughout the U.S.—and many of the latter likely to be closed in the coming years—lightweight aggregate produced from CCPs has a ready source of raw material inputs that do not have to be quarried or extracted from deep underground.

To date, the technology has been successfully deployed at a full-scale production plant in Sowlany, Poland, which since 2015 has used coal ash from a utility landfill as

feed material to produce approximately 50,000 metric tons per year of lightweight aggregate. The product has been sold in Poland and exported for high-performance concrete applications, such as high-rise buildings. Boral is now making this technology available for both concrete and non-concrete applications in the U.S. market.

The Technology

The heart of the technology involves the use of a high-efficiency dryer coupled with a rotary kiln to sinter the pelletized raw materials—typically fly ash, but bottom ash can also be comingled—to impart the desired physical characteristics. The high-capacity counter-current dryer with mobile shelves uses a compact design requiring only a small amount of energy to dry the pre-agglomerated pellets. The sintering operation is autogenous, with external fuel required only for start-up. Process heat is recovered from the kiln flue gas (up to 1000° C), which is partly used for drying and production purposes. Additional surplus heat can also be recovered for other beneficial uses, including industrial heating or to generate electricity for added revenue.

The technology is fully automated and can be set up as a stand-alone or integrated installation. As an integrated installation, the LWA facility is interconnected into an operating power plant to effectively eliminate the disposal of CCPs. This configuration supplies the power plant with the recovered heat and relies on the power plant for emissions control and other basic utility needs. As a stand-alone installation, the facility is ideally suited to recover ash from an existing landfill or pond for clean closure. The stand-alone installation is fully equipped with all necessary emission control devices.

The ceramic material produced from the high-temperature sintering process is a safe, chemically neutral product consisting of lightweight and durable spherical pellets with both internal and external pores. The aggregate's bulk density ranges from 550 to 720 kg/m^3 and has a crushing resistance of 5 MPa. The LWA also possesses additional characteristics that further enhance its marketability, including:

- High strength-to-weight ratio
- Resistance to fungi, mildew, rodents, and insects
- Freeze-thaw and fire resistance
- Heat and sound insulation
- Non-degradability/reusability

LWA Applications

This combination of traits gives sintered LWA diverse uses in concrete manufacturing, building applications, geotechnical engineering/road construction, and horticulture.

Building Applications

Walls made from sintered LWA are highly insulative and protect against frost, heat, and noise. The product's thermal and acoustic properties, combined with its resistance to mold, fungi, and pests, further make it a good substitute in place of insulation made from mineral wool or foam polystyrene. The LWA is also suited to use in green roofs, providing lightweight thermal protection while facilitating water drainage to allow plants' root systems better accessibility to water and air.

Geotechnical Engineering/Road Construction

This LWA is an excellent substrate for pipelines and other underground installations, functioning both as a load-bearing material to ensure even settlement of an installation and as a thermal insulator to help prevent pipes from freezing. As an alternative to traditional road ditches, the LWA can be used as fill in French drains, resisting clogging and reducing the transmission of road vibration to buried pipe. The aggregate is also highly effective as a replacement for weak or loose soil in road shoulders and embankments to secure them against wind and water erosion.

Horticulture

Lightweight aggregate performs well as a mulching agent in the cultivation of plants and shrubbery. For indoor potted plants, LWA can be used as a subsoil layer to improve drainage or for soilless (hydroponic) cultivation. In outdoor applications, the lightweight aggregate can be used for landscaping, e.g., to fill forms and as a surface application to prevent weed growth. In addition to regulating water temperature and helping to prevent freezing of root systems, it also adds a decorative landscape element.

Sintered LWA: Poised for U.S. Market Growth

Although lesser known to most U.S. consumers than "traditional" natural aggregates, lightweight aggregate manufactured from coal combustion products is ripe for discovery. With an abundance of raw material available—both from current coal-fueled electricity production as well as landfills and surface impoundments—Boral's sintered lightweight aggregate represents a versatile substitute to natural aggregates for many end-use applications.

Rafic Minkara, Ph.D., P.E. is the Vice President for Product and Business Development for Boral Resources Inc. (a Boral Limited company). His team is responsible for quality assurance, technical services, research, and commercialization of new technologies as well as marketing and new business development. He has B.S., M.S., and Ph.D. degrees in engineering and an MBA degree from the University of Toledo. He is a registered professional engineer.

Beneficial Use of Dry Scrubber Ash in Mainline Asphalt Paving

By Travis Collins

The ultimate win-win equation for beneficial use of CCPs in construction is to improve quality, reduce cost, and conserve other resources. The use of fly ash in concrete has achieved these simultaneous goals for over 50 years and is now an essential product in the construction industry. Another encapsulated application with potential for increased utilization is the use of CCPs in asphalt paving, specifically in specialty, high-performance mix designs called stone matrix asphalt (SMA).

SMA Mix Design

Stone matrix asphalt is a specific mix design that originated in Europe in the 1960s and has seen steady growth in the United States over the past 30 years. SMA mixes are designed to be more durable and provide longer-lasting surfaces that are more resistant to rutting. Beginning with pilot projects in a few states, use of SMA has grown to include annual paving programs by several state DOTs, including Oregon and Georgia. There is a higher initial cost to produce and place SMA over conventional hot-mix asphalt, but several DOTs recognize the life-cycle cost benefit of using SMA, particularly in areas of high truck traffic.

The SMA mix design is unique primarily due to the higher proportion of coarse aggregate designed for increased stone-on-stone contact. This high-stone mix is held together by a binder of asphalt cement that is enriched with a mineral filler

NMC supplied 750 tons of dry scrubber ash for this stone matrix asphalt paving project on I-94 in central Wisconsin.

to increase viscosity. The fine particle sizing of fly ash is often used as the preferred mineral filler to increase the viscosity of the asphalt cement paste, which lessens the drain down of this binder due to a mix intentionally deficient in fine aggregate. Other bulk powders such as dry scrubber material or cellulose fibers can also be used as the mineral fillers in SMA.

Dry scrubber ash is the residual material created from the combination of fly ash and the reagent lime from the dry scrubber unit used to absorb acidic exhaust gases. The residual ash/lime is stored dry in a silo at the power plant. This material is often high in sulfur and calcium, making it useful to improve soil characteristics in agriculture. But due to seasonality and competition with other fertilizer products, dry scrubber ash is often in surplus at power plants. Finding other beneficial use outlets where there is a cost benefit and an encapsulated end use can be a challenge for utilities.

National Minerals Corporation (NMC) has supplied fly ash and dry scrubber ash produced at several different generating stations for mineral filler in various stone matrix asphalt projects in the Midwest over the past 10 years. The particle sizing and spherical shape of fly ash work very well and it is almost universally accepted. That said, the size, shape, and chemistry of dry scrubber ash vary from plant to plant. Since each scrubber unit and plant setup is somewhat unique, dry scrubber ashes are not all equally acceptable and require job-specific testing to verify compatibility. If the dry scrubber material is compatible with the asphalt plant setup, storage, weigh scales, and feeder systems, then it can make an excellent, cost-effective, fully encapsulated mineral filler in SMA paving.

I-94 SMA Paving Project

This past summer, NMC supplied 750 tons of dry scrubber ash for an SMA paving project on I-94 in central Wisconsin between Tomah and Sparta. The dry scrubber ash was sourced from the John P. Madgett Station (Dairyland Power Co-op), in Alma, Wisconsin, for the mineral filler portion of the SMA mix. Mathy Construction Co., which has significant experience in designing, batching, and paving SMA mixes, was selected to perform the work. Mathy's material handling experience and a plant designed for accurate metering of the dry powder into the mix yielded very consistent production and placement of the SMA mix. Use of a locally available surplus CCR reduced project costs and resulted in an effective encapsulated beneficial use.

Asphalt paving schedules are often difficult to service because of the high daily volume demands and potential for short-notice delays due to weather and other unforeseen variables. However, with adequate on-site storage, these projects can be successfully supplied with CCRs from nearby power plants. With fly ash having a higher-value end use in concrete, and seasonal production often committed to concrete producers during the construction season, using alternative CCRs such as dry scrubber ash in asphalt can be a win-win equation for the utility, the contractor, and the owner of the project.

Travis Collins is Vice President of National Minerals Corporation, a Minnesota-based fly ash marketer. Prior to National Minerals, he spent 18 years in the chemical admixture industry. For more information, please visit www.nmcflyash.com.

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Structural Fill: Conserving Natural Resources Through Projects Featuring Rigorous Engineering Standards

By John Ward

The numbers speak for themselves. According to ACAA production and use survey data, 188.7 million tons of coal combustion products have been placed in structural fill applications since 1980. The application represents one of the largest-volume opportunities to safely utilize CCPs in ways that reap environmental benefits while keeping material out of disposal impoundments and landfills.

Like many things related to coal ash, structural fill activities are frequently mischaracterized by anti-coal activists. The real story of structural fill is a long history of careful engineering and study by a wide variety of interested parties.

What Is Structural Fill?

Coal combustion products have been widely used to convert sites with unsuitable topography into valuable, productive property. These materials can be placed, spread, and compacted using the same equipment as conventional fill materials. Placement to a controlled density and configuration can produce stable fills for site developments, roadways, parking areas, and building construction.

Several coal combustion products—including fly ash, bottom ash, and synthetic gypsum—routinely make their way into structural fill settings. The unique properties of each of these materials determine where they can add value in a construction setting. For instance, the qualities that make bottom ash a preferred material for construction bedding also make it desirable as a backfill material for small areas. Bottom ash is uniform, well graded, drains readily, is not sensitive to moisture variations, and is relatively lightweight compared to many natural materials. Bottom ash can be handled, placed, and compacted using the same techniques as other natural granular materials.

In the United States, the use of CCPs in structural fills dates back to at least 1971. The materials have been widely used in transportation (highway, rail, and airport) settings for constructing embankments and leveling uneven topography. They have also been used in housing developments, shopping malls, industrial parks, and other types of commercial, residential, and industrial developments.

Engineered structural fills are typically constructed in layers of uniform thickness or homogeneity and, where appropriate, compacted to a desired unit of density in a manner that will control the compressibility, strength, and/or hydraulic conductivity of the placed material as required in order to meet engineering specifications.

Structural Fills: Not Born Yesterday

The use of CCPs for structural fill applications is widespread throughout the United States. Some of the earliest uses for CCPs in structural fills began in the 1970s as reported extensively by the National Ash Association in Technical Bulletins and through workshops hosted by NAA at West Virginia University. The NAA (later the American Coal Ash Association) held biannual symposia on beneficial uses for CCPs beginning in 1968, and at each symposium case studies of geotechnical applications, including structural fills, were included.

Coal Ash Used in Structural Fill Applications, 2000 - 2017

In 1979, the Electric Power Research Institute (EPRI) issued a "Fly Ash Structural Fill Handbook" (Report EA-1281). This document contained detailed information on materials characteristics, test and analytical methods, and types of embankments and structural backfills. Subsequently, in 1988, EPRI published "High Volume Fly Ash Utilization Projects in the United States and Canada" (Report CS-4446, Second Edition). This lengthy document identified more than 170 projects, of which approximately half described the use of CCPs in embankments related to highway construction. At the same time, EPRI was conducting a number of demonstration projects in Maryland, Kansas, Michigan, and Georgia that used CCPs in geotechnical applications such as pavement base course and structural fills. In October 1988, EPRI issued "Fly Ash Construction Manual for Road and Site Applications" (CS-5981, Volumes 1 and 2). The technical discussions about using CCPs in the geotechnical projects covered in these two volumes further documented design considerations and construction techniques.

The historical documentation prepared by EPRI clearly demonstrates that the industry did not consider structural fills to be some form of disposal, but rather an accepted engineering practice that would achieve specific technical performance and allow incorporation of CCPs into civil engineering projects.

As a result of these many projects, the geotechnical community recognized a need for standardized guidance that would address the technical, construction, and environmental issues pertaining to the use of CCPs in geotechnical projects. First issued in 1995 by ASTM as a provisional standard, "Provisional Standard Guide for the Use of Coal Combustion Fly Ash in Structural Fills" (PS23-95) was provided to the engineering community to give specific technical and design guidance on the use of CCPs in structural fills that reflected the field experience seen in the previous two decades. Drawing from additional field experience, PS23-95 was extensively revised and re-issued in May 1997 as ASTM E1861-97 "Standard Guide for Use of Coal Combustion By-Products in Structural Fills."

ASTM E1861 was superseded in 2003 with the publication of ASTM E2277-03. The revision was again based on increased field experience and development of best management practices for CCPs in geotechnical projects. All technical documents published by ASTM required specific engineering practices for the use of CCPs in engineered structural fills and do not condone "indiscriminate" placement of CCPs into "projects similar to disposal." Since 2003, ASTM E2277 has been continually updated through a consensus process in order to address better methods of engineering and placement of materials, including CCPs in engineered structural fills.

Today, sectors utilizing CCPs for structural fill applications include state departments of transportation, county and city road districts, and private commercial construction. By adhering to standard construction guidelines such as the ASTM and other documents cited above, achieving high-strength structural fills with CCPs is a safe and beneficial use.

But "Unencapsulated" Uses Must Be Bad, Right?

Wrong! Although the U.S. Environmental Protection Agency studied all forms of CCP beneficial use extensively beginning in 1980, issuing multiple reports and regulatory determinations supporting the practices, the agency's 2010 proposal for disposal regulations marked the first time it attempted to make a distinction between "encapsulated" and "unencapsulated" beneficial uses. ACAA and its members commented at the time that they were concerned about the distinction because EPA failed to adequately define the difference between the classifications, and EPA's proposed language indicated that the agency might take an overly restrictive view of what constitutes an encapsulated use.

ACAA's concerns have turned out to be well founded. In EPA's 2015 Final Rule for Disposal of Coal Combustion Residuals, beneficial use was once again exempted from regulation, but EPA advanced a definition of beneficial use that required enhanced evaluation of non-roadway structural fill activities larger than 12,400 tons—what EPA thought was the size of the smallest landfill in its rulemaking database. When EPA was shown that the 12,400-ton threshold was a mathematical error (in actuality, the smallest landfill in its database was more than 70,000 tons), the agency failed to correct it and recently proposed an entirely new approach to requiring enhanced

Photo: John Barker

evaluations. ACAA is pushing back against this unwarranted and potentially harmful regulatory mission creep. (See "ACAA Objects to Proposed Revisions to EPA's Definition of Beneficial Use" in the News Roundup section of this edition of *ASH at Work.)*

Rigorous Engineering Standards Are Already in Place

EPA's regulatory concern in advancing an evaluation requirement for large, non-roadway beneficial uses was the potential for "indiscriminate placement" of large volumes of CCPs. The agency did not present scientific analysis or relevant damage cases to justify its concern, but adopted an approach that could be described as "if it looks like a landfill, then it might be a landfill, so demonstrate its impacts."

As shown above, most structural fill projects conducted over the past four or five decades are anything but "indiscriminate."

"Like many things related to coal ash, structural fill activities are frequently mischaracterized by anti-coal activists. The real story of structural fill is a long history of careful engineering and study by a wide variety of interested parties."

The enormous volume of historic structural fill projects in the United States has not resulted in damage cases precisely for the reasons EPA itself noted in its 2015 Final Rule. States already regulate these types of beneficial uses and consensus-based engineering standards are in place to establish best practices.

The use of CCPs as structural fill has been widely demonstrated to be a safe and beneficial use throughout the United States. The technical data contained in field reports and the sampling of groundwater near various projects have shown that when both the site and the CCPs are appropriately characterized for the conditions and intended use of the land, there is no adverse environmental impact. EPA, the Federal Highway Administration, state departments of transportation, public and private universities, and various other state and federal agencies have studied and evaluated the uses of CCPs and concluded that the material has favorable geotechnical properties for structural fill. In addition to the previously mentioned ASTM standard, additional standards and technical guidance have been developed by organizations such as the Portland Cement Association, the Federal Highway Administration, the Recycled Materials Resource Center, the American Concrete Institute, the American Association of State Transportation and Highway Officials, and many individual states.

ASTM E 2277-14 "Standard Guide for Design and Construction of Coal Ash Structural Fills" addresses important criteria that

should be followed whenever constructing structural fill projects using CCPs. These criteria include materials characterization, site location restrictions, environmental protection procedures, testing procedures, and construction best practices.

A Beneficial Use Worth Protecting

Use of CCPs as a replacement for the soils or alternative fill material that would require excavation and import from a borrow site creates numerous environmental benefits, including:

- Conserving natural resources
- Minimizing land disturbance and associated runoff from extracting native materials
- Reducing energy use and carbon emissions from mining or excavation of native materials
- Reducing the volume of CCPs that would otherwise be landfilled

Conformance with the engineering standards developed over decades of testing and actual use ensures that these benefits are achieved with protection of human health and the environment as the primary concern.

Acknowledgement: Large portions of this article are drawn from the American Coal Ash Association's November 2010 written comments on the U.S. Environmental Protection Agency's then-proposed coal ash disposal regulation. Those comments were the product of approximately 100 volunteer ACAA members who expended more than 14,000 hours reviewing and drafting responses to EPA's proposals.

John Ward entered the coal ash marketing business in 1998 as Vice President, Marketing and Government Affairs, for ISG Resources (later Headwaters). For the past decade, he has served as president of John Ward Inc., a public affairs consultancy to the coal ash and energy industries. He is the longstanding chairman of ACAA's Government Relations Committee and was the first recipient of ACAA's Champion Award. He is the author of ACAA's weekly *Phoenix* newsletter and introduces himself the way his son did at a seventh-grade career day 12 or so years ago—as a used coal salesman.

How Well Do You Know CLSM?

By Thomas H. Adams

Controlled low strength materials (CLSM) provide a solution for many, many engineering challenges. CLSM, also known as flowable fill, is most commonly used as backfill for geotechnical applications. However, there are numerous other applications in which CLSM is used successfully. Controlling corrosion, lightweight and insulating fill, mitigating permeability, and managing electrical conductivity are examples of applications less familiar to the casual observer.

CLSM, by definition, is a low-strength material with a compressive strength of less than 1200 PSI and unconfined compressive strength of less than 300 PSI. If future excavation is a consideration, compressive strength should be less than 100 PSI. The material is not intended to be freeze/thaw resistant or resistant to abrasion or aggressive chemicals.

Among the many advantages of CLSM are the following:

- Readily available—a very wide spectrum of materials can be utilized. Locally available materials, both meeting specifications and non-specification materials, may be used depending on the application.
- Versatile—mixes can be tailored to meet the application and placement needs.
- Uses existing equipment—no special mixing or delivery equipment is required.
- Easily placed—placement is directly from the chute or through a pump, conveyor, or bucket. Since most mixtures are self-leveling, little or no labor is required for placement. Weather is not a factor for most CLSM placements.
- Fast and consistent—filling excavations with CLSM generally goes much faster than filling with aggregates, reducing closure to traffic for pavement repairs. Aggregate fill must be placed in layers with each layer tested for compaction. CLSM is generally prequalified, eliminating testing during placement.
- Smaller, safer trenches—when backfilling trenches, the trench can be narrower due to the fluidity of the CLSM mixture. The site is safer, since no workers are needed in the trench, eliminating the hazard of embankment collapse.

While a cubic yard of CLSM often costs more than a cubic yard of aggregate fill, CLSM often is much lower cost in place due to reduced labor costs and speed of placement.

Many state departments of transportation have their own CLSM specifications. Requirements vary from state to state, but generally cement factors are in the range of 50 lbs. to 80 lbs. per cubic yard. Mixes may or may not contain fly ash or other supplementary cementitious materials. When fly ash is used, the quantity can be as much as 2000 lbs. per cubic yard. No coarse aggregates are commonly used. Air entraining agents and foaming agents are used to control strength development and reduce density.

CLSM has been used for filling voids, backfilling utility cuts, encasing and protecting conduits, emergency response to fill sinkholes and slope stabilization, erosion control, lightweight and cellular structural fills, and many, many more applications. Some of the more creative examples of CLSM use are found below.

- In some local communities, CLSM advocates have convinced specifiers to require the use of colored CLSM in backfill for some infrastructure. When backfilling lines for natural gas transmission, electrical cables, telephone cables, fiber optic lines, and water and sewer lines, not only is the fill more consistent in support and encasement, it can be placed much faster with less labor. However, the biggest benefit is in safety. CLSM colored with pigments provides a warning to excavators that a utility line is nearby. This is especially important when dealing with explosive materials like natural gas or critical data transmission lines.
- In a large Midwestern city, the convention center started to exhibit some odd behavior in its basement. Doors would not close properly; cracks started to appear in the joints of the masonry; and floor slabs started to settle. Upon examination by a structural engineer, it was determined that the foundation was settling. The scope and location of the settling was established quickly with the use of sounding technologies. It was determined that a drainage line under the floor was not sealed properly prior to backfilling. The granular backfill around this line was washed away as stormwater flowed through the pipe. Approximately 2000 cubic yards of CLSM were pumped under the slab to fill the void and seal the pipe, resulting in significant savings to the owner without disruption to the use of the convention center.
- In Kansas City, an underground limestone mine was backfilled with CLSM. After mining operations were completed in a part of the mine, CLSM with Class C fly ash was pumped into the void to support the walls and create structural stability. Class C fly ash is not typically used in CLSM, since it hardens very rapidly without the use of set controlling materials. In this case, rapid set was a primary objective. The use of CLSM in this mine made the property above the mine suitable for commercial development. Today this property is populated with multi-story commercial development valued at several million dollars.

These are just a few examples of the creative and versatile use of CLSM.

The American Coal Ash Association (ACAA) has funded a risk evaluation of the use of CLSM utilizing the methodology developed by the U.S. Environmental Protection Agency (EPA). The EPA created this methodology to demonstrate the safety of beneficial uses in comparison to other conventional materials. It applied the process to the use of fly ash in concrete and FGD gypsum in wallboard. It did not examine other CCP beneficial uses. The ACAA has funded this work to demonstrate the safety of the use of CLSM containing CCPs. The risk evaluation report is expected by the end of 2019.

CLSM has been, and will continue to be, a valuable tool for solving engineering challenges. With some imagination and an understanding of the work and available materials, the choice of CLSM has proven to be a cost-effective answer to some serious challenges. The American Concrete Institute has a detailed report on CLSM from Committee 229. To obtain this report, visit www.concrete.org/publications.

Thomas H. Adams is Executive Director of the American Coal Ash Association and Chair of American Concrete Institute (ACI) Committee 229 on Controlled Low Strength Materials.

Using Business Intelligence to Gauge the U.S. Coal Ash Market

By David Cox, P.E.

The U.S. coal ash market remains in a dynamic state since the Environmental Protection Agency's (EPA's) 2015 issuance of "final" disposal rules regarding coal combustion residuals (CCRs). Owners and operators of units covered by the CCR rule are now grappling with closure options and compliance deadlines even as EPA considers further regulatory changes.

In the larger picture, U.S. coal consumption has dropped to its lowest levels since the late 1970s amid the closure of 546 coal-fueled generating units between 2010 and the first quarter of 2019. The latest figures from the Energy Information Administration (EIA) show a continuance of that trend through 2025, albeit at a slower pace (see Figure 1).

With this as background, we look at three dimensions of the U.S. coal ash materials market. First, we focus on the compliance impact of the CCR regulation on owner/operators. Next, we look at existing coal ash inventories and market trends. Finally, we expand our discussion to CCR demand in relation to its sources. Our perspective is informed by the inventory of materials currently in place within coal ash handling units at power plants, as well as on how regulatory drivers impact the ways in which those materials may become available.

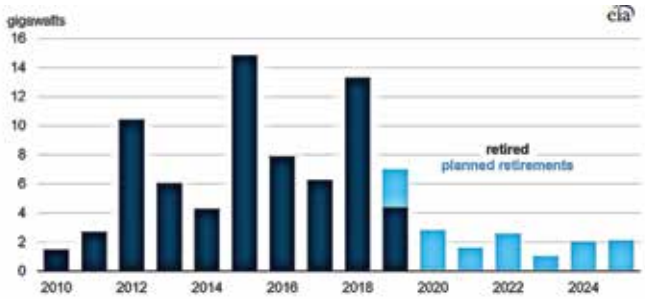


Figure 1. Total net summer capacity of retired and retiring coal units (2010-2025). Source: EIA.

Coal Ash Materials and the Regulatory Environment

Making educated predictions about the future of the U.S. coal ash market involves understanding the regulatory impacts of EPA's 2015 CCR rule. Here we'll provide a summary to set the stage. The regulatory challenge for operators/owners is twofold with respect to the CCR rule: the management of coal ash due to landfill closures and environmental obligations on compliance.

Currently, owner/operators coming into conflict with the CCR rule face at least two primary challenges to keeping CCR units (existing landfills and surface impoundments) open:

- Location restrictions
- Groundwater protection standard exceedance

Concerning location restrictions, five criteria drive the compliance program with specific timeframes. CCR units cannot be:

1. Located within five feet of the uppermost aquifer
2. Situated within a wetland
3. Located in fault areas
4. Situated within an active seismic zone
5. Located within unstable areas

Referring to these criteria by number, restrictions #2 through #5 required CCR unit closure by April 17, 2019. Restriction #1 has an action date of October 31, 2020, to cease operations and initiate shutdown.

Notably, there is pending regulation, and White House Office of Management and Budget review, that would extend the October 2020 deadline. Looking across the total CCR units facing closure at that time due to the location restriction relative to aquifer separation, the top five states are identified in Figure 2.

All told, we estimate that units requiring closure due to their proximity to the uppermost aquifer represent more than 200 million cubic yards of material. Note that these figures are based on "at-risk" CCR units, not those that are already closing.

Next, we look at annual groundwater monitoring requirements and groundwater protection standards (GWPS). Each year, §257.90 requires that owner/operators monitoring CCR units for groundwater problems issue a report on their groundwater monitoring and corrective actions taken. Determining whether there is a problem at a site is an involved process. If any statistically significant levels of contaminants are identified, and where GWPS exceed regulated analyte, the EPA will require action. Fifteen analytes are monitored, and lithium, cobalt, and arsenic are the most common elements with excessive measurements.

As shown in Figure 3, most sites had exceedances with two or three analytes. One location reported exceedances on nine analytes.

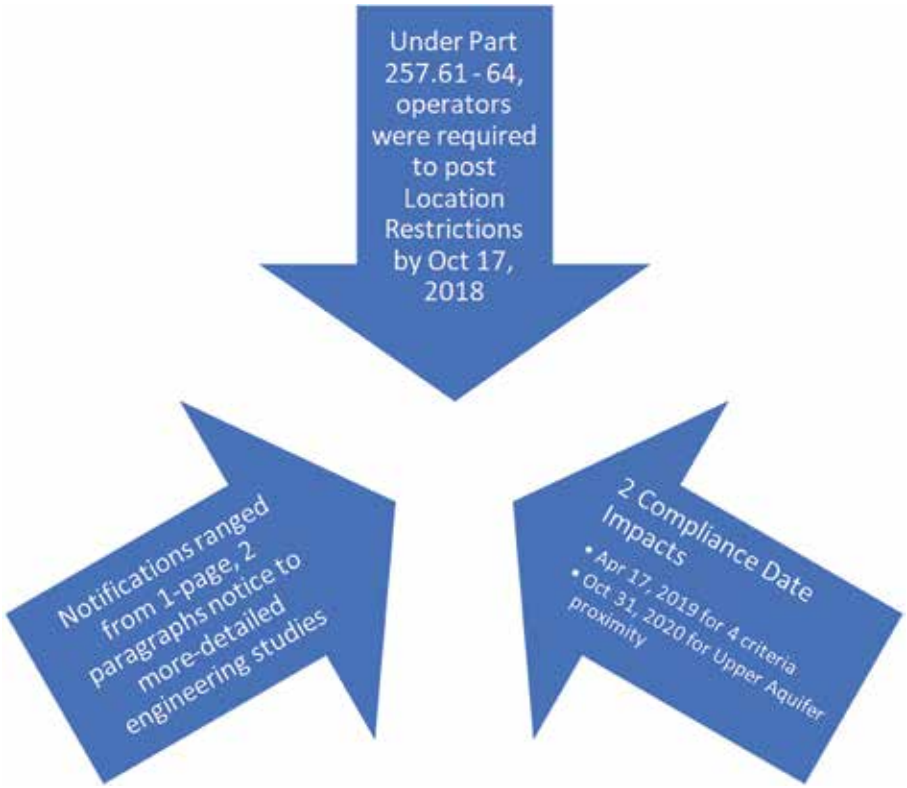
The analysis is based on onsite groundwater monitoring wells, meaning that there is not necessarily any off-site groundwater migration. Nevertheless, if a CCR unit is linked to an increase in monitored well levels of any of the 15 analytes, it may be required to close by October 31, 2020.

On the following page is a partial heat map of the eastern U.S., in which the intensity of the shading corresponds to the number of GWPS exceeded at nearby sites (see Figure 4).

Some further explanation on this point: if there is only one GWPS exceeded, there will be a small, lightly shaded circle at the plant location. If there are multiple analytes, there is a yellow-to-red color.

With everything included, we estimate that units requiring closure due to GWPS exceedances represent more than 1 billion cubic yards of material.

The amounts between location restrictions and GWPS are not additive since some CCR units are facing double jeopardy. Both are drivers that contribute to the risk of closure. Once closure is initiated and public notification occurs, the closure project is on a timeline that is based on factors such as state regulatory approval, whether the CCR unit will be closed in place or closed by removal, ongoing power plant operations, and the size and complexity of the closure project.



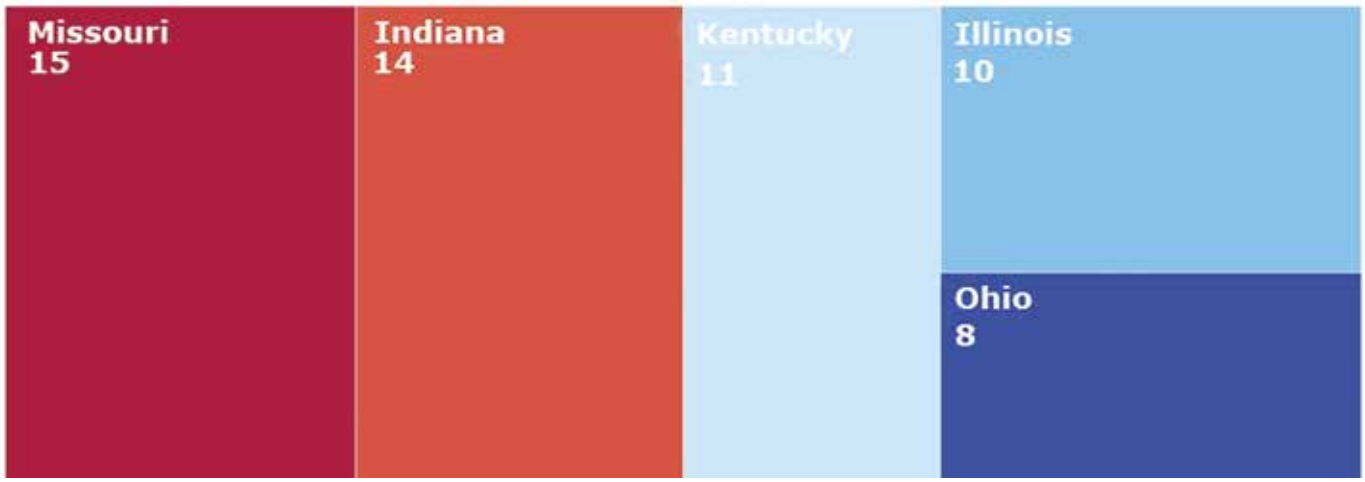


Figure 2. Location restriction pending closure.

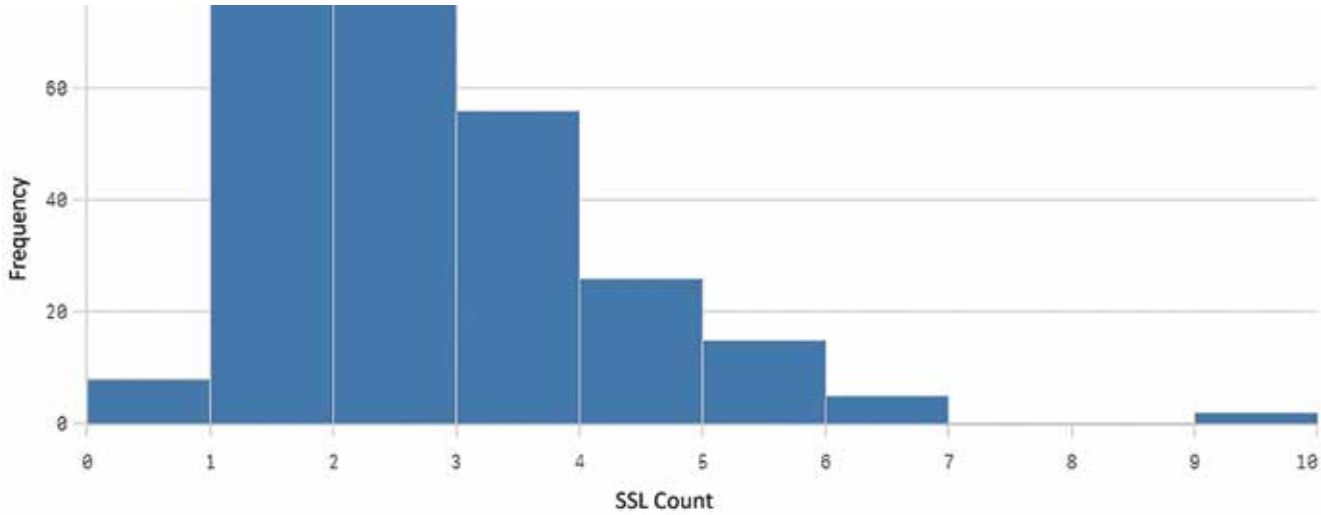


Figure 3. GWPS histogram.

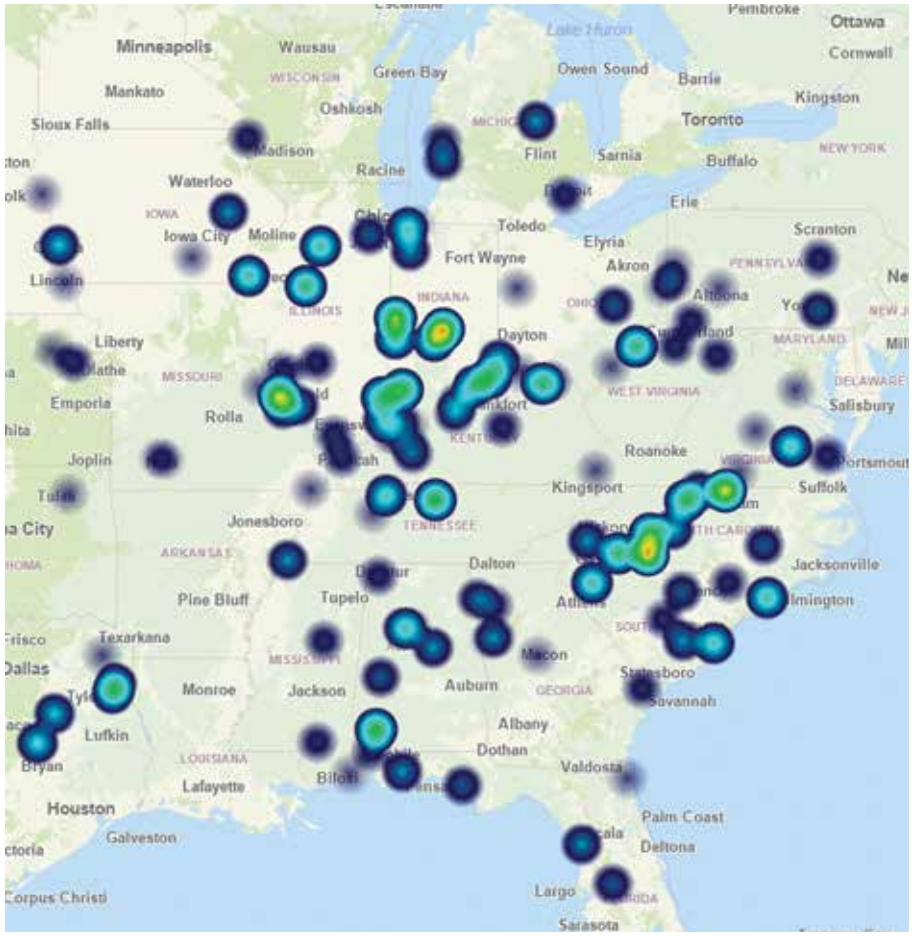


Figure 4. Heat map showing the relative number of GWPS exceeded at nearby sites.

Estimating the Coal Ash Inventory

How much ash is already out there? U.S. coal-fueled electricity generation has declined from its peak of a decade ago and, in April 2019, was surpassed by generation from renewables for the first time ever. While this decreasing trend is bad news for the total coal inventory in the long term, CCR usage reached 71.8 million tons in 2017, which was a record high.

Now, let's get into the details on the estimation of the number and total volume of CCR-regulated and legacy coal ash landfills and surface impoundments. With respect to the CCR-regulated U.S. market, the available figures include:

- 111 owners and operators
- Approximately 300 sites
- Over 700 CCR units

Figure 5 shows the CCR material volume for the top five U.S. states. Pennsylvania is first with more than 250 million cubic yards of material, followed by Kentucky and West Virginia. We maintain comprehensive datasets in this regard nationwide.

Regarding legacy materials, there is an opportunity for some serious detective work to estimate the amount of material produced, disposed of onsite or off-site, and not previously beneficiated. The oldest power plants still in use in the U.S. are more than 70 years old. According to EIA, more than 88% of coal-fueled capacity, as of December 2016, was built between 1950 and 1990. It stands to reason that these legacy plants, some of which no longer exist, had coal ash accumulations. The EIA data repository also includes some coal boiler retirements going back to the 1960s and 1970s. The changes to the coal industry were happening before the CCR rule—and if you go back far enough, there was no regulation on how coal ash materials were handled.

Knowing the extent of legacy ash repositories could maximize the potential beneficial use. In addition to the materials buried or otherwise stored at plant sites, materials in waste monofills could be harvested and used. *ASH at Work* (Issue 1, 2019, p 23) refers to the Washingtonville monofill, where approximately 2 million tons of high-grade fly ash is available for harvesting

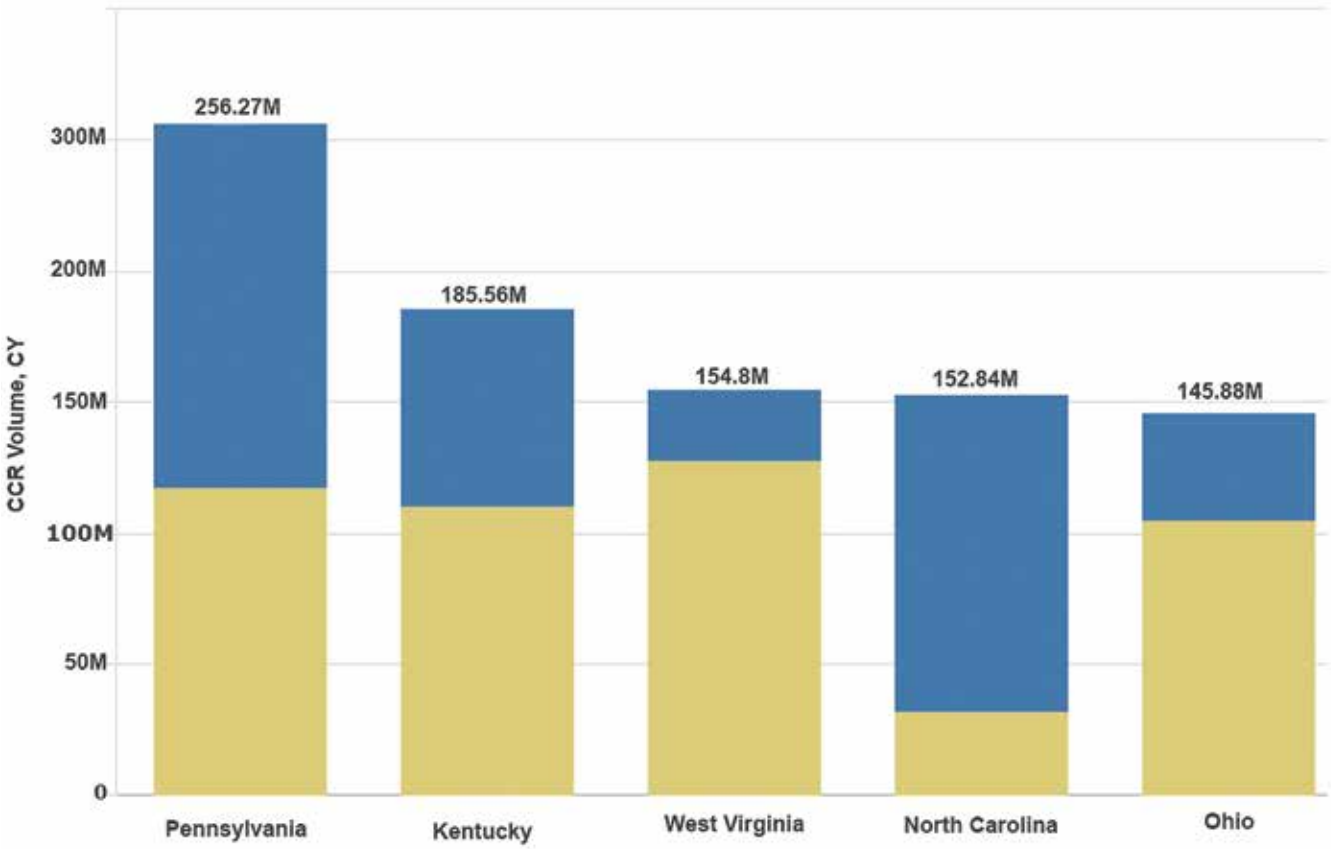


Figure 5. CCR material volume by top five states, CY.

and beneficial use. The fly ash originated from power plants in the 1980s and 1990s.

At this time, owners of a legacy impoundment are not obliged to comply with the federal CCR regulations.

Coal Ash Demand in Relation to the Sources

Using fly ash and bottom ash as replacement materials in cement and concrete applications represents high-value alternatives to disposal that help reduce raw material extraction from quarries and generate lower manufacturing-related greenhouse gas emissions. The location of ash vis-à-vis the manufacturers that would beneficially use it is key to unlocking new opportunities for sustainable coal ash usage.

The U.S. Department of Transportation maintains approved source and location supplier lists. The supply source and location are supported by the respective state DOTs to supply coal ash, in particular, fly ash, to Department projects. FirmoGraphs has recently started tracking and updating approved coal ash suppliers and source plants at the request of the SEFA Group, which provided the source information.

On a large scale, organizations are looking into the proximity of coal ash sources to customers and the accessibility of those locations by road, barge, and rail. These factors are a crucial determinant of transportation costs, freight charges, labor, and wages. Significantly, full excavation is regarded as the most expensive option, often counterbalanced by the permanent removal of a liability. Such factors drive the economics for strategic thinking and offer the potential to offset the costs associated with CCR challenges.

Conclusion

In a market such as that for U.S. coal ash, it is critical to be aware of the inherent risks and upcoming trends. On an ongoing basis, there are regulatory developments, both federal and state, site environmental obligations, decisions around site operations and CCR unit mitigation, changes to coal ash inventory, and beneficial use opportunities. FirmoGraphs tracks and updates these changes daily, creating a structured and reliable data set that is presented in modern and flexible business intelligence software, Qlik Sense Enterprise™.

Rather than handling all of these challenges themselves, involved organizations such as AECOM, Suez, and the SEFA Group have joined forces with FirmoGraphs in using the Ash Mart™. Data subscriptions are available to use within our provided software or in your system. See our website for more subscription details and market insights at https://www.firmographs.com/ash-mart-0.

David Cox is the founder of FirmoGraphs LLC, a business intelligence and data science firm specializing in the North American utility and industrial markets. He holds BS and MS degrees in civil and environmental engineering and is a professional engineer in the state of California. His background includes engineering, consulting, marketing, and sales work in utilities and heavy industry.

FGD Gypsum Is for the Birds

By Thomas H. Adams

The U.S. Department of Agriculture Agricultural Research Service (USDA-ARS) has studied the use of flue gas desulfurization (FGD) gypsum in various agricultural applications for many years.

The poultry industry in the U.S. raises several billion broilers each year for both domestic consumption and export. The majority of the industry is concentrated in the southeast United States. The floors in most of the chicken houses consist of clay or other soils covered by a layer of bedding. Wood shavings have been widely used for many years, as this material was available in large quantities at reasonable cost. However, as the poultry market has expanded, demand for bedding material has grown. Poultry farms needed to find additional materials.

Could FGD gypsum be used as a substitute for traditional poultry bedding material? Using FGD gypsum as a bedding material for chicken houses was proposed as it was widely available and was produced in large quantities by coal-fueled power plants. The chemistry of the gypsum also suggested it may offer improvements over the locally available materials traditionally used. A team of researchers at the USDA-ARS National Soil Dynamics Lab took on this project along with faculty at nearby Auburn University. Major contributors to this work were Joseph Hess, Dexter Watts, Allen Torbert, Jeremiah Davis, and Jeff Sibley.

Photo: Dr. Dexter Watts

These researchers listed the following as the most important attributes for study:

- Broiler body weight, feed consumption, feed conversion
- Broiler mortality
- Footpad disease
- Ammonia accumulation and release from the litter
- Loss of phosphorus in water run-off
- Litter moisture attraction and release
- Impact of the litter on other crops, pasture, and hay

Three separate flocks of broilers were evaluated. Each flock was divided into exposure to differing treatments, including bedding with pine bark, pine shavings, FGD gypsum, blends of pine bark

FGD gypsum was found to be a viable material for chicken bedding, improving ammonia control and reducing the incidence of footpad disease. Photo: Dr. Dexter Watts

with gypsum, and pine shavings with gypsum. A total of eight bed compositions were evaluated in each test.

The research team concluded that FGD gypsum was a viable material for this application. In each portion of the testing, bedding made with gypsum performed as well or better than other traditional materials across a range of criteria, including improved ammonia control, reduced footpad disease, and equal body weight.

However, the most important environmental benefit of using FGD gypsum for bedding came from an application of the litter after its removal from the chicken houses. Chicken farmers make significant revenue from selling the litter as a fertilizer. The gypsum litter helps reduce the loss of phosphorus (P) into run-off water from agricultural fields. The use of gypsum to reduce P loss is a recommended practice of the USDA Natural Resource Conservation Service. Research has also documented soil quality improvements from gypsum use. While farmers must bear the cost of spreading the litter, the benefits are significant.

The use of FGD gypsum in chicken house litter is a win-win-win situation. The health of the birds, the quality of the poultry litter as a fertilizer, and soil and water quality are all improved.

In 2015, the American Coal Ash Association selected the U.S. Department of Agriculture's Agricultural Research Service to receive its Champion Award. This award recognizes extraordinary contributions by an individual or organization to the advancement of beneficial use of coal combustion products. The USDA-ARS award specifically noted the contributions to the understanding of FGD gypsum in agriculture by Drs. Ray Bryant, Rufus Chaney, Dinku Endale, Michael Jenkins, Martin Locke, Harry Schomberg, Allen Torbert, and Dexter Watts. The legacy of USDA-ARS contributions continues.

Thomas H. Adams is Executive Director of the ACAA. He would like to thank Dr. Allen Torbert, USDA Agricultural Research Service, for providing data and quality assurance for this article.

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CFB Ash's Diverse Beneficial Uses

By John Simpson

Circulating fluidized bed (CFB) boilers are increasingly utilized for electric power production today, both for their ability to accommodate multiple fuel sources and to generate clean energy without conventional external emissions control equipment. Worldwide, there are believed to be approximately 600 coal-fueled CFB units in operation or under construction.[1] In the U.S. alone, these units produced more than 14 million tons of ash in 2017—the latest year for which data is available—over 97 percent of which was beneficially used.[2]

Fluidized Bed Boilers vs. Pulverized Coal Units

Fluidized bed combustion units come in several forms. The earliest variants, introduced on a large scale in the 1970s, use a bubbling-bed system in which fuel is burned within a hot bed of inert particles, typically sand. Upward flowing air within the bed suspends the fuel-particle mix, which achieves fluid-like properties after sustained combustion. In CFB boilers, the velocity of the combustion air is higher than in bubbling fluidized bed boilers, and hot particles are circulated throughout the combustion chamber.[3]

Fluidized boilers are particularly suited to burning fuels with lower heating values[4]—including various types of coal, petroleum coke, wood biomass, paper sludge, and waste tires[5]—at high efficiency and without the requirement for costly fuel preparation, such as pulverization. CFB boilers burn fuel at substantially lower temperatures (850° C to 900° C) than do pulverized coal-fueled boilers (1400° C to 1500° C), which minimizes the formation of nitrogen oxides.[6] Moreover, up to 95 percent of sulfur dioxide emissions can be captured by the addition of limestone or dolomite directly to the combustor.[7]

Adding sorbents such as limestone to CFB boilers helps these units generate significantly greater volumes of solid residues than are produced by pulverized coal-fueled boilers of the same capacity, and they impart distinct chemical characteristics to the ash as well. CFB fly ash, a fine material captured from the flue gas, contains high levels of alumina and silica. CFB bottom ash, a coarser material recovered from the combustion bed off-take, contains comparably higher levels of calcium sulfate and lime. Lime, alumina, and calcium sulfate confer cementitious properties to CFB ash when it is mixed with water.[8]

Mine Reclamation

The elevated alkalinity and sulfur content of CFB ashes generally make them unsuitable for use as a cement replacement in concrete. However, their high pH makes them highly suited for use in mitigating acid mine drainage. This has become an important beneficial use of CFB ash over the past 30 years, particularly in the coal mining regions of Pennsylvania and West Virginia, where abandoned mines from two centuries of coal extraction continue to discharge acid runoff into local streams.[9]

In 1989, the Appalachian Region Independent Power Producers Association (ARIPPA) formed in part to help address this issue. ARIPPA members' CFB boilers use anthracite and bituminous coal refuse as their primary fuel to generate electricity, in the process generating ash that is used for reclamation.[10] The reclamation processes typically involves processing of coal refuse material at the mine site via screening to remove rock and other inert materials. The finer refuse materials are used as fuel for the CFB boiler, to which limestone is added to the furnace to capture sulfur dioxide emissions. The ash that results from the combustion process is then returned to the mine site and mixed with any unusable coal refuse to help neutralize on-site acidic materials. The materials can then be compacted in place for ground contour restoration.[11]

[1]Peltier, Robert, P.E. "Advanced CFB Technology Gains Global Market Share." *Power Magazine*. November 1, 2016.
[2]American Coal Ash Association. *2017 Coal Combustion Product Production & Use Survey Report*. November 2018.
[3]Crawford, Mark. "Fluidized-Bed Combustors for Biomass Boilers." August 30, 2012. www.asme.org. Retrieved on 10/18/19.
[4]Peña, J.A. Pascual. "Bubbling Fluidized Beds: When to Use This Technology." 2011. p 1.
[5]Mitsubishi Hitachi Power Systems. "Circulating Fluidized Bed (CFB) Boilers." https://www.mhps.com/products/boilers/lineup/cfb/. Retrieved on 10/18/19.
[6]Ibid.
[7]LA Ash. "What is Fluidized Bed Combustion?" http://www.laash.net/PageDisplay.asp?p1=3956. Retrieved on 10/18/19.
[8]Jewell, Robert, Robl, Tom, and Rathbone, Robert. *Center for Coal-Derived Low Energy Materials for Sustainable Construction Final Scientific/Technical Report*. July 2012. pp. 4-5.
[9]ARIPPA. "Coal Refuse." White Paper. October 2015. p 3.
[10]ARIPPA. www.arippa.org. Retrieved on 10-18-19.
[11]Brisini, Vincent. Testimony of ARIPPA before the House Committee on Energy and Commerce, Subcommittee on Energy and Power. February 3, 2016. pp 9-10.

The Mikawa Power Plant, in Omuta, Japan, can burn a variety of fuels in its circulating fluidized bed boiler. Source: Toshiba.

Coal mine refuse such as this pile near Trevorton, Pennsylvania, can be used as fuel for CFB plants to generate electricity, with the resulting ash utilized for mine reclamation. Source: CC Attribution-ShareAlike 4.0/Jakec.

CFB plants consume 10 million tons of coal refuse annually. Because much of these fuel inputs comprise rock that does not burn, CFB units produce greater amounts of ash than do pulverized coal boilers.[12] With the addition of limestone to the furnace to control sulfur emissions, the volume of residue produced by a CFB plant can be up to two times greater than that of a similarly sized pulverized coal-fueled plant without a flue gas desulfurization unit.[13] In addition to providing a highly effective agent for neutralizing the acidic drainage at such mine sites, the large quantities of CFB ash can be utilized as structural fill at such sites.

The beneficial use of CFB ash at mine sites in Pennsylvania is regulated under the state's Solid Waste Management Act.[14] As such, extensive chemical testing of the ash is required to verify that element concentrations are within statutorily prescribed levels to ensure environmental safety. In all, 21 different parameters are used to assess the dry ash composition and leachate characteristics. If ash exceeds regulatory limits, it cannot be used beneficially and must be disposed of in a lined facility.[15]

Sludge Stabilization

Owing to its high pH and calcium content, CFB ash is also recognized as useful in sludge management. For example, blending CFB fly ash in with sewage sludge can increase the pH and temperature of the sludge to inactivate or destroy pathogenic organisms.[16] In other instances, it can be added simply to solidify sludge and allow for its off-site disposal.

In one case of the latter, CFB byproduct from a Jacksonville utility in 2008 was used to solidify sludge left over from a nearby oil recycling company after it had abruptly ceased operations and vacated its premises. Left behind were numerous tanks containing hundreds of thousands of gallons of oily sludge that required the addition of a solidification agent to meet Subtitle D landfill requirements that it contain no free liquid.[17]

While cement and kiln dust are sometimes used to solidify such wastes,[18] in this case fly and bottom ash were sourced from CFB units at Jacksonville Energy Authority's Northside Generating Station. These boilers are fueled by a blend of coal and petroleum coke (with lime added to help control sulfur emissions). This CFB ash was chosen for the project because it was deemed to be less expensive than competing materials, and its lime content gave it good solidification potential.[19]

After bench-scale testing had confirmed the effectiveness of the CFB ash in solidifying the sludge,[20] samples of the solidified material were then evaluated via the toxicity characteristic leaching

[12]ARIPPA. "Environmentally Beneficial Alternative Energy." p 35.
[13]Basu, Prabir. *Circulating Fluidized Bed Boilers: Design, Operation and Maintenance.* Springer International Publishing. 2015. p 255.
[14]Hornberger, Roger J., Dalberto, Alfred D., Menghini, Michael J., Kania, Timothy C., Scheetz, Barry E., Koury, Daniel J., and Owen, Thomas D. "Coal Ash Beneficial Use at Mine Sites in Pennsylvania." p 1.
[15]Pennsylvania Department of Environmental Protection. Response to Clean Air Task Force Report: "Impacts On Water Quality From Placement Of Coal Combustion Waste In Pennsylvania Coal Mines." November 9, 2007. p 2.
[16]Grillasca-Rodriguez, Cristina. "Agricultural Use of Organic Wastes Stabilized With Fluidized Bed Combustion Solid Residues." 1996. p ii.
[17]Beech, J.F. Ph.D., P.E., Elder, Scott, MBA, and Weeks, Nandra, P.E. "Case Study: Use of Circulating Fluidized Bed Boiler Byproduct to Solidify Oily Sludge." 2009. p 1.
[18]Ibid. p 4.
[19]Ibid. p 5.
[20]Ibid. p 5-6.

Land reclaimed from a mining operation in Fayette County, Pennsylvania.

CFB ash has proven to be a useful liming agent for both food and non-food crops.

procedure. Testing verified that addition of the CFB ash did not increase the potential for the sludge's hazardous constituents to leak into a landfill.[21] The CFB ash and sludge were then blended together and allowed to cure, assessed via the paint filter test to verify the absence of free liquids, and loaded into trucks for landfill disposal.[22]

Other Beneficial Uses of CFB Ash

The basic characteristics of most CFB ashes—highly alkaline with self-cementing properties—give these materials a wide variety of potential beneficial use applications. Beyond mine reclamation and sludge stabilization, research and field studies indicate that it has good potential as both a soil stabilizer and as a soil amendment in agricultural applications.

- An innovative application was employed by the aforementioned Jacksonville Energy Authority to recycle both fly ash and bottom ash to stabilize non-cohesive sands that are common in north Florida. Laboratory testing and field applications established the effectiveness of stabilizing such soils in pavement and roadway construction applications.[23]
- The U.S. Department of Agriculture/Agricultural Research Service has extensively investigated the agricultural use of CFB ash in a series of laboratory, greenhouse, field plot, and animal feeding experiments.[24] The agency found that the "best and safest" agricultural use was as a substitute for lime to neutralize soil acidity and boost its fertility in humid climates.[25] Other studies have supported the application of CFB ash as a useful liming agent for both food and non-food crops.[26]

Variations in the types of coal and other fuels used for CFB combustion—as well as the specific CFB combustion technology employed—can greatly impact the chemistry of the resulting ash and its fitness for a particular beneficial use. Appropriate testing is warranted to ensure health, safety, and performance criteria will be met in any given application. That said, given the growing utility of CFB technology around the world—and the comparatively large volumes of ash that these plants generate—further research is encouraged to develop additional beneficial uses for this product.

John Simpson is editor of *ASH at Work*.

[21]Ibid. p 6.
[22]Ibid. p 8-9.
[23]Jackson, N. Mike, Mack, Robb, Schultz, Scott, and Malek, Mag. "Pavement Subgrade Stabilization and Construction Using Bed and Fly Ash." 2007. p 10.
[24]U.S. Department of Agriculture/Agricultural Research Service. "Manual for Applying Fluidized Bed Combustion Residue to Agricultural Lands." 1988. Abstract.
[25]Ibid. p 4.
[26] Richards, William, P.E. "Utilization of Point Aconi CFB Ash as an Agricultural Soil Amendment." October 2000. p iii.

Requirements for Safety Data Sheets

Editor's Note: With this issue, ASH at Work *begins a recurring series on health and safety topics. We welcome contributions from readers with expertise in these issues. Article length should be approximately 500 words. Please submit topic suggestions in advance to John Simpson at johnfsimpson@gmail.com.*

To help ensure workplace safety, the U.S. Department of Labor's Occupational Safety and Health Administration (OSHA) requires that companies which produce, import, or otherwise handle hazardous chemicals in their workplace observe and carry out the agency's Hazard Communication Standard (HCS). The standard, most recently updated in 2012, requires:

- Chemical manufacturers and importers to evaluate the hazards of the chemicals they produce or import, and prepare labels and safety data sheets (SDSs) to convey the hazard information to downstream customers; and
- All employers with hazardous chemicals in their workplaces to provide labels and safety data sheets for their exposed workers and train them to handle the chemicals appropriately.

This article focuses on the requirements for maintaining safety data sheets (formerly known as material safety data sheets). ACAA members—including generators, marketers, handlers, repackagers, and distributors—are advised to accurately and consistently assess the potential hazards associated with coal combustion products (CCPs) so that individual SDSs developed by each member company reflect the potential hazards of the CCPs during normal shipping and handling from initial development through the supply chain.

Under the revised HCS, safety data sheets are required to be in a uniform format and include the section numbers, headings, and associated information as outlined below:

Section 1. Identification—Names the chemical on the SDS and its recommended uses.
Section 2. Hazard(s) Identification—Includes all hazards regarding the chemical and the appropriate warning information associated with those hazards.
Section 3. Composition/Information on Ingredients—Identifies the ingredient(s) contained in the product indicated on the SDS, including impurities and stabilizing additives.
Section 4. First-Aid Measures—Describes the initial care that should be given by untrained responders to an individual who has been exposed to the chemical.
Section 5. Fire-Fighting Measures—Provides recommendations for fighting a fire caused by the chemical.
Section 6. Accidental Release Measures—Provides recommendations on the appropriate response to spills, leaks, or releases.
Section 7. Handling and Storage—Gives guidance on the safe handling practices and conditions for safe storage of chemicals.
Section 8. Exposure Controls/Personal Protection—Indicates the exposure limits, engineering controls, and personal protective measures that can be used to minimize worker exposure.
Section 9. Physical and Chemical Properties—Identifies the physical and chemical properties associated with the substance or mixture.
Section 10. Stability and Reactivity—Describes the reactivity hazards of the chemical and the chemical stability information.
Section 11. Toxicological Information—Identifies toxicological and health effects information or indicates that such data are not available.
Section 12. Ecological Information—Provides information to evaluate the environmental impact if the chemical were released to the environment.
Section 13. Disposal Considerations—Provides guidance on proper disposal practices, recycling or reclamation of the chemical(s) or its container, and safe handling practices.
Section 14. Transport Information—Provides guidance on classification information for shipping and transporting of hazardous chemical(s) by road, air, rail, or sea.
Section 15. Regulatory Information—Identifies safety, health, and environmental regulations specific to the product that are not indicated elsewhere on the SDS.
Section 16. Other Information—Includes the date of preparation of the SDS or the last revision.

ACAA commissioned Haley & Aldrich to prepare guidance documents to help ACAA member companies and others in the coal ash beneficial use community in the development of SDSs for their CCPs—whether fly ash, bottom ash, circulating fluidized bed (CFB) fly ash, CFB bed ash, or flue gas desulfurization (FGD) gypsum. ACAA's *Coal Combustion Products Safety Data Sheet Guidance Document* and companion *FGD Gypsum Safety Data Sheet Guidance Document* can both be downloaded free from the ACAA website. Both guides helpfully contain both a checklist and template designed to facilitate member companies' development of compliant SDSs for their products.


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2019 Breaks All-Time Attendance Record

World of Coal Ash 2019, held May 13-16 in St. Louis, established an all-time attendance record with 1,075 registrants. The sold-out exhibit hall, featuring more than 100 companies, was likewise the largest in the history of the symposium.

WOCA 2019 Award Winners

The following individuals were recognized at WOCA 2019:

Alice Marksberry Memorial Award 2019 (Sponsored by UK CAER)

Joseph Robb, ERM - Abstract #205, Modified Piper Diagrams to Support Alternate Source Demonstrations at CCR Units

WOCA 2019 Poster Award (Sponsored by EPRI)

1st Place: Laura Powers and Victoria Jennings, CTL Group - Abstract #272, How Clean? A Methodology to Assess Progress of CCR Cleanup in Real Time
2nd Place: Tristana Duvallet, UK CAER - Abstract #276, Sulfate-Activated Class C Fly Ash Based Cements

WOCA 2019 Student Oral Presentation Award (Sponsored by Midwest Coal Ash Association)

Samuel Mathews, Tennessee Technological University - Abstract #27, Preliminary Study of the Potential of a Beneficiated Ultrafine Class F Fly Ash

Midwest Coal Ash Association Student Stipend Awards

Omar Amer, Clemson University
Wenlong Zhang, Georgia Institute of Technology
Annika Han, Tufts University
Mehedy Amin, The Ohio State University
Rosicky Kalombe, University of Missouri–Kansas City

WOCA 2019 Student Poster Award (Sponsored by ACAA Educational Foundation)

Ana Santos, University of Porto, Porto, Portugal - Abstract #226, Recovery of Carbonaceous Solid Residue (Char) from Coal Ash to Use as Possible Substitute Graphite-Based Materials in Green Energy Applications

WOCA 2019 Papers Now Available

The WOCA 2019 submitted papers are now available on the Ash Library proceedings website: www.flyash.info.


Joseph Robb

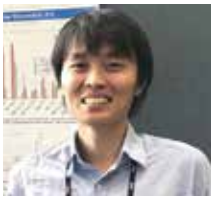

Laura Powers


Victoria Jennings


Tristana Duvallet


Samuel Mathews


Omar Amer


Wenlong Zhang


Annika Han


Mehedy Amin

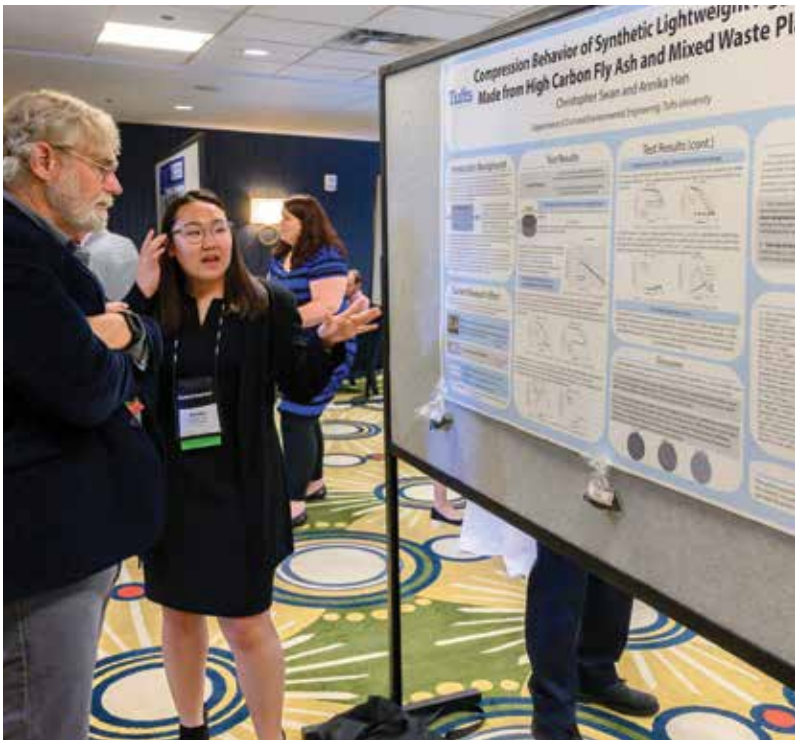

Rosicky Kalombe


Ana Santos


ARCADIS


HOTEL LOBBY
wood


UNION STATION HOTEL


Compression Behavior of Synthetic Lightweight
Made from High Carbon Fly Ash and Mixed Waste Pl
Tufts


Vast array of
ash-based
products
• Fly Ash
• Bottom Ash
• Synthetic Gypsum
• Micron™
• Light Weight Aggr
• Calcarox®
RESOURCES
America's
Extensive
solutions
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rbon Burn-Out
ormance Pozzola


Leaders in e

Coal Ash Recycling Rate Declines Amid Shifting Production and Use Patterns

Fifty-eight percent of the coal ash produced during 2018 was recycled—down from 64 percent in 2017, but marking the fourth consecutive year that more than half of the coal ash produced in the United States was beneficially used rather than disposed.

"As coal ash production declines, beneficial use markets are adopting new logistics and technology strategies to ensure these valuable resources remain available for safe and productive use," said Thomas H. Adams, Executive Director of the American Coal Ash Association. "Closures of coal-fueled power plants are disrupting product distribution channels, but ash marketers are adapting quickly and enormous volumes of material remain available for beneficial use. We look forward to continuing to grow these practices that conserve natural resources, make products that are more durable, and dramatically reduce the need for landfills."

According to ACAA's most recent "Production and Use Survey," 59.4 million tons of coal combustion products were beneficially used in 2018 out of 102.3 million tons that were produced. The rate of ash utilization decreased from 64.4 percent to 58.1 percent, and the total volume of material utilized decreased by 12.3 million tons. Coal ash production volume decreased 8 percent (or 9.1 million tons) from 2017 levels.

"Coal ash" is a generic term that encompasses several coal combustion products (CCPs) that can be beneficially used in a wide variety of applications. Highlights of CCP production and use in 2018 include:

- Use of coal fly ash in **concrete** declined 11 percent to 12.5 million tons—the same rate of decline as all coal combustion products in all beneficial use applications. Concrete producers and consumers indicated a desire to use more fly ash, but several regional markets were affected by shifting supply dynamics associated with closures of coal-fueled power plants. Fly ash improves concrete durability and significantly reduces greenhouse gas emissions associated with concrete production.
- Use of all coal combustion products in **cement production** declined 26 percent to 6.4 million tons.

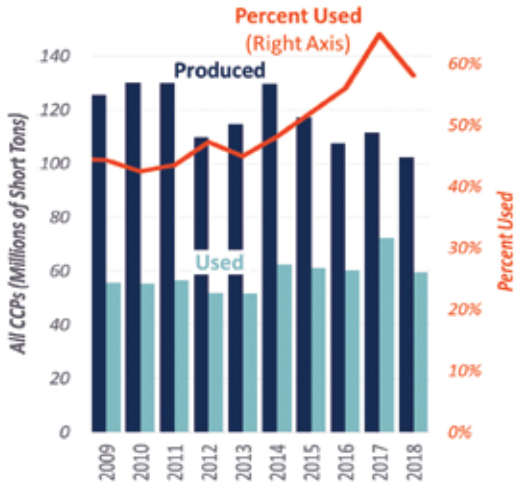


Figure 1. All CCPs Production and Use, 2009 - 2018.

- Utilization of a key "non-ash" coal combustion product returned to expected levels. Synthetic gypsum is a byproduct of flue gas desulfurization units, also known as "scrubbers," located at coal-fueled power plants. Use of synthetic gypsum in **panel products** (i.e., wallboard) declined 23 percent to 12.3 million tons. This volume is consistent with utilization volumes in the 2014-2016 period following a 2017 in which users took advantage of an opportunity to increase stockpiles of gypsum for raw material.
- Synthetic gypsum use in **agricultural applications**—in which the gypsum improves soil conditions and prevents harmful runoff of fertilizers—declined 16 percent to 1 million tons. Lower utilization is likely related to wet weather that prevented many farmers from applying material to fields.
- Use of CCPs in **pond closure activities** declined 28 percent to 3.2 million tons but remained well above 2016's total of only 435,000 tons. This activity is driven by utility compliance with coal ash regulations that effectively require an end to the practice of wet disposal. Fly ash, bottom ash, and synthetic gypsum were all used in construction of new permanent disposal facilities.
- Use of fly ash and bottom ash in **structural fills** rebounded strongly to 4.6 million tons following a multi-year decline.
- Production of boiler slag declined 40 percent as the number of cyclone boilers producing this material also declined. Approximately 468,000 tons of boiler slag were utilized in the production of **blasting grit and roofing granules**.
- Approximately 1.2 million pounds of **cenospheres** were sold in 2018, up from 148,000 in the prior year. Increased cenosphere recovery was likely linked to increased pond closure activities.

"As America's electricity grid changes, the coal ash beneficial use industry is evolving as well," said Adams. "As we work diligently to utilize the 40 percent of coal combustion products that are still disposed annually, our industry is also taking significant strides in developing strategies for improving the quality and availability of these materials."

Adams explained that increasing beneficial use requires ash marketers to ensure that products are consistent and available when customers need them—requiring large investments in technology and logistics. Additionally, the coal ash beneficial use industry is actively deploying technologies and strategies for harvesting coal ash materials that were previously disposed.

For historical charts and more detailed information on coal ash production and use, see the "American Recycling Success Story" special insert in this issue of *ASH at Work*.

EPA Advances Revisions to Coal Ash Disposal Regulations

The U.S. Environmental Protection Agency (EPA)—responding to petitions for reconsideration, court decisions, and Congressional action—has undertaken a series of rulemakings to revise coal ash disposal regulations originally enacted in 2015.

On July 30, 2019, EPA proposed to revise its definition of beneficial use and regulatory treatment of "piles" staged for beneficial use. (See story on the following page regarding

American Coal Ash Association's response to these proposals.) The agency also proposed changes to data reporting requirements and the establishment of an alternative groundwater protection standard for boron.

On November 4, 2019, EPA announced two proposed regulations—one revising the 2015 Resource Conservation and Recovery Act (RCRA) solid waste regulation for coal combustion residuals and another revising the 2015 Clean Water Act Effluent Limitation Guidelines (ELG) for steam electric power plants.

The RCRA proposals included a new date of August 31, 2020, for facilities to stop placing waste into disposal units that are leaking and a requirement to either retrofit them or begin closure. EPA also moved to implement a court-mandated change in the classification of compacted soil-lined or clay-lined surface impoundments from "lined" to "unlined," which means that clay-lined surface impoundments would no longer be considered lined units and need to be retrofitted or comply with closure requirements.

The ELG proposals include changes to the requirements for two specific waste streams: flue gas desulfurization wastewater and bottom ash transport water. EPA said its proposal would achieve greater pollution reductions than the 2015 rule at a lower cost. By leveraging newer and less-costly pollution control technologies and taking a flexible, phased-in implementation approach, EPA's proposal is estimated to save more than $175 million annually in pre-tax compliance costs while reducing the amount of pollutants discharged to our nation's waters by approximately 105 million pounds per year over the 2015 rule.

Additional proposals to revise EPA's coal ash disposal regulations are expected in the near future, including the establishment of a federal permit program for use in states that do not seek approval of their own permit programs and regulations to address "legacy" coal ash disposal sites that ceased receipt of materials before the 2015 regulation.

Although EPA is working on several proposed revisions to its coal ash disposal regulations, the vast majority of the 2015 CCR rule remains in place and its implementation continues. All units managing coal ash are required to monitor groundwater, publicly report the data, and take action to address exceedances of the groundwater protection standards.

ACAA Objects to Proposed Revisions to EPA's Definition of Beneficial Use

American Coal Ash Association representatives appearing at a U.S. Environmental Protection Agency public hearing October 2, 2019, testified that the agency's proposal for revising coal ash regulations will erect significant barriers to safely recycling coal ash.

"EPA's proposals related to the definition of coal ash beneficial use are the opposite of a regulatory rollback," said Thomas H. Adams, ACAA Executive Director. "Without any damage cases or scientific analysis to justify its actions, the agency is seeking to impose burdensome new restrictions that will cause millions more tons of material to be disposed rather than be used in ways that safely conserve natural resources and energy."

Decades of EPA activities under both Democratic and Republican administrations—including Reports to Congress in 1988 and 1999; Regulatory Determinations in 1993 and 2000; and the 2015 Final Rule now under consideration for revision—all concluded that beneficial use should be exempt from regulation and encouraged to contribute to sustainability. The 2015 Final Rule issued under the Obama Administration "…found no data or other information to indicate that existing efforts of states, EPA, and other federal agencies had been inadequate to address the environmental issues associated with the beneficial use of CCR." The 2015 regulation established a definition of beneficial use intended to screen out large-quantity indiscriminate uses that might be disposal activities masquerading as beneficial use.

"The problem with EPA's beneficial use definition was that it contained a math error," said Adams. "But instead of simply fixing the math error, EPA is now proposing unjustified and sweeping changes to the definition that will have the effect of discouraging recycling. EPA is proposing to vastly expand the number of beneficial use activities that must be evaluated on a project-by-project basis and the record keeping that must accompany legitimate recycling activities. People won't do it. They'll just let the materials go to the landfill instead."

Adams pointed out that since 1980, 188.7 million tons of coal ash have been utilized in structural fill applications without a damage case being presented associated with the activity. "States already regulate these activities," said Adams. "Consensus-based standards that include site location criteria and industry best

Source: CC 2.0 Generic/dave_7

practices already guide how these projects are carried out. Despite this, the agency has now strayed from its original objective of focusing greater scrutiny on large-volume indiscriminate placements of coal ash to propose project-by-project evaluations of a whole host of activities that may involve volumes as small as a single ton."

Adams predicted that if EPA enacts its proposals, the United States will see more CCRs disposed; more natural resources consumed; more water, fossil fuels, electricity, and other resources consumed as virgin natural resources are extracted; and increased project costs. "Any environmental benefits to be achieved by erecting these barriers to beneficial use are at best speculative and non-quantifiable and, more likely, simply non-existent," Adams said.

Second State Moves to Enact Coal Ash Regulation Permit Program

The U.S. Environmental Protection Agency proposed to approve Georgia's permit program for the disposal of coal combustion residuals, making it the second state after Oklahoma to complete the shift from citizen lawsuit enforcement of EPA standards.

"EPA encourages other states to follow Georgia's lead and assume oversight of coal ash management within their borders," said EPA Administrator Andrew Wheeler. "EPA is committed to working with the states as they establish coal ash programs tailored to their unique circumstances that are protective of human health and the environment."

EPA determined that Georgia's permit program application meets the standard for approval. Congress in 2016 granted EPA the authority to approve of state permit programs. Prior to the action by Congress, enforcement of EPA's 2015 coal ash disposal regulations required action by citizen lawsuits.

ASTM Approves Major Change to Coal Ash Specification

Following almost two years of consensus-building discussions, the definition of what constitute Class C and Class F fly ashes is now officially changed.

The ASTM C618-19 Standard Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use in Concrete now uses calcium oxide instead of the sum of silica, alumina, and iron oxide to classify fly ash. Henceforth, fly ash with less than 18 percent CaO will be categorized as Class F and that with more than 18 percent will be categorized as Class C. There is still a requirement for a minimum of 50 percent sum of oxides for both C and F ashes.

Publication of the new standard was delayed while the change was harmonized within the related AASHTO M295 specification. As part of the C618-M295 harmonization efforts, AASHTO is now discussing deleting the available alkali and the effectiveness in mitigating ASR (C441) tests from the optional requirements in M295. Also under discussion is harmonizing the lower LOI limit of 5 percent in AASHTO and the ASTM limit of 6 percent. A group volunteered to gather compelling data showing not only why the LOI limit of 6 percent should be kept, but also that LOI has become a rather irrelevant number in light of emission control technologies implemented in power plants across the country, new advances in measuring adsorption capacity of fly ash, and other factors.

In Memoriam

Michael Lawstan Mings, 1958 - 2019

Mike Mings, Utility Services Manager at Lafarge North America and a former ACAA Director, passed away on November 5, 2019, at Mercy Hospital, in Springfield, Missouri. Born in Minneapolis, Mike graduated from Washington High School, in Washington, Iowa, and later earned his bachelor's degree in civil engineering and his master's degree in geotechnical engineering from Iowa State University. Shortly after graduation, Mike began his career with the Walter N. Handy Company, where he would become part owner. After Lafarge Corp. purchased the Walter N. Handy Company in 1994, he went on to become Executive Vice President. Mike was also co-owner of Analytical Testing Service Laboratories Inc., a material testing lab in Joplin, Missouri. He was interred at Rivermonte Memorial Gardens, in Springfield.

In & Around ACAA

Denver, CO

ASTM International Committee C 09 on Concrete and Concrete Aggregates has awarded Honorary Membership to ACAA Executive Director Thomas H. Adams in recognition of his outstanding service to the Committee and devotion to its objectives. He has been an active member of Committee C 09 and several of its subcommittees for over three decades and is also a member of Committee C 01 on Cement; E 50 on Environmental Assessment, Risk Management and Corrective Action; and E 60 on Sustainability.

Pittsburgh, PA

Samuel Boxerman, Partner, Sidley Austin LLP, discusses the current coal ash situation in Puerto Rico and proposed revisions to EPA coal ash disposal regulations at the ACAA's Fall Meeting.

Pittsburgh, PA

Steve Bonebrake, Partner, Schiff Hardin LLP, addresses attendees of the ACAA's Fall Meeting on the new Illinois coal ash disposal regulations and proposed revisions to EPA coal ash disposal regulations.

Washington, DC

(L-R): Rafic Minkara, Boral Resources (ACAA Technical Committee Chairman); Danny Gray, Charah Solutions (ACAA Board Member); Dr. Lisa Bradley, Haley & Aldrich (ACAA Secretary/Treasurer); Thomas Adams, ACAA Executive Director; and John Ward, John Ward Inc. (ACAA Government Relations Committee Chairman) gather at a recent National Coal Council meeting.

Welcome, New ACAA Members!

Resource Materials Testing (Associate Member) has provided testing services to the CCP industry since 1988. The company routinely performs ASTM/AASHTO testing and certification for clients that include utilities and marketers. The firm is an AASHTO-accredited laboratory for pozzolan and slag and participates in the CCRC Inspection and Proficiency Sample Program. As a small laboratory, the company works closely with clients and any issues that may arise for them from a technical standpoint. Over the years, Resource Materials Testing has worked on projects and evaluations of products for many clients engaged in both research and development and quality control. **www.rmtiflyash.com**.

FirmoGraphs LLC (Associate Member) is a business intelligence and data science firm specializing in the North American utility and industrial markets. The firm helps customers go to market more efficiently by applying business intelligence (BI) tools and techniques. With respect to the coal ash market, the company developed the Ash Mart™, which contains nearly 200 attributes for more than 300 locations and 700 surface impoundment and landfill units involving nearly 100 owner/operators. Estimates of CCR material totaling approximately 2B cubic yards, and final cover of 10,000s of acres, are made. Compliance status is provided with respect to location restrictions, groundwater protection standards, and recurring requirements. **www.firmographs.com**.

Huadian Electric Power Institute Co. Ltd. (Associate Member) is a wholly owned subsidiary of China Huadian Corporation (CHD), which operates 84 coal-fired power plants nationwide. As the leading research institution of CHD, Huadian Electric Power Institute Co. Ltd. (CHDER) is committed to technological innovation and invention in thermal power, hydropower, and new energy as well as R&D in recycling and utilization of CCP. It also serves as a platform for technological cooperation and communication, academic exchanges, and talent training between CHD and organizations, universities, and corporations worldwide. The Coal Ash Comprehensive Utilization Research Center of CHDER is a professional research center with the primary responsibility of studying the utilization of CCP and FGD gypsum and providing high-value solutions for commercial application. **www.chder.com**.

Ad Index

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.

Jim Roewer is Executive Director of the Utility Solid Waste Activities Group (USWAG), which is responsible for addressing waste, byproduct, and chemical management and transportation issues on behalf of the utility industry. USWAG's core mission is to support the industry's efforts to comply with federal environmental regulations, protect the environment, and serve its customers. As part of that effort, USWAG engages in regulatory advocacy, regulatory analysis and compliance assistance, and information exchange pertaining to RCRA, TSCA, and HMTA.

Jim has worked as Senior Environmental Manager in the Energy Policy Department of the National Rural Electric Cooperative Association (NRECA); Environmental Scientist in the Natural Resources Section of the Edison Electric Institute; Manager, State and Local Government Relations, with the American Society of Mechanical Engineers; and Research Assistant with the Science Unit of the Illinois Legislative Research Service. He holds an MS in Environmental Science from the School of Public and Environmental Affairs at Indiana University and a BA in Biology from Wittenberg University.

Ash at Work (AW): The U.S. Environmental Protection Agency has several proposed revisions to coal ash disposal regulations in the pipeline. Which do you see as the most important?

Jim Roewer (JR): While the ongoing refinement of the rule—to respond to court decisions and to implement sound environmental policy regarding waste and materials management—is important, having the federal rule implemented by the states, with regulatory obligations clearly spelled out in enforceable permits, is our ultimate goal. That construct will provide for regulatory certainty that will allow the industry to make sound management decisions—for both CCR disposal and use—that will ensure environmental protection. Finalizing rule revisions should open the door to the approval of additional state CCR permit programs, and EPA's proposal to establish a federal regulatory program in so-called non-participating states will ensure that the industry's management of CCRs is conducted pursuant to permits rather than the current self-implementing rule.

AW: Environmental groups and the news media are fond of referring to these actions as "rollbacks" of environmental protections. Is that a fair characterization?

JR: You have to keep in mind that ENGOs continue to press for regulation of CCR as hazardous waste, so any revision of the rule that doesn't result in Subtitle C regulations will be labelled a "rollback" by those groups. EPA's actions are not "rollbacks": groundwater protection standards remain in place, companies continue to comply with groundwater monitoring rules, and corrective action is being undertaken when and where needed. The fact is that EPA is working to produce a rule that is both environmentally protective and attainable, in terms of requirements and timetables.

AW: Is EPA going to have time to get all of this done?

JR: The wheels of regulatory bureaucracy seem to turn painfully slowly. EPA needs to establish rules that are durable, that will stand up to judicial review. Building a record is key to that effort, and that takes time. And the agency understands all stakeholders' need for regulatory certainty and is working diligently to finalize their rulemaking efforts. We should see proposals later this year and final rules in early 2020.

AW: Should we expect all of these actions to be litigated, and how long will that take?

JR: As I noted earlier, ENGOs will not rest in their pursuit of hazardous waste regulation of CCR. They are well funded and should be expected to appeal all rule revisions, as well as the rule establishing a federal CCR permitting program and EPA approval of state CCR permit programs. Regarding the schedule, assuming the rule revisions and the federal permit program are finalized in early 2020, litigation won't likely be concluded before early- to mid-2021.

AW: Some states are moving forward with setting up their own permit programs. Do you expect that effort to pick up steam?

JR: We certainly hope so. The key to a protective, predictable, and sensible implementation of the federal CCR rules is implementation through permits issued by the states. We understand a number of states are working on securing approval from EPA, and our members continue to encourage those efforts.

AW: What are the implications of all of this regulatory activity and litigation for beneficial use of coal combustion products?

JR: We avoided a disastrous impact to beneficial use when EPA decided to regulate CCR as non-hazardous waste. But ENGOs' continued push for hazardous waste regulations must be regarded as a real threat to continued beneficial use, and EPA's recent Phase 2 proposal to change the CCR rule's beneficial use criterion is itself a significant threat to unencapsulated uses. USWAG has a keen interest in protecting beneficial use, and we are pleased to partner with ACAA in this effort. And as the industry moves to close CCR disposal units, it will be important to maintain, and expand, environmentally sound CCR beneficial use.

AW: Thank you, Jim.

ASH Classics

Coal Ash Use in Road Construction Applications

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

The 1970s saw the expanding use of coal ash in highway construction applications. This ASH Classic*, from 1970, highlights the use of coal combustion products as mineral filler and anti-skid aggregate, as well as in embankments and road bases.*

ASH AT WORK

PUBLISHED BY NATIONAL ASH ASSOCIATION, 1819 H STREET NW, WASHINGTON, D.C. 20006

Vol. II, No. 3 1970

ASH IN ROAD BUILDING

Paver laying ash base near Newark, Ohio.

Structural Fill In Minnesota ...

The Minnesota Highway Department (MHD) recently approved the use of fly ash for common borrow in embankments on a project to bridge the Chicago, Milwaukee, St. Paul and Pacific Railroad tracks in St. Paul.

Standard Proctor density tests on fly ash from Northern States Power Company's High Bridge plant were favorable, showing that the fly ash was about 90 percent silt size (under 200 mesh), had an optimum moisture content of 27 percent, and had a dry density of 85.7 pounds per cubic foot (pcf), compared with about 110 pcf for silt and from 110 to 125 pcf for sand.

The bridge embankments were composed of 50,000 cubic yards of fly ash, 40,000 cubic yards of sand, plus 10,000 cubic yards of clay for the slopes.

Use of fly ash had the following advantages: 1) even with about 9 percent stockpile moisture, the lower density of fly ash allowed up to 40 percent more legal yardage of fill material to be hauled per trip; 2) the higher optimum moisture content of fly ash, 27 percent as compared to 9 percent for silt, made compaction easier and faster; and 3) use of fly ash created a hard, drivable, fill surface immediately after compaction.

Stabilized Base In Ohio ...

The state of Ohio in collaboration with the Bureau of Public Roads has decided to place stabilized base under all continuous reinforced concrete road surfaces. At the suggestion of Poz-O-Pac Company of America, a pozzolanic base containing fly ash has been specified for a total of 6 state projects to date. A project on State Route 16 south of Newark has been completed with a pozzolanic base containing fly ash. The Poz-O-Pac Company expects approximately 50,000 yards of pozzolanic base will be placed in Ohio in 1970. Ohio approved a specification (available from NAA) for pozzolanic pavement in January 1969.

Several advantages of this type of base course are cited. Raw materials can be delivered to the site and stockpiled during the winter and laid anytime temperatures get above freezing. No special equipment is needed for mixing; in fact, on the Newark job, the same plant was used to produce base and concrete paving. Very important also is the fact that the pavement can be brought to grade by skimming and the excess material reused. And finally, standard compaction equipment can be used to obtain the required density.

(Continued on Page 3)

ECE GROUP TO MEET IN TURKEY

The United Nations Economic Commission for Europe has announced that this year's meeting of the Group of Experts on Ash Utilization will be held in Ankara, Turkey, November 9-11. Attending from the United States will be John H. Faber, Executive Director, NAA; Oscar Manz, Associate Professor, North Dakota University; and W. W. Reichert, Director of International Operations, G. & W. H. Corson Company.

Since 1960 the ECE has sponsored frequent international meetings concerning ash utilization. Symposiums attracting experts from all over the world have been held annually since 1967, when the first Fly Ash Utilization Symposium was held in Pittsburgh. The usefulness of these international meetings is illustrated by the fact that only 2 percent of the 100 million tons of ash produced worldwide in 1959 was used, while approximately 15 percent of the 200 million tons produced annually now is utilized.

This year's meeting, entitled "Symposium on the Use of Ash in Production of Concrete and Prefabricated Construction Elements," will be followed by a 3-day field trip in Turkey. In addition to the field trip, the U.S. delegation plans to visit several other European countries before returning to the United States.

NAA ADDS NEW STAFF MEMBER

George A. Kladnik joined NAA as Director of Information in July. Previously he had been at Brandeis University working on a doctorate in public administration with an emphasis on environmental problems.

Mr. Kladnik has been particularly interested in solid waste disposal problems. Upon joining NAA, he remarked that "the possibilities for recycling fly and bottom ash and boiler slag are very exciting and challenging."

HARRY PERRY JOINS THE LIBRARY OF CONGRESS

The Library of Congress announced September 1 the appointment of Harry Perry as Senior Specialist in Environmental Policy of the Library's Legislative Reference Service. Mr. Perry, who has been associated with the Department of the Interior since 1940, will leave his post as Mineral Resources Research Adviser in the Office of the Assistant Secretary for Mineral Resources. Mr. Perry was instrumental in making the first Fly Ash Utilization Symposium in Pittsburgh a success and has initiated many research projects on ash utilization while serving at the Bureau of Mines.

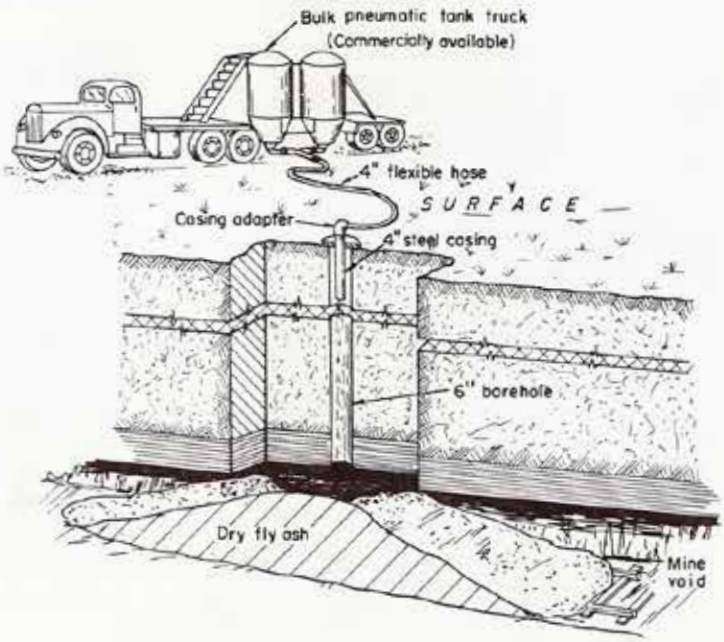
METROPOLITAN EDISON ASH SALES INCREASE

A recent NCPC *Newsletter* notes that Metropolitan Edison sold 105,000 tons of ash out of 214,000 tons produced in 1969. According to James W. Peters, a research engineer for Met-Ed, the utility has current commitments for about 120,000 tons out of 170,000 tons of ash expected to be produced at its four generating plants this year.

DRY FLY ASH INJECTION SYSTEM PATENTED

A system for filling voids and caved areas in mines and for controlling and containing mine fires with pneumatically injected dry fly ash, invented by Malcolm O. Magnuson of the Bureau of Mines, was patented in March (Patent No. 3,500,934). The dry ash is injected from the bulk pneumatic tank trucks directly into boreholes drilled from the surface. The fly ash readily penetrates crevices and rubble and forms an air-tight, nonsettling plug.

In 1969, approximately 90,000 tons of fly ash were used to fight mine fires and subsidence in this country. To date over a dozen field projects have been successfully completed using dry fly ash injection and fly ash water slurry injection methods.



ASH IN ROAD BUILDING ...

(Continued from Page 1)

Structural Fill In England ...

The July issue of the Central Electricity Generating Board (CEGB) news-paper *Power News* describes what may be the first example in the world of large scale transport by rail of fly ash for highway construction. Over one million tons of fly ash are expected to be hauled 75 miles from the Aberthaw power plant in South Wales to the construction site near Somerset for use in the construction of a 17-mile section of the new M5 expressway. Rail transportation costs alone may reach 1.8 million U.S. dollars.

Now over 40,000 tons of fly ash are being delivered every week by train from Aberthaw. A total of 850,000 tons of fly ash are contracted to be delivered this way in 1970.

The ash is being used for structural fill on embankments for 14 bridges and two interchanges on a section of the highway which runs through peaty land having a poor bearing capacity. According to CEGB, the project has been an outstanding success and could serve as a "blueprint" for similar projects in other areas of the country.

Unit train leaving the Aberthaw power station with a load of fly ash for the new M5 expressway.

Anti-Skid Paving In West Virginia ...

The West Virginia Department of Highways recently announced that there had been a substantial reduction in the number of traffic accidents on a 5.73-mile section of U.S. 460 paved in 1968 and 1969 with a thin, experimental, skid-resistant surface containing boiler slag. The number of accidents fell from 101 in 1967 to 53 in the 12-month period following the project's completion; and the number of accidents when the road was wet declined from 53 to 19. Furthermore, property damage resulting from the accidents declined from $133,600 in 1967 to $57,500 after the surface treatment, a reduction of $76,100. Total cost of the anti-skid surface, which has an expected life of four years, was about $50,000.

In August 1970, the Department of Highways initiated a similar project on a 3.35-mile segment of Route 35 near Winfield in Putnam County. In this project, boiler slag will be used as anti-skid aggregate in 2 and fly ash as mineral filler in 11 of 20 types of bituminous surfaces to be tested.

Skid-resistant surface containing boiler slag is being laid and rolled in West Virginia.

WEST VIRGINIA UNIVERSITY RECEIVES NAPCA RESEARCH GRANT

The University of West Virginia has received a $58,192 contract from the National Air Pollution Control Administration for research on the use of modified fly ash, created when limestone or dolomite is injected into utility boilers to reduce sulfur dioxide emissions.

This pilot-plant scale study is designed to investigate sulfur dioxide regeneration; soil stabilization and amendment; and the production of mineral wool, ceramic materials and sand lime brick. Charles F. Cockrell, research engineer at WVU's Coal Research Bureau, is supervising the program.

Should limestone or dolomite injection prove to be a commercially viable method of controlling sulfur dioxide emission, this study might prove to be particularly important, for limestone or dolomite injection will almost double the amount of ash produced.

AEC REPORT CITES WESTERN COAL AS POSSIBLE URANIUM SOURCE

A Brookhaven National Laboratory study, *The Western Coal Deposits: A National Source of Power,* completed under an AEC contract, notes the possibility of a shortage of low-cost uranium toward the end of this century if breeder reactors do not become commercially successful. Such a shortage, the study states, might be averted by reclaiming uranium from fly ash produced at large, coal-fired, western-based MHD power generating plants. It is estimated there may be as much as 21.9 million tons of recoverable U_3O_8 in sub-bituminous and lignite deposits in the western states of North Dakota, Montana, Wyoming, and Alaska.

Evidence continues to accumulate from field experience that boiler slag significantly improves skid resistance in asphaltic road surfaces. One phase of NAA's current advertising program has been directed to the use of boiler slag as an anti-skid material. For instance, the Association has placed ads in *Civil Engineering, Engineering News Record, Public Works,* and *Professional Engineer,* emphasizing boiler slag's anti-skid and other valuable properties.

In another facet of this program, NAA, in collaboration with highway officials, material suppliers, and utility and academic personnel, has initiated efforts 1) to collect and synthesize laboratory and field data relating to skid resistance of asphaltic pavements containing slag, 2) to develop freeze-thaw information on asphaltic mixtures containing slag, and 3) to relate all data to the question of optimum mix design.

NAA
NATIONAL ASH ASSOCIATION, INC.
1819 H Street, N. W.
Washington, D. C. 20006

Beneficial Use Case Study

Apogee Stadium

Coal Combustion Product Type:
Fly ash

Project Location:
Denton, Texas

Project Participants:
HKS Sports & Entertainment Group, HKS DesignGreen, Manhattan Construction Co., HKS Commercial Interiors, Smith Seckman Reid Inc., Aguirre Roden, Jaster-Quintanilla, Rogers Moore Engineering/Walter P Moore, Caye Cook & Associates, Henneman Engineering Inc.

Project Completion Date:
2011

Project Summary:
In 2008, the University of North Texas (UNT) approved a dedicated athletic fee to fund construction of a new stadium to replace Fouts Field, which had housed football operations since 1952. That same year, UNT President Gretchen Bataille signed the American College and University Presidents' Climate Commitment to eliminate net greenhouse gas emissions from specified campus operations. As part of UNT's climate commitment, all new university facilities were required to attain a minimum of Silver LEED certification. The university spared no expense to make the construction of its new football stadium a model of green building practices.

Project Description:
UNT's sports teams go by the nickname the "Mean Green"—a reference to NFL Hall of Famer Mean Joe Greene, who played football at the university in the 1960s. School administrators and architects HKS Sports and Entertainment Group took that name to heart in developing a sustainable design covering all facets of the new stadium's operations—starting with the specification of green and recycled construction materials.

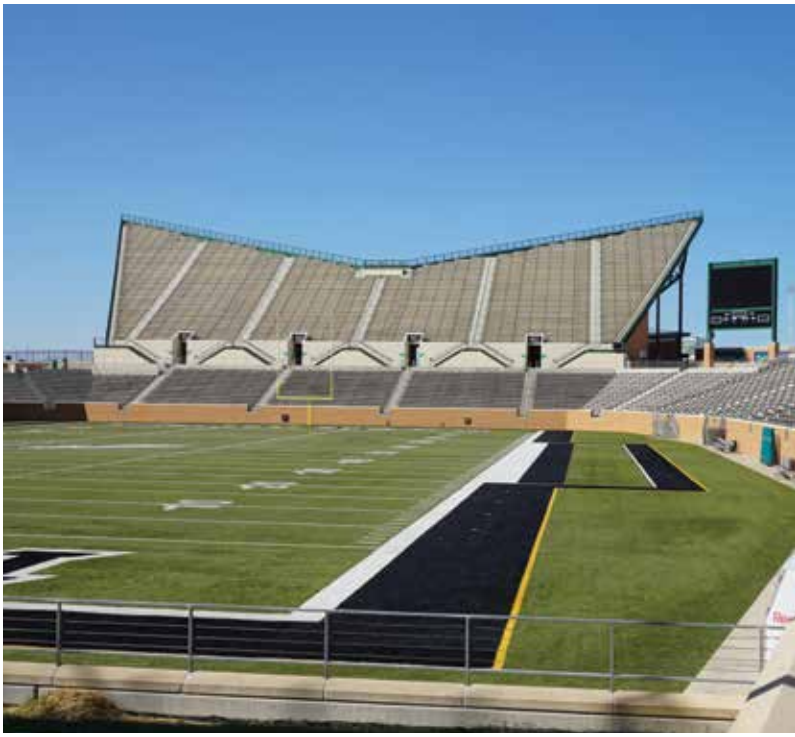
The design team opted for a steel-reinforced concrete skeleton for the stands. Fly ash was used to replace 6.2 million pounds of portland cement for the concrete portions—for an overall replacement of 35%—resulting in a carbon offset equivalent to the environmental impact of the stadium's electricity production for three years. Twenty percent of the products and materials used in the construction of the stadium featured recycled content and 47% were manufactured locally. Eighty-three percent of construction waste materials (including 6,373 tons of concrete and 188 tons of metal) were diverted from landfills via recycling.

Structural engineers Walter P Moore volunteered to develop an educational outreach program to share with UNT students information about the sustainable design of the stadium. Engineers ultimately delivered three classroom presentations on the environmental impact of construction materials and the strategies employed to reduce embodied carbon dioxide through material selection, replacement of cement with fly ash, and sustainable sourcing.

Although initially aiming for Silver LEED certification, the design team built in enough sustainable features that the facility qualified for Platinum LEED—the first newly constructed college football stadium in the nation to achieve this highest level of LEED certification awarded by the U.S. Green Building Council. Among those features were:

- Use of low-flow plumbing fixtures to reduce water consumption by over 50%
- Incorporation of native landscaping and permeable pavers to reduce heat absorption and reduce storm water runoff
- Installation of three wind turbines capable of generating a half-million kilowatt hours per year for the university's power grid—eliminating the equivalent of over 300 metric tons of carbon dioxide emissions annually

Apogee Stadium earned a host of awards for its green construction, including being named *Engineering News-Record*'s "Best Green Project" in 2012.



SOURCE: CC Attribution-Share Alike 4.0-Michael Barera.

Beneficial Use Case Study

Capitol Tower/Bank of America Tower

Coal Combustion Product Type:
Fly ash

Project Location:
Houston, Texas

Project Participants:
Skanska USA Commercial Development, Baker Concrete Construction, Gensler, Walter P Moore, Wylie Consulting Engineers

Project Completion Date:
2019

Project Summary:
In 2015, Skanska USA Commercial Development placed the concrete foundation mat for a proposed 35-story tower in downtown Houston. In an unusual sequencing, Skanska held off on building the tower itself until it could pre-lease a significant portion of the 750,000 square feet of office space. However, that didn't preclude Skanska from having its building design pre-certified at the LEED Platinum v4 level—just the third building in the U.S. to receive such certification. Construction of the tower itself began in 2017 and was completed in 2019.

Project Description:
Shortly after the U.S. Green Building Council's beta launch of LEED v4, Skanska Commercial Development enrolled their planned office building, Capitol Tower (later to be renamed Bank of America Tower), in the program. To achieve Platinum pre-certification, the project would need to achieve most of the LEED "Materials and Resources" credits, including the "whole building life-cycle assessment," which is awarded based on a building's reduction in the impacts associated with the manufacturing and building materials.

Structural engineers Walter P Moore worked closely with concrete suppliers to assess the environmental impact of the project's concrete across six criteria: carbon dioxide emissions, depletion of stratospheric ozone, acidification, eutrophication, formation of tropospheric ozone, and depletion of non-renewable resources. A key strategy in achieving these included an aggressive program of cement minimization. Ultimately, 55% of the cement in the custom concrete mix was replaced with fly ash, which led to a 33% reduction in the production of ozone-depleting materials, a 19% decrease in global warming potential, and 12% less acidification. Use of fly ash in place of cement saved more than one million pounds of carbon dioxide, the equivalent emissions associated with driving a car 1.2 million miles.

The 20-hour continuous placement of 9020 cubic yards of concrete for the foundation carried with it some significant operational and logistical challenges. Among them were Houston's hot weather—temperatures remained in the 80s and 90s throughout placement—and a construction site with limited perimeter access. Overcoming the site constraints—which included an active light-rail line adjacent to one side of the foundation—meant the pour had to be carried out with only four mobile pumps. The placement's 902 concrete deliveries were executed at precise 10-minute intervals—the cycle time for trucks to discharge concrete at the pumps. To reduce the heat of hydration and minimize the risk of thermal cracking, engineers not only specified a high-percentage replacement of cement with fly ash, but also pre-cooled aggregates with water spray. Concrete placement temperatures ranged from 88° F to 92° F—well below the 98° F limit.

To minimize the risk of logistical mishaps preventing completion of the foundation in the allotted time, the team built redundancies into the plan. A backup pumper was stationed on site, and a tow truck was on standby to tow away any concrete pumps were they to have failed. Additional batch plants were used to maintain concrete production.

Source: Skanska USA.

Beneficial Use Case Study

Global Change Institute Building

Coal Combustion Product Type:
Fly ash

Project Location:
Brisbane, Australia

Project Participants:
Wagners, University of Queensland, Hassell Group, Bligh Tanner, Arup, Medland Metropolis, Precast Concrete Pty. Ltd., McNab Builders

Project Completion Date:
2013

Project Summary:
Established in 2010, the Global Change Institute's (GCI) mission is to address the impacts of climate change and population growth through collaborative research in areas such as clean energy, food systems, and healthy oceans. When the Institute's headquarters was being designed, sustainable building principles were employed to serve as an outward reflection of the organization's objectives. To that end, among the construction materials specified was geopolymer concrete incorporating recycled fly ash and granulated blast furnace slag (GBFS).

Project Description:
Intended as a showcase of the "next generation of environmental building technologies," the Global Change Institute headquarters is a four-story building comprising three suspended concrete floors made from 33 precast geopolymer concrete panels. Toowoomba-based construction materials company Wagners supplied 330 cubic meters of Earth Friendly Concrete (EFC) for the large floor beams that form the floor plates.

EFC is a proprietary blend of fly ash and GBFS that uses no portland cement. Wagners supplied 110,550 metric tons of the slag and fly ash—the latter sourced from the Millmerran power station, a nearby plant fueled by bituminous coal. The fly ash complies with AS/NZS 3582.1: 2016, which is similar to the ASTM C618 Class F standard used in the U.S. Batched at the Toowoomba EFC plant, each beam required the delivery of two truckloads of EFC to the precast facility in Carole Park, Brisbane. Chemical activation was carried out at the precast yard when the trucks arrived to eliminate the risk of holds-ups on the busy highway between those two locations.

According to Wagners, use of EFC boasts a number of environmental and performance advantages over portland cement concrete, including:

- Emissions reductions of 80-90%
- 30% higher flexural strength
- High sulfate, acid, and chloride ion ingress resistance
- Low shrinkage
- Low heat of hydration

Use of EFC in the construction of the Global Change Institute represented the first-ever application of geopolymer concrete in the structure of a multi-story building; the only prior use was in test batches used for sidewalks. The EFC beams also play a significant role in low-energy space heating, with the placement of water pipes inside them to achieve temperature-controlled hydronic heating of the building spaces above and beneath.

Designed to function as a zero-energy and zero-carbon workplace, the Institute has earned a Green Building Council of Australia 6 Star Green Star Design rating and received numerous awards, including being named the 2013 BPN Sustainability Awards winner for innovation of the year.

SOURCE: Wagners.

SOURCE: Wagners.

Beneficial Use Case Study

ACAA

I-35W Saint Anthony Falls Bridge

Coal Combustion Product Type:
Fly ash

Project Location:
Minneapolis, Minnesota

Project Participants:
Minnesota Department of Transportation, Cemstone, Flatiron Constructors, Manson Construction, Figg Engineering, TKDA, Ayres Associates, Great River Energy

Project Completion Date:
2008

Project Summary:
On August 1, 2007, the primary spans of the I-35W bridge over the Mississippi River in Minneapolis collapsed into the water below, killing 13 people and injuring 145. Investigators found that the bridge had 16 undersized gusset plates that fractured, causing the bridge deck to give way. Engineers of the replacement bridge had two overarching goals: to build a sturdy, state-of-the-art bridge that would last 100 years and to build it expeditiously so as to minimize the disruption to the surrounding community.

Project Description:
Given the importance of I-35W as a major artery connecting points southwest of Minneapolis with the city's northern suburbs, the Minnesota Department of Transportation set a fast-track schedule for completion of the replacement bridge. Eight days after the bridge collapse, five companies had been approved to bid on the project and, six weeks later, contract awards were announced. Concrete reinforced by rebar was selected for the 10-lane replacement span, which would be fabricated under a design/build contract that allowed for the design and construction to be carried out simultaneously.

Custom concrete mixes were created for the different sections of the bridge, including footings, piers, drilled shafts, and superstructure. Fly ash—from Great River Energy's Coal Creek Station, near Underwood, North Dakota—featured in the mixes of all four of those concrete elements, with the highest percentage incorporated into the superstructure. The concrete superstructure, which carried a strength specification of 6500 psi, incorporated 25% fly ash replacement of cement. Footings, drilled shafts, and piers contained 18%, 18%, and 16% fly ash replacement of cement, respectively. In all, 45 high-performance mix designs were employed.

In addition to the aggressive construction schedule, engineers faced an array of challenges, including cold winter temperatures during which much of the concrete casting took place and the adjacency of existing infrastructure such as roads, tunnels, and the foundations of the collapsed bridge, which affected where the substructures of the new bridge could be located. Contractor Flatiron-Manson configured a casting yard near the bridge, employing heated prefabricated buildings in which operations could take place. Ultimately, 120 concrete box girder sections were cast onsite, after which they were cured, floated by barge, and hoisted into place at the bridge site by barge-mounted crane.

Construction of the Saint Anthony Falls Bridge, which incorporates 50,000 cubic yards of concrete, was completed in 11 months—three months ahead of schedule—and is designed for a 100-year life. It has earned a number of plaudits, including the Federal Highway Administration's Award of Excellence and an Excellence in Structural Engineering Award from the National Council of Structural Engineers Association.

SOURCE: CC Attribution-Share Alike 3.0-Elkman.

SOURCE: CC Attribution-Share Alike 3.0-Elkman.

Beneficial Use Case Study

MnROAD Stabilized Road Base Course

Coal Combustion Product Type:
High-carbon fly ash

Project Location:
Albertville, Minnesota

Project Participants:
U.S. Department of Energy, Minnesota Department of Transportation, Washington State University, University of Wisconsin, Bloom Companies LLC, Xcel Energy

Project Completion Date:
2008

Project Summary:
High-carbon fly ash is generally regarded as substandard for use in concrete, as the carbon's absorption of air-entraining admixture can reduce the concrete's durability. However, this is not necessarily a concern in applications such as for use as a base course under asphalt pavement, where maximum density and minimal air void can help to produce a sturdier road underpinning. A U.S. Department of Energy-sponsored study undertook to compare the strength, cost, and environmental effects of a base course of reclaimed pavement materials (RPM) stabilized with high-carbon fly ash against those of traditional road base materials.

Project Description:
Three test sections were built at the Minnesota Road Research Project (MnROAD) facility, each of identical length (500 feet), asphalt surface, subbase, and subgrade layer—but each with a different base course material. The three base courses consisted of conventional crushed aggregates, full-depth RPM, and fly ash-stabilized RPM. Fly ash was supplied from unit 8 of Xcel's Riverside Generating Plant, in St. Paul, Minn., and contained carbon content of 16.35% and calcium oxide content of 22.37%.

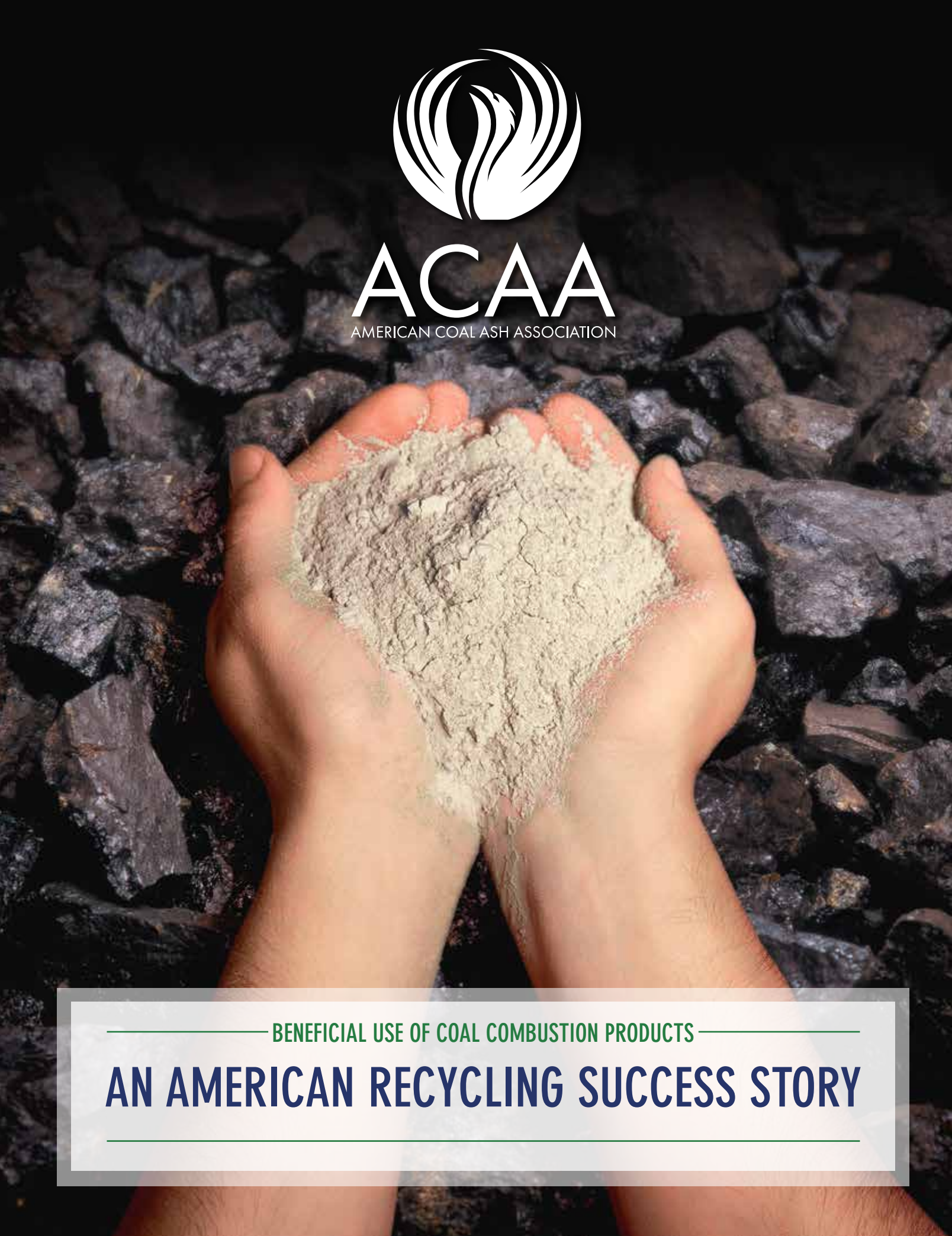
After the test sections were built, construction costs were compared among the three base courses. Because of heavy rainfalls, the untreated-RPM and crushed-aggregate sections had to be replaced, resulting in added costs. The fly ash-treated RPM base was not affected, helping it to achieve the lowest overall construction costs. Comparing the initial energy consumption and greenhouse gas emissions associated with the three base courses, the researchers found that the high-carbon, fly ash-treated RPM had the lowest figures in both of these categories as well.

During and after the construction of the three asphalt sections, laboratory and field tests were carried out to characterize the material properties. The test results were used in the mechanistic-empirical pavement design guide (MEPDG) to predict long-term pavement performance. Tests showed that the fly ash-stabilized RPM had a higher modulus than those of crushed aggregate and full-depth RPM and, based on the MEPDG performance prediction, a service life of 23.5 years—over twice the service life of the full-RPM base (11 years) and more than three times that of the crushed aggregate base (7.5 years). Life-cycle analysis indicated that the use of fly ash-stabilized RPM as a base for flexible pavement can greatly reduce life-cycle costs, energy consumption, and greenhouse gas emissions.

SOURCE: MnDOT.

ACAA

AMERICAN COAL ASH ASSOCIATION



BENEFICIAL USE OF COAL COMBUSTION PRODUCTS

AN AMERICAN RECYCLING SUCCESS STORY

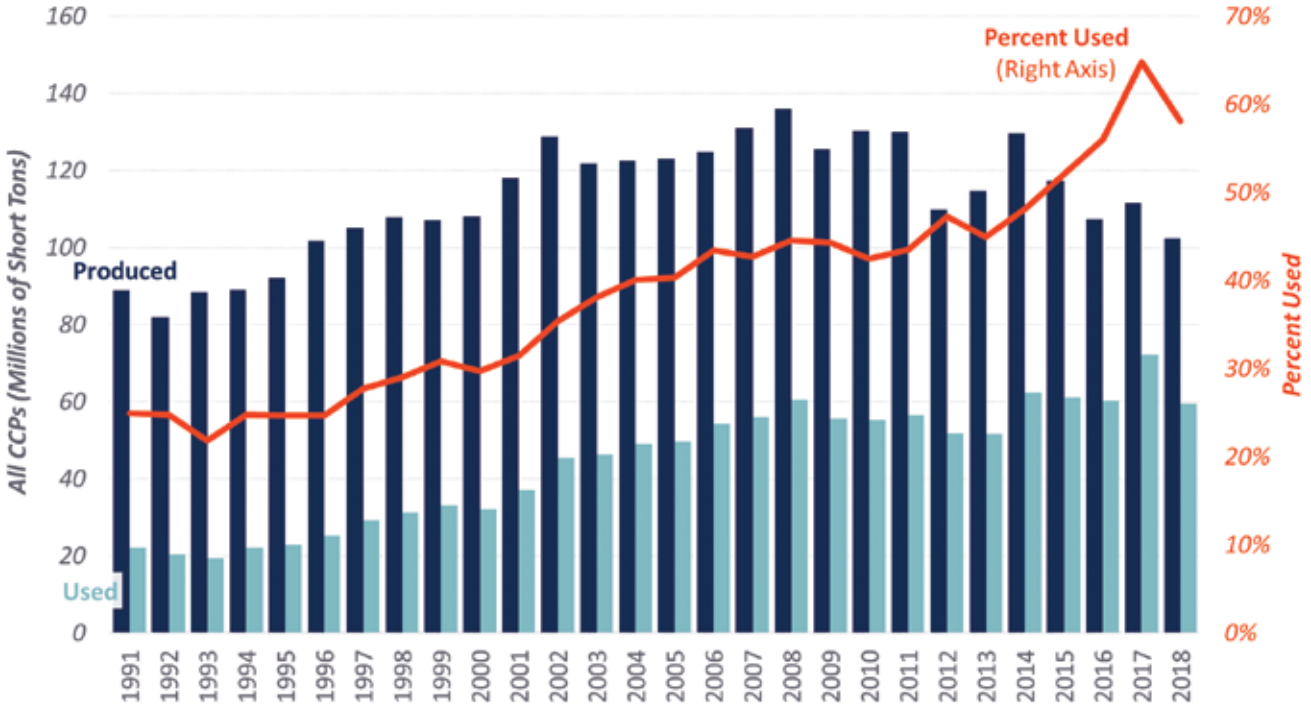
AN AMERICAN RECYCLING SUCCESS STORY

Coal combustion products – often referred to as "coal ash"– are solid materials produced when coal is burned to generate electricity. There are many good reasons to view coal ash as a resource, rather than a waste. Using it conserves natural resources and saves energy. In many cases, products made with coal ash perform better than products made without it.

As coal continues to produce approximately one-third of the electricity generation in the United States, significant volumes of coal ash are produced. Since 1968, the American Coal Ash Association has tracked the production and use of all types of coal ash. These surveys are intended to show broad utilization patterns and ACAA's data have been accepted by industry and numerous government agencies as the best available metrics of beneficial use practices.

Fifty-eight percent of the coal ash produced during 2018 was recycled—down from 64 percent in 2017, but marking the fourth consecutive year that more than half of the coal ash produced in the United States was beneficially used rather than disposed. Use of coal fly ash in **concrete** declined 11 percent to 12.5 million tons. Concrete producers and consumers indicated a desire to use more fly ash, but several regional markets were affected by shifting supply dynamics associated with closures of coal-fueled power plants. Utilization of a key "non-ash" coal combustion product returned to expected levels. Use of synthetic gypsum in panel products (i.e., wallboard) declined 23 percent to 12.3 million tons. This volume is consistent with utilization volumes in the 2014-2016 period following a 2017 in which users took advantage of an opportunity to increase stockpiles of gypsum for raw material.

All CCPs Production and Use with Percent



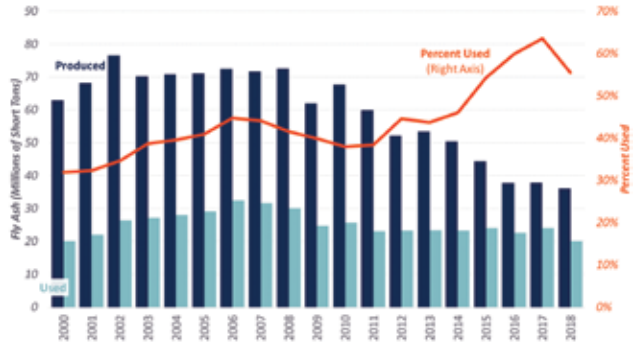
Fly Ash

Fly ash is a powdery material that is captured by emissions control equipment before it can "fly" up the stack. Mostly comprised of silicas, aluminas and calcium compounds, fly ash has mechanical and chemical properties that make it a valuable ingredient in a wide range of concrete products. Roads, bridges, buildings, concrete blocks and other concrete products commonly contain fly ash.

Concrete made with coal fly ash is stronger and more durable than concrete made with cement alone. By reducing the amount of manufactured cement needed to produce concrete, fly ash accounts for approximately 12 million tons of greenhouse gas emissions reductions each year.

Other major uses for fly ash include constructing structural fills and embankments, waste stabilization and solidification, mine reclamation, and use as raw feed in cement manufacturing.

Fly Ash Production & Use 2000 – 2018



Fly ash ranges in color from gray to buff depending on the type of coal.

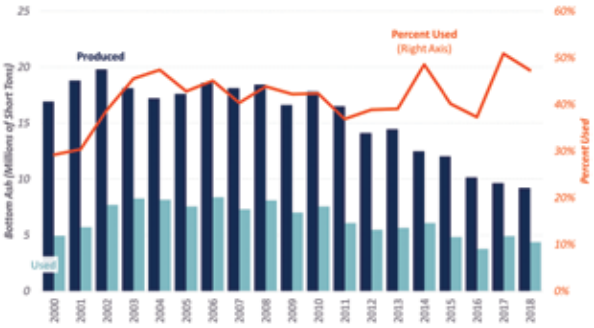
The American Road & Transportation Builders Association estimates coal fly ash use in roads and bridges saves $5.2 billion per year in U.S. construction costs.

Bottom Ash

Bottom ash is a heavier, granular material that is collected from the "bottom" of coal-fueled boilers. Bottom ash is often used as an aggregate, replacing sand and gravel. Bottom ash is often used as an ingredient in manufacturing concrete blocks.

Other major uses for bottom ash include constructing structural fills and embankments, mine reclamation, and use as raw feed in cement manufacturing.

Bottom Ash Production & Use 2000 – 2018



Bottom ash can be used in asphalt paving.

Bottom ash is a granular material suitable for replacing gravel and sand.

Synthetic Gypsum

Power plants equipped with flue gas desulphurization ("FGD") emissions controls, also known as "scrubbers," create byproducts that include synthetic gypsum. Although this material is not technically "ash" because it is not present in the coal, it is managed and regulated as a coal combustion product.

Scrubbers utilize high-calcium sorbents, such as lime or limestone, to absorb sulfur and other elements from flue gases. Depending on the scrubber configuration, the byproducts vary in consistency from wet sludge to dry powdered material.

Synthetic gypsum is used extensively in the manufacturing of wallboard. A rapidly growing use of synthetic gypsum is in agriculture, where it is used to improve soil conditions and prevent runoff of fertilizers and pesticides.

Other major uses for synthetic gypsum include waste stabilization, mine reclamation, and cement manufacturing.

Synthetic Gypsum Production & Use 2002 – 2018

Synthetic gypsum is often more pure than naturally mined gypsum.

More than half of the gypsum wallboard manufactured in the United States utilizes synthetic gypsum from coal-fueled power plants.

Synthetic gypsum applied to farm fields improves soil quality and performance.

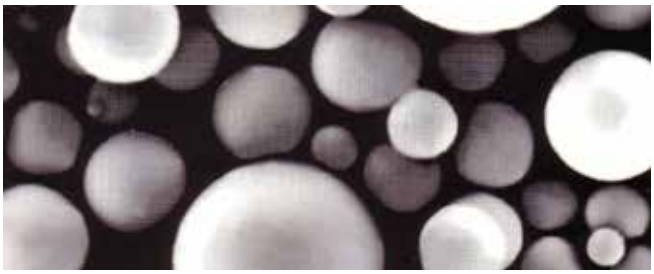
ACAA
AMERICAN COAL ASH ASSOCIATION

Other Products and Uses

Boiler Slag – is a molten ash collected at the base of older generation boilers that is quenched with water and shatters into black, angular particles having a smooth, glassy appearance. Boiler slag is in high demand for beneficial use as blasting grit and roofing granules, but supplies are decreasing because of the retirement from service of older power plants that produce boiler slag.

Nearly 90 percent of all boiler slag is beneficially used.

Cenospheres – are harvested from fly ash and are comprised of microscopic hollow spheres. Cenospheres are strong and lightweight, making them useful as fillers in a wide variety of materials including concrete, paint, plastics and metal composites.



Because of their high value, cenospheres – seen here in a microscopic view – are measured by the pound rather than by the ton.

FBC Ash – is a category of ash from Fluidized Bed Combustion power plants. These plants reclaim waste coal for fuel and create an ash by-product that is most commonly used to reclaim abandoned surface mines and abate acid mine drainage. Ash from FBC power plants can also be used for waste and soil stabilization.

This regional park was constructed with FBC ash on the site of a former waste coal pile.

New Uses on Horizon

New beneficial uses for coal ash are continually under development. Researchers and ash marketers are currently focusing heavily on the potential for harvesting ash that has already been disposed for potential beneficial use. There is also renewed interest in the potential for extracting strategic rare earth minerals from ash for use in electronics manufacturing.

ACAA
AMERICAN COAL ASH ASSOCIATION

American Coal Ash Association Phone: 720-870-7897

2018 Coal Combustion Product (CCP) Production & Use Survey Report

Beneficial Utilization versus Production Totals (Short Tons)

2018 CCP Categories	Fly Ash	Bottom Ash	Boiler Slag	FGD Gypsum	FGD Material Wet Scrubbers	FGD Material Dry Scrubbers	FGD Other	FBC Ash	CCP Production / Utilization Totals
Total CCPs Produced by Category	**36,178,427**	**9,197,362**	**1,534,945**	**32,783,995**	**4,732,900**	**2,154,301**	**121,126**	**15,571,824**	**102,274,881**
Total CCPs Used by Category	**20,081,330**	**4,350,321**	**1,036,919**	**18,337,477**	**91,036**	**498,532**	**0**	**15,045,225**	**59,440,839**
1. Concrete/Concrete Products /Grout	12,520,492	582,010	0	235,578	0	0	0	93,555	13,431,635
2. Blended Cement/ Feed for Clinker	3,127,447	1,218,581	167,996	1,865,279	0	0	0	5,585	6,384,889
3. Flowable Fill	83,761	0	0	0	0	0	0	0	83,761
4. Structural Fills/Embankments	1,515,590	1,320,439	0	1,735,008	0	0	0	0	4,571,036
5. Road Base/Sub-base	234,798	160,061	0	4,978	0	1,159	0	0	400,997
6. Soil Modification/Stabilization	245,197	2,070	0	0	0	0	0	0	247,267
7. Mineral Filler in Asphalt	10,424	0	0	0	0	173	0	0	10,597
8. Snow and Ice Control	0	134,503	11,018	0	0	0	0	0	145,521
9. Blasting Grit/Roofing Granules	0	27,148	468,365	0	0	0	0	0	495,513
10. Mining Applications	530,444	0	0	20,487	0	0	0	14,827,122	15,378,053
11. Gypsum Panel Products (formerly Wallboard)	0	0	0	12,282,870	0	0	0	0	12,282,870
12. Waste Stabilization/Solidification	953,235	101,890	0	34,068	0	19,746	0	90,753	1,199,692
13. Agriculture	0	0	0	918,386	0	85,671	0	0	1,004,057
14. Aggregate	0	2,927	0	0	0	0	0	0	2,927
15. Oil/Gas Field Services	39,400	0	0	0	0	13,558	0	0	52,958
16. CCR Pond Closure Activities	600,861	732,022	389,539	1,035,612	91,036	378,224	0	0	3,227,295
17. Miscellaneous/Other	219,681	68,669	0	205,210	0	0	0	28,210	521,771

Summary Utilization to Production Rate

CCP Categories	Fly Ash	Bottom Ash	Boiler Slag	FGD Gypsum	FGD Material Wet Scrubbers	FGD Material Dry Scrubbers	FGD Other	FBC Ash	CCP Utilization Total
Totals by CCP Type/Application	20,081,330	4,350,321	1,036,919	18,337,477	91,036	498,532	0	15,045,225	**59,440,839**
Category Use to Production Rate (%)	**55.51%**	**47.30%**	**67.55%**	**55.93%**	**1.92%**	**23.14%**	**0.00%**	**96.62%**	**58.12%**
2018 Cenospheres Sold (Pounds)	1,192,568	Data in this survey represents 127.52499152 GWs of Name Plate rating of the total industry wide approximate 248.928 GW capacity based on EIA's July 2018 Electric Power Monthly.							

2019 American Coal Ash Association Membership Directory

These listings are organized into the following five membership categories:

Utility ▪ Marketer ▪ Specialty Marketer ▪ Associate ▪ Individual

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