

ISSUE 1 • 2015

ASH **at work**

Applications, Science, and Sustainability of Coal Ash

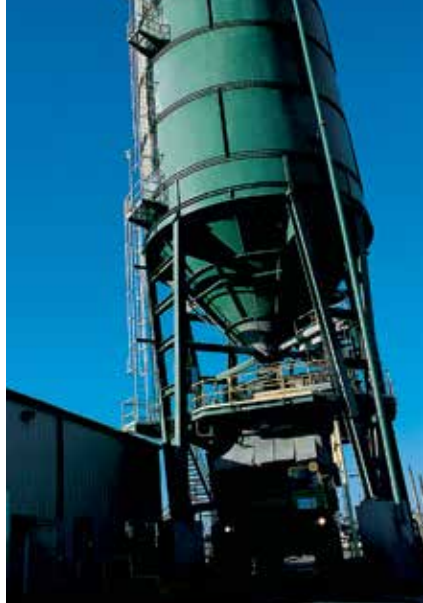
Sustainability

Improving Product Performance and Longevity with Coal Ash

Special Section: *Annual Coal Ash Production and Use Report*

PLUS:

Ash News Roundup
In and Around ACAA
6 Questions for...
Ash Classics
And much more...



Powdered

PACT® is a proven, proprietary process for beneficiating fly ash that is contaminated with powdered activated carbon.

Activated

Allows marketing of usually disposed ash because it effectively treats PAC.

Carbon

Can be applied on demand to create a sustainable solution.

Treatment

PACT® is a low cost non-hazardous patented chemical application that can be applied directly to fly ash. Since 2008, BMT has successfully treated approximately 8 million tons of fly ash with this process.

For innovative fly ash solutions, optimum concrete performance, and groundbreaking new products, BMT is the solid choice. With our superior quality products, in depth research, extensive support services, and over 40 years of industry knowledge, BMT is uniquely positioned to help build and sustain your business.

Build something great™ with Boral Material Technologies

To learn more about PACT® or BMT's other technologies, contact us at: 1-800-964-0951 or visit us online at **www.boralflyash.com**.





American Coal Ash Association
38800 Country Club Drive
Farmington Hills, MI 48331
Phone: 1-720-870-7897
Fax: 1-720-870-7889
www.acaa-usa.org
www.FGDProducts.org
www.WWCCP.org

Executive Director
Thomas Adams

Member Liaison
Alyssa Barto

Editor
John Ward

Advertising
Alyssa Barto

Creative Association Management
Publishing Services Manager
Barry M. Bergin

Editors
Carl R. Bischof (Senior Editor),
Tiesha Elam, Kaitlyn J. Hinman,
Kelli R. Slayden (Senior Editor)

Editorial Assistant
Angela R. Matthews

Graphic Designers
Gail L. Tatum (Senior Designer),
Susan K. Esper, Ryan M. Jay,
Aimee M. Kahaian

On the Cover

Kauai's Iraiwan Hindu Temple used coal fly ash to create a concrete foundation capable of lasting 1000 years.



ASH **at work**

Applications, Science, and Sustainability of Coal Ash

TABLE OF CONTENTS

Message from the ACAA Chair 2

Message from the ACAA Executive Director 4

FEATURES

In & Around ACAA 8

ACAA Educational Foundation Rejuvenated with Scholarship Awards. 10

2014 ACAA Educational Foundation Scholarship Application 13

By Ross Taggart

Coal Combustion Product Utilization is Limited by Lack of Research and Legislation. 16

By Brigitte Brown, Research Assistant, University of Wisconsin-Madison

Kauai's Hindu Temple 20

By John Ward

Coal Ash Underground Mine Stabilization 25

Comparative Life Cycle Assessment of Traditional Concrete and Concrete Made with Fly Ash 27

By Christa Heavey, Angelica Hernandez, Shea Hughes, and Lindsay Willman

Ash Classics 37

New Coal Ash Report Published 42

Beneficial Use Of Coal Combustion Products
An American Recycling Success Story 44

AD INDEX

Agri Management. 3

Boral Material Technologies . . Inside Front Cover

Charah, Inc 5

Headwaters Resources. . . . Outside Back Cover

HillTop Enterprises 35

Moretrench 9

MRT Cemex 15

SCB International 7

The SEFA Group. 19

SYNMAT Inside Back Cover

Tank Connection. 6

Trans Ash. 41

Waste Management 52

WL Port-Land Systems, Inc. 43



FINALLY, A RESPITE FROM PLAYING DEFENSE

By Hollis Walker, ACAA Chair

Three days. Three days from the sixth anniversary of the Kingston ash pond failure conveys the extent of the protracted battle waged against coal ash.

Almost immediately after the failure, we saw inaccurate and irresponsible use of words to better sensationalize stories of the dike failure. Thus began ACAA's battle to counter the stigmatizing effects immediately caused by the improper use of "toxic," "hazardous," and other variants of these words, negatively impacting the reuse of ash and gypsum.

Finally, after 6 full years, the coal combustion products (CCP) industry can take a collective sigh of relief having seen the final coal combustion residuals (CCR) rule made public in late December. Truth, scientific data, and proper application of the law won—CCP will be regulated as nonhazardous materials.

While the final rule surely has its warts, such as the Environmental Protection Agency leaving the door cracked to revive this whole hazardous-versus-nonhazardous war again, we can finally come out from under the cloud of uncertainty that has plagued the reuse industry for years. Instead of playing defense with all our resources, now we can focus on being proactive with promoting the benefits of beneficial uses of CCP.

One such effort has been the reinstitution of a scholarship program conducted under ACAA's Educational Foundation (EF). The purpose of the program is to reach future leaders through an application process that promotes individual research and assessment of facts

Instead of playing defense with all our resources, now we can focus on being proactive with promoting the benefits of beneficial uses of CCP.

regarding the environmental safety and benefits of CCP reuse.

While there were a few scholarships awarded in the early years of the EF, it has been nearly a decade and a half since doing so. The revival of the program was led by ACAA's past Chair Lisa Cooper as one of the last initiatives of her term. Under her leadership, an adequate corpus was invested in a financial instrument that is expected to provide the funding for annual scholarships through the interest earned, thus making the annual funding of \$7500 in scholarships a self-sustaining program.

With the reboot of a program came the need for volunteers to develop it from scratch, and usher it through what could be, without strong leadership, a tenuous first round. The program benefited from having such a capable leader in Dawn Santoianni to volunteer to chair the newly formed Scholarship Committee. While many association members provided input and support throughout the process, a special debt of gratitude is owed to a few key contributors who, from the early stages, provided invaluable input and ideas into making the program a success.

Dawn DeJardin and Ann Couwenhoven have my deepest thanks for their many hours of work to support Dawn Santoianni. In addition to the names I've listed, there were many more that had a share in making this first round of scholarship awards come to fruition.

The EF Board members, the Scholarship Committee members, and the panel of judges who gave up so much of their precious holiday hours in December are also deserving of a great big thank you.

The culmination of all the hard work resulted in two scholarship awards given to two incredible applicants. While I was not fortunate enough to hear the presentations by the two winners at our winter conference, I am comforted by the words of our Executive Director Tom Adams, "...I am not sure we could have designed two more worthy recipients. Ross Taggart and Brigitte Brown were both articulate and tightly focused on their individual interests in CCP. Listening to the summaries of their papers and how they came to be interested in CCP beneficial use truly reinforced for me the importance of supporting young talent whenever possible." This was a fitting end to the first round of a well-developed and well-executed scholarship program.

While we can enjoy being proactive on a new front, such as the scholarship program and other activities being contemplated, in our ever-diligent efforts to promote and protect environmentally sound beneficial uses, we must also keep a persistent watch addressing flare-ups arising from the battle of the past 6 years. This is evident almost weekly, as we can see from articles posted in our newsletter, *The Phoenix*. I can assure you that your association is on the post to address any such flare-ups. ♦

Agru America Coal Ash Closure Solutions

Subtitle D Compliant Closure Systems for Coal Ash Impoundments

ClosureTurf® System

A proven "hybrid" composite system that outperforms traditional closure methodologies.

Engineered
Turf 1-2"

0.5" Sand infill

Agru 50 mil Super Gripnet® with
spikes down and integrated drainage layer


ClosureTurf®
Brought to you by **Agru America**

Agru Integrated Drainage System

Agru Super
Gripnet®
Geomembrane

24" min. cover
soil layer

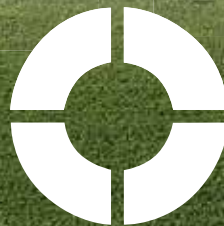
Agru Geotextile

Agru Traditional Closure System

24" min. cover
soil layer

Agru
Geocomposite

Agru
40 mil
MicroSpike®



agru
america
Made in USA

www.AgruAmerica.com • 800-373-2478

Chris Eichelberger: ceichelberger@agruamerica.com

ClosureTurf® is a product of Watershed Geosynthetics LLC. U.S. Patent Nos. 7,682,105 & 8,585,322. Canada Patent No. 2,663,170 • Other Patents Pending.
This information is provided for reference purposes only and is not intended as a warranty or guarantee. Agru America, Inc. assumes no liability in connection with the use of this information.



GRADING EPA'S CCR REGULATION

By Thomas H. Adams, ACAA Executive Director

On December 19, 2014, U.S. Environmental Protection Agency (EPA) Administrator Gina McCarthy did something that Lisa Jackson, Stephen Johnson, Michael Levitt, Christine Todd Whitman, Carol Browner, William Reilly, Lee Thomas, William Ruckelshaus, Anne Gorsuch Burford, and Douglas Costle could not do—sign a regulation for management of coal combustion residuals (their term, not ours). Thirty-four years after the Beville Amendment was passed, the EPA announced the regulation after two previous determinations by the agency itself, including one called “final.” Under a consent decree resulting from a suit in federal district court involving ENGOs and two major coal ash marketers, Headwaters Resources and Boral Materials, the EPA met the deadline to announce its regulation. So the question is: how did the EPA do? While issues surrounding the rule are still unfolding, some general observations are possible.

Issue one—Hazardous or Non-hazardous? Because CCR has never qualified as a hazardous material based on its toxicity, the hazardous option was on shaky ground since day one of the most recent rulemaking effort. However, high-level officials at the EPA seemed to be determined to create a hazardous rule to capture enforcement authority over coal ash management. The ACAA’s primary goal has been to get the hazardous waste regulation off the table, for consideration as such a rule would seriously cripple the beneficial use industry. The EPA said they would exempt beneficial use and use hazardous waste authority over disposal activities only. Despite the best efforts of the agency to sell this concept, we were never convinced. ACAA’s

primary objective of removing a hazardous waste regulation of any kind from consideration was met. Therefore the only grade possible is: A.

Issue two—Beneficial use restrictions. “Large” structural fills have been an EPA target since the beginning. For a long time, no one could tell us what “large” meant. Now we know—anything over 12,399 tons (11,248 tonnes). Where did that number come from? When you find out, let us know. Nevertheless any structural fill of 12,400 tons (11,249 tonnes) and greater must jump through some hoops. In addition, early reading led some to believe that stockpiles of CCR intended for beneficial use could be considered as disposal. There are other ambiguities that are being clarified. In an attempt to put a fence around “unencapsulated” (again, their word, not ours) beneficial uses, the rule is clumsy and ambiguous. Grade: C–.

Issue three—Preamble versus rule. The EPA writes at length in the preamble to explain what their intent is within the following regulatory language. This is troubling as they set up a problem with conflicts between the preamble and the rule. For example, while the rule falls under RCRA Subtitle D, the preamble expresses the possibility of needing to revisit the Subtitle D designation due to the changing nature of CCR. There is no science which demonstrates that CCR is changing as of yet. But the inference is that as generators make process changes to comply with other EPA regulations, CCR will transition into a different material with the potential to justify hazardous waste regulation. Do they really believe that? Or were they just trying to keep the door open for another crack at

regulation? How many times must the agency state that CCR does not qualify as hazardous before we get a FINAL status? Grade: D

Issue four—Enforcement authority. I think we have to cut the EPA a little bit of slack on this one. Under RCRA Subtitle D, enforcement only comes via citizen suits. The disposal requirements come in a self-implementing form. Should a citizen or group of citizens be unhappy about the way a generator is managing disposal, they must sue the generator. Generators could be facing actions in multiple jurisdictions at once. Some generators will be subject to conflicting federal and state regulations. It is not clear how the EPA could work around these important structural problems. The real solution to the enforcement authority issue does not reside within the EPA’s authority. That solution is for enactment of legislation. The U.S. House of Representatives recently passed the Improving Coal Combustion Residuals Regulation Act of 2015. Senate action is pending. This legislation includes the EPA regulation and provides for enforcement through mandatory permits. Only action by the 114th Congress and a presidential signature can clean up this mess. Grade: C+

While there are many questions being posited regarding the EPA’s regulation for CCR disposal that have yet to be resolved, the primary issue has once again been resolved in favor of science and beneficial use. It is time we get Beyond Coal Ash Fiction as practiced since 2009 and resume growing the recycling markets for the sake of the environment and the sake of our economy. ♦



CCP Management And Power Plant Support Services

- Landfill Design, Construction, Management, Operations and Closure
- Fly Ash, Bottom Ash, Gypsum Sales and Marketing
- Ash Pond Management and Closure
- Structural Fill Projects
- Power Plant Support Services including Limestone Supply and FGD Operations
- SUL4R-PLUS® Product and Other Products for the Agricultural Market
- IGCC Slag Beneficiation and Other Innovative Solutions



FOR INNOVATIVE SOLUTIONS AND SUPERIOR SERVICE, CALL 877-314-7724 OR VISIT CHARAH.COM.



Craig Cain (left) in retirement with another coal ash pioneer, Oscar Manz (right).

In Memoriam—Craig Cain

Craig J. Cain, an Honorary Member of ACAA, died August 29, 2014, at the age of 91. A resident of Hanover, NH, Cain was a coal ash beneficial use pioneer. His career focused on the design, manufacture, and sale of concrete pipe as well as the development of markets for fly ash and related products from steam power plants for use in concrete. He was a corporate president for 45 years: of the American Fly Ash Company from 1980 to 1991; of American Admixtures Corp. from 1965 to 1980; of Chicago Fly Ash Co. from 1950 to 1965; and of Continental Concrete Pipe Corp., Chicago, IL, from

1946 to 1974, where he was also CEO and Chairman of the Board. He was an Honorary Member and Fellow of ASTM International. Other professional memberships included the American Society of Civil Engineers and the American Concrete Institute. Cain was Acting Mayor of Evanston, IL, in 1971 and was an Alderman on the city council from 1964 to 1972. He was Chairman of ASTM Subcommittee C09.24, Supplementary Cementitious Materials, which is responsible for writing the specifications for fly ash in concrete, for 10 years and a member for over 45 years. He received ASTM's prestigious Frank E. Richart Award for notable contributions in research and standardization concerned with concrete and concrete aggregates.

ACAA MEETS IN SAVANNAH

The American Coal Ash Association held its Winter Membership Meeting in historic Savannah, GA, on February 9 and 10, 2015. Attendance was strong with 180 people registering for the event. The first day of the meeting was filled with committee meetings. The

Executive Committee, Communication and Membership Committee, Technical Committee, Governmental Relations Committee, Educational Foundation, and Board of Directors all held sessions to conduct the business of the association. The highlights of these meetings include the following:

- **Communications and Membership**—The committee will be developing an award program to recognize innovation in beneficial use.
- **Technical**—Safety Data Sheets (SDS) are required by a revised Hazard Communication Standard from OSHA as of June 1, 2015. To avoid unintended consequences from a poorly written SDS, the committee requested funds to create templates for coal combustion products (CCPs). The Board of Directors authorized up to \$10,000.00 to generate templates. Voluntary contributions from members will be sought.
- **Governmental Relations**—Review of the EPA regulation on coal combustion residual (CCR) was the main topic. The future prospects for legislative action were covered in this discussion. A panel discussion was held to discuss the regulation from the U.S. Environmental Protection Agency (EPA) on CCR management. Chris Hardin, PE, CH2M Hill; Joshua More, Schiff Hardin LLP; and Mark Rokoff, PE, AECOM, provided engineering and legal perspectives on this important rule. John Ward, Chair of the Governmental Relations Committee, was the moderator for this session. A number of interesting questions were posed to the panel, which served to highlight some of the ambiguities in the regulation.
- **Educational Foundation**—The ACAAEF Board of Directors discussed the successful scholarship drive for 2014 and some potential changes for 2015. The Board agreed that more funds are needed to expand the number of awards. The ACAA Board of Directors will be asked to consider this request.
- **Board of Directors**—The Board heard a report on renewal of the agreement for management services from Creative Association Management, approved the request of the ACAAEF

THE ENGINEER'S 1ST CHOICE

AFFILIATE GROUP

BOLTED RTP TANKS
 Hopper applications to 80,000 cu. ft.

FIELD-WELD SILOS
 Hopper bottom capacities to 200,000 cu. ft.

SHOP-WELD SILOS
 Hopper capacities up to 10,000 cu. ft.

Tank Connection will prescribe the best solution for your particular application, with specification development and material testing. Our streamlined design/build processes produce functional mass flow discharge designs and reliable performance for single tanks through complete integrated systems. Tank Connection delivers modular construction, turnkey field installation and golden rule customer service worldwide.

Tank Connection Affiliate Group
 3609 North 16th Street • Parsons, KS 67357 • 620.423.3010
sales@tankconnection.com • www.tankconnection.com

for funds for matching new contributions to the scholarship fund, approved funds for creation of SDS templates along with an appeal to members for contributions, and approved an operating budget for 2015. During the Board meeting, member delegates elected directors to fill expiring terms. Elected to the Board of Directors were Larry LaBuz, PPL; Willie Mills, Consumers Energy; Peggy Rennick, SCB International Materials; and Bob Spoerri, Beneficial Reuse.

Day two of the winter meeting began with introduction of ACAAEF scholarship recipients. Lisa Cooper, Past Chair of ACAAEF, and Dawn Santoianni, Chair of the Scholarship Committee, introduced Ross Taggart and Brigitte Brown. Taggart, Duke University, and Brown, University of Wisconsin – Madison, were recognized for the award-winning submittals. Taggart won the David C. Goss Scholarship, worth \$5000. Brown won the John H. Faber Scholarship, worth \$2500. Both students provided a summary of their essays as well as information on their interest in coal combustion products.

The remainder of the day was devoted to technical presentations on a wide variety of topics. Speakers included Jerry Yudelson, Green Building Initiative, who spoke on building rating systems. Professor Larry Sutter, Michigan Technical University, and Dr. Toy Poole, CTLGroup, debated the usefulness of fly

ash classification under ASTM C618. Steve Putrich, Haley & Aldrich, provided more information on the EPA CCR rule. Janet Gellici, National Coal Council, discussed the NCC's report on the value of the U.S. coal-fired power fleet. Dr. Ish Murarka, Haley & Aldrich, detailed groundwater monitoring requirements. Professor John Daniels, University of North Carolina – Charlotte reviewed developments in North Carolina under recently passed coal ash regulations.

The success of this meeting was the sum of many parts. The work of the committees was vital to moving the association forward. The presentations were interesting and informative. Presenting scholarships was important to recognizing the need to encouraging future talent. The opportunity to see old friends and meet new friends is always an important benefit of attending. Finally, the support of the meeting sponsors was vital to providing the infrastructure to support the event. Our thanks go out to Charles River Associates; Civil & Environmental Consultants; Environmental Specialties International; Hilltop Enterprises; Hull & Associates; National Gypsum; SEFA Group; USA Environmental; and Wear-Con.

The next ACAA member meeting will take place October 6-7 in Raleigh, NC.



The ACAA Educational Foundation thanks these companies and individuals who contributed financially to fund expansion of the Foundation's scholarship activities.

Ameren	Josh More
Beneficial Reuse	Lisa Bradley
Management/Gypsoil	Lisa Cooper
Boral Material Technologies	LB Industrial Systems
Charah, Inc.	LG&E and KU Services
Civil & Environmental	Company
Consultants, Inc.	Mark Bryant
Dairyland Power	Republic Services, Inc.
Cooperative	Silar Services
Duke Energy	Southern Company
GHD Services Inc	Tau Technical
Headwaters Resources	Communications
Hilltop Enterprises, Inc.	Thomas H. Adams
Hollis Walker	We Energies
John Ward	



- ◆ *Ash Reclamation and Beneficiation*
- ◆ *Ash Pond Management*
- ◆ *Transportation & Logistics Management*
- ◆ *Technical Support*
- ◆ *Removal of Mercury and Carbon*
- ◆ *Fly Ash and Bottom Ash Marketing*
- ◆ *Synthetic Gypsum Marketing*



Learn more about how we can help you

SCB International
153 South Main Street, Newtown, CT 06470

www.scbinternational.com
Ph: 1-203-270-1416

IN & AROUND ACAA



SAVANNAH, GA

ACAA's Winter Meeting (February 10-11, 2015) attracted 188 attendees to hear speakers such as Dr. John Daniels of the University of North Carolina at Charlotte, as well as a lively debate between Dr. Toy Poole of CTLGroup and Professor Lawrence Sutter of Michigan Technological University regarding coal ash "Class Warfare: Are C and F Needed Anymore?"



WASHINGTON, DC

A well-attended news conference at the National Press Club (December 17, 2014) was the setting for the release of ACAA's annual coal ash Production and Use Survey results. The latest data on coal ash beneficial use received wide coverage as the U.S. Environmental Protection Agency released its Final Rule for coal ash disposal regulation 2 days later.



MORETRENCH

No one has seen more.™

TALK TO OUR POND CLOSURE EXPERTS TODAY.

NO ONE HAS SEEN MORE, THAN MORETRENCH.



Groundwater Control

Earth Retention

Deep Foundations

Grouting

Ground Freezing

moretrench.com



PHOTO CAPTION: Scholarship winners Brigitte Brown and Ross Taggart are flanked by ACAA Educational Foundation Scholarship Committee Chair Dawn Santoianni (left) and ACAA Immediate past Chair Lisa Cooper (right)

ACAA EDUCATIONAL FOUNDATION REJUVENATED WITH SCHOLARSHIP AWARDS

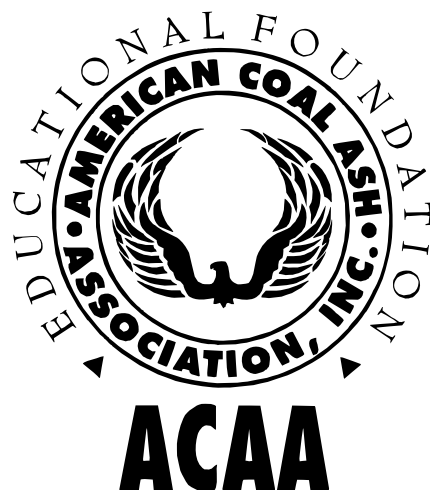
The American Coal Ash Association (ACAA) Educational Foundation has awarded \$7500 in scholarships to two university students with interests in advancing the sustainable and environmentally responsible use of coal combustion products. The Foundation also announced new names for the scholarships honoring coal ash beneficial use industry leaders.

Ross Taggart of Duke University was selected to receive a \$5000 scholarship that was named in honor of David C. Goss. Goss is a former Executive Director of ACAA who

was instrumental in establishing the Educational Foundation.

Brigitte Brown of University of Wisconsin, Madison, was selected to receive a \$2500 award that was named in honor of John Faber. Faber served as ACAA's first Executive Director, beginning in 1968.

The scholarship winners were chosen from a field of applicants who submitted essays on topics related to the beneficial use of coal combustion products (CCPs), which are materials produced when coal is burned to generate electricity. Ross Taggart, a graduate student studying



environmental engineering, wrote about coal fly ash as a potential source for strategic rare earth metals and yttrium, which are critical to the automobile, energy, electronics, and defense industries. Brigitte Brown, a graduate student studying geological engineering, wrote about public policy initiatives needed to increase the use of CCPs in applications beyond concrete and wallboard.

“The Educational Foundation was exceptionally pleased by the quality of scholarship applications,” said Dawn Santoianni, Scholarship Committee Chair. “Increasing the utilization of coal ash in order to prevent its disposal depends on knowledge and creativity. We are proud to help support the next generation of professionals interested in developing safe and environmentally beneficial uses for coal ash.”

In addition to receiving the scholarships, Taggart and Brown presented their essays to ACAA membership during the group's winter membership meeting in Savannah, GA, February 11, 2015.

Taggart, a PhD candidate in environmental engineering, began researching the recovery of strategic rare earth metals and yttrium from CCPs in January 2014. He wrote about how coal fly ash is a potential source of rare earth metals and yttrium, which are critical to the automobile, energy, electronics, and defense industries. He has been working to characterize the rare earth metal content of coal ashes, acquiring ash samples from plants in North Carolina and South Carolina. Taggart has begun experiments testing the effects of physical and chemical parameters on the extraction of rare earth metals from coal ash. His research will also compare the economic feasibility of recovering strategic metals from coal ash to traditional mining. Taggart's advisor is Dr. Heileen Hsu-Kim, Associate Professor of Environmental Engineering at Duke University. Taggart is a self-reliant backpacker and resourceful engineer who strives to reduce waste (“Leave No Trace”) and use resources in imaginative ways. He plans to pursue a career in the mining or energy industries, hoping to reduce costs and improve processes through sustainable waste reuse.

Brown, an MS candidate in geological engineering, is researching leachate information from use of coal ash as base in roadway construction. Brown is compiling and analyzing a database of leachate information from more than 10 large-scale pan lysimeters that have been installed beneath road bases constructed with fly ash and bottom ash in Wisconsin and Minnesota. The lysimeters have been capturing the water emanating from the bottom of the pavement profile for more than a decade, enabling the analysis of volumetric flow rate and trace element concentrations from roadways constructed with CCPs. In her essay, Brown wrote about how public policy initiatives are needed to increase the use of CCPs in applications beyond concrete and wallboard. Her advisor is Dr. Craig Benson, Distinguished Professor and Chair of Civil and Environmental Engineering at University of Wisconsin-Madison. Brown's goal is that her research will help influence public policy and perception and promote the safe and beneficial reuse of CCPs in roadway applications. Her career ambitions are to become a licensed Professional Engineer and work on sustainability-related water resource engineering projects.

Both winning scholarship essays are published in their entirety in this edition of *ASH at Work*.

Scholarship Committee chair Santoianni said committee members were exceptionally pleased by the quality of scholarship applications and selected five other outstanding students to receive Honorable Mention (listed alphabetically):

- Jamie Clark, Senior in Civil Engineering at Georgia Institute of Technology;
- Matt Jansen, MS candidate in Civil Engineering at University of Minnesota-Duluth;
- Mina Mohebbi, PhD candidate in Civil and Environmental Engineering at Pennsylvania State University;
- Richard Pepper, JD candidate at UNC Chapel Hill School of Law; and
- Xenia Wirth, PhD candidate in Civil and Environmental Engineering at Georgia Institute of Technology.

Scholarship applications were reviewed by a panel of judges comprised of ACAA members representing diverse fields including engineering, law, business administration, and environmental sciences. The success of the program would have been impossible without the judges, who volunteered their time during the busy holiday season to read and score students' essays and applications. The 2014-2015 ACAAEF Scholarship Judges are:

- Ann Couwenhoven
- Dawn DeJardin
- Dale Diulus
- Veronica Foster
- Fred Gustin
- Bob Jewell
- Tim Kyper
- Jeff McNelly
- Karen Milligan
- Rafic Minkara
- Jennifer Rafferty
- Peggy Rennick
- Mark Rokoff
- Mike Schantz
- Judy Wilfrom

The ACAA Educational Foundation Scholarship Program will be an annual competition, with the 2015-2016 program kicking off in July, at which time application materials will be available on the ACAAEF website. The program aims to foster and support students' interests in CCP research and sustainable use.

The ACAA Educational Foundation is a financially self-sustaining, not-for-profit organization which promotes understanding of CCP management and use through communications and outreach initiatives that are aimed at government and industry decision-makers and the public. Foundation initiatives consist of awarding university-level scholarships, development and distribution of educational materials, financial support for research, and sponsorship of CCP forums. Visit www.acaa-usa.org/About-ACAA/Educational-Foundation for more information. ❖

Beneficiate: North America takes CCRs and converts to CCPs for beneficial applications; examples include: synthetic gypsum to fertilizer, dry scrubber material to aggregate, etc.

Keith Day – keith@bnamerica.com

Cementitious Solutions LLC provides products and services to the utility, cement, lime, and construction industries. Primary products involve the use of by-products to accomplish engineered outcomes. Their products reduce emissions from boilers and kilns and include materials used in remediation and construction to meet specific project requirements. Cementitious Solutions also provides design and consulting services related to the use of CCPs and other by-products. Cementitious Solutions is affiliated with several related companies who offer engineered fuels and permitted landfill encapsulation.

Jeff Fair – jeff@cdbspec.com

Coal Ash Recycling, LLC, owns a 5-million-ton Class F fly ash monofill located in Dunkirk, NY. The fly ash was produced at the 600 MW Dunkirk Steam Generating Station between 1964 and 1989. The monofill is located in close proximity to Lake Erie with barge, rail, and direct highway access. The ash will be processed to low carbon levels required to meet the ASTM C618 standard for use in ready mix concrete plants.

Andrew Dorn – adorn@coalashrecycling.com

Cooper, Barnette & Page is interested in landfill construction, landfill closures, and ash pond conversions. They also do heavy civil construction at numerous power plants.

Dustin McNally – dustin@cbpinc-ga.com

Fly Ash Cement Technology uses high-temperature and low-temperature ashes in the cement industry and innovates the encapsulation of ashes to eliminate heavy metals leakage to groundwater, process technology development, fabrication, and installation.

Wendell Cibulka – eng@csq1.com

Greencraft LLC does research and development in the use of low carbon concrete with high replacement of OPC with pozzolanic materials. They are interested in fly ash and would like to contribute further use of fly ash in concrete, mortar, and other applications.

Romeo Ciuperca – romeo@greencraftllc.com

Kercher Industries (KI) is an engineering and manufacturing company established in 1945. Through the use of its proprietary Lancaster Mixers and associated material processing systems, KI offers the processes and the equipment often needed to get the most beneficial use out of a particular CCR.

Ed Kercher – edk@lancasterprd.com

LiteEarth is a composite capping system comprised of EPDM and synthetic turf. The system is for final closure and land remediation of coal ash ponds and impoundments.

Charles Fleishman – cfleishman@liteearth.com

Moretrench has extensive dewatering and groundwater control experience, as well as developing groundwater cutoff structures.

Paul Schmall – pschmall@mtac.com

National Mineral Corporation is a Minneapolis-based, family-owned and -operated company dedicated to maximizing beneficial reuse opportunities for CCPs. Their main focus is serving the cement replacement market throughout the Midwest. They employ their own transportation fleet and operate a network of storage terminals to achieve 100% use for their utility partners.

Travis Collins – travis@nmcflyash.com

Nelson, Mullins, Riley & Scarborough has been involved in compliance counseling, project planning, permitting activities, and policy-making of clients whose business involves coal ash.

Karen Crawford – karen.crawford@nelsonmullins.com

Palmetto Water Solutions' water processing and fluid treatment division offers a full array of products and services, starting from the beginning of the fluid treatment process with solids screening, and ending with solids handling.

Terry Williams – terry.williams@palmettowater.com

Periodic Products Inc. developed, patented, and manufactures nontoxic polymers that bind heavy metals and rare earth elements in both soil and water. They have recently successfully applied their proprietary extraction and isolation technology to the removal of heavy metal contaminants from coal ash, and believe this technology can address several pressing issues related to the use and storage of CCPs.

David McLaren – dmclaren@periodicproducts.com

Pincelli & Associates, Inc., works closely with end users to develop new markets for CCPs. They also manage materials for producers and help identify reuse opportunities to keep CCPs out of landfills.

Beth Hamilton – bhamilton@pincellienergy.com

Republic Services is an industry leader in the U.S., nonhazardous solid waste industry with revenues in excess of \$8 billion. Across 39 states and Puerto Rico, they have a dynamic team of 30,000 employees all focused on serving their customers and providing superior recycling and waste solutions.

Bob Pickens – bpickens@republicservices.com

RJMccall, LLC, is a highly experienced utility consulting firm. The principal owner has over 30 years of experience consulting to utilities in the U.S., Canada, and the Caribbean. They develop governance and management tools for the organization, its key internal customers, and suppliers. They work with coal power producers throughout the U.S. and internationally, and can provide services to develop and implement CCP management practices and governance.

Roger McCall – roger@rjmccall.com

Silar Services a small environmental consulting business that provides services to utility clients. They are involved in ash impoundment remediation and groundwater monitoring for several utilities.

Tim Silar – tsilar@silarservices.com

Tons Per Hour, Inc., supplies filter plate presses and other related equipment for coal ash dewatering.

Paul Lessard – paul.lessard@tonspershourinc.com

2014 ACAA EDUCATIONAL FOUNDATION SCHOLARSHIP APPLICATION

By Ross Taggart

ABSTRACT

Coal fly ash disposal is a major economic and environmental burden in the United States due to its abundance and leaching of toxic metals. However, fly ash is a potential source for rare earth metals and yttrium (REY), which are critical to the automobile, energy, electronics, and defense industries. The goal of this project is to explore the feasibility of recovering strategic metals from coal fly ash. I will characterize fly ashes of varied geological origin, test scalable extraction techniques, and conduct a cost-benefit analysis comparing mining of fly ash with traditional ore deposits. I have found that Appalachian Basin coal ashes are richer in REY than Illinois Basin or Powder River Basin ashes, suggesting that ashes from power plants burning Appalachian coal should be prioritized for further study. Recovering REY from fly ash will not only provide an additional domestic source for these critical metals, but also remove leachable toxic metals from fly ash. This project will reduce the environmental impact of fly ash disposal while reusing it for a beneficial purpose.

ESSAY

Coal energy played a transformative role in the rise of modern industrial civilizations and will remain a dominant power source in the 21st century. The United States possesses abundant coal reserves and in 2013 generated 39% of its electricity from coal power plants.¹ However, coal energy is not without drawbacks. Coal combustion generates vast amounts of waste products. Each year, the United States alone generates over 50 million metric tons of fly ash, about half of which is disposed of in landfills or wet impoundments.² In addition to the huge volume of waste produced, coal ash is often enriched in toxic metals such as arsenic and selenium which may leach into groundwater and nearby surface water.

One beneficial reuse option would be “mining” coal ash for valuable strategic metals, such as gallium, germanium, and the rare earth elements. Depending on the geological origin of the coal, these metals may be present in concentrations rivaling those of

ore deposits.³ The rare earth elements are the lanthanide series but also include yttrium and scandium due to their similar qualities. They are critical materials in a myriad of technologies, including electronics, displays, guidance systems, MRIs, petroleum cracking catalysts, catalytic converters, hybrid/electric vehicles, and permanent magnets.⁴ Global demand for rare earths is outstripping production. Presently, China controls 85 percent of production, nearly half of known reserves, and the lion's share of rare earth processing and separation.⁵ The restriction of Chinese export quotas in 2010 spurred the investigation of additional mines and alternative REY sources.

Coal ash is one promising alternative source, with some ashes containing up to one weight percent REY (1000 ppmw).⁶ The rare earth content of coal ash depends heavily on the geological origin of the feed coal.⁷ Like traditional mineral deposits, fly ashes can be assayed and ranked according to the REY they contain. My current research is characterization of fly ashes from the Eastern United States to determine which are most promising for REY extraction. I have found that Appalachian Basin coal ashes contain a much higher REY content than Illinois Basin or Powder River Basin ashes. My goal is to create a database of regional fly ashes to estimate the total value of REY available from various power plants and to prioritize them for extraction.

I use hydrofluoric (HF) acid digestion to determine the total concentrations of metals of interest in the fly ash, including REY, trace metals, and major cations. Based on the recovery of elements in the National Institute of Standards and Technology (NIST) coal fly ash SRM 1633c, I have concluded that HF digestion dissolves the ash samples almost completely and provides a close estimate of total metal concentrations. I also use sodium peroxide sintering, the U.S. Geological Survey (USGS) method for analyzing REY in coal ash, for method validation.⁸

1 U.S. Energy Information Agency (2014), pg. 95

2 ACAA (2013)

3 Mayfield and Lewis (2012), Seredin and Dai (2012)

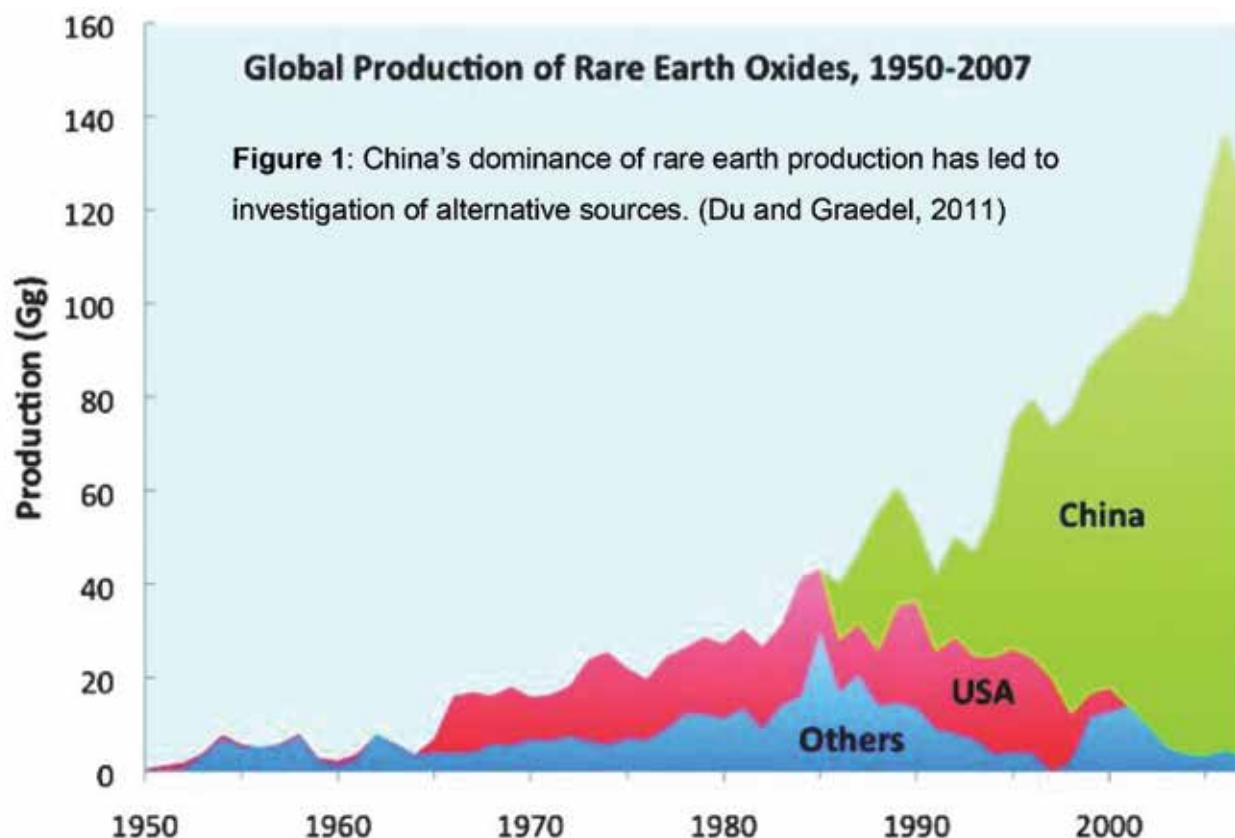
4 U.S. Department of Energy (2011), U.S. Environmental Protection Agency (2012)

5 U.S. Environmental Protection Agency (2012)

6 Seredin (1996)

7 Mardon and Hower (2004)

8 Meier et al. (1996), Meier and Slowik



Finally, I use nitric acid digestions to estimate the fraction of REY that is reasonably extracted at an industrial scale (HF is too hazardous for large-scale use). After digestion, I measure metal concentrations using inductively-coupled plasma mass spectrometry (ICP-MS). In the next phase of my research, I will test extraction methods so that fly ash can be incorporated into the existing rare earth purification supply chain. Based on my extraction efficiencies, I will estimate the concentrations and metal prices necessary for REY recovery from fly ash to be economically feasible.

This research will directly benefit the industry, environment, and security of the United States. First, REY recovery from fly ash will benefit utilities by making fly ash more saleable. The energy, electronics, automobile, and defense industries will also benefit from additional REY production. Second, this research will benefit the environment by using CCPs as a source of raw materials crucial to many clean energy technologies. Using fly ash as an REY source will mitigate the need for new rare earth mines, reducing the environmental impact of metal production. Recovering the strategic metals will also remove many toxic metals from the ash, making its eventual disposal or reuse safer. Finally, fly ash mining would contribute to a stable domestic supply of REY. REY are critical materials to the defense industry and economy of the United States, yet most of global REY mining and purification takes place in China. Fly ash could become an additional domestic REY source to supplement Molycorp's Mountain Pass mine in California (reopened in 2012). The clear benefits to the industries, environment, and security of the United States make this research well worth funding. By viewing coal

combustion products as a resource rather than refuse, we can address rising rare earth demand while managing CCPs more sustainably. ❖

REFERENCES

1. ACAA. (2013). *2012 Coal Combustion Product (CCP) Production & Use Survey Report*. Aurora, CO: American Coal Ash Association. Retrieved from: <http://www.acaa-usa.org/Portals/9/Files/PDFs/revisedFINAL2012CCPSurveyReport.pdf>.
2. Mardon, S.M., Hower, J.C., 2004. Impact of coal properties on coal combustion byproduct quality: examples from a Kentucky power plant. *Int. J. Coal Geol.* 59, 153–169.
3. Mayfield, David B., Lewis, Ari S., *Environmental Review of Coal Ash as a Resource for Rare Earth and Strategic Elements*. 2013 World of Coal Ash (WOCA) Conference. Lexington, KY: April 22–25, 2013.
4. Meier, A.L., Lichte, F.E., Briggs, P.H., Bullock, J.L., 1996. Analysis of coal ash by inductively coupled plasma emission spectroscopy and inductively coupled plasma –mass spectroscopy. In: Arbogast, B.F. (Ed.), *Analytical Methods Manual for the Mineral Resource Surveys Program*, US Geological Survey U.S. Geological Survey Open File, 96-525, pp. 109–125.
5. Meier, Allen L., Slowik, Tara, *Rare earth elements by inductively coupled plasma-mass spectrometry. Analytical methods for chemical analysis of geologic and other materials*, U.S. Geological Survey. U.S. Geological Survey Open File Report 02-223-K.
6. Seredin, V.V., 1996. REE-bearing coals from Russian Far East deposits. *Int. J. Coal Geol.* 30, 101–129.
7. Seredin, V.V., Dai, S., 2012. Coal deposits as potential alternative sources for lanthanides and yttrium. *International Journal of Coal Geology* 94, 67–93.
8. U.S. Department of Energy: *Critical Materials Strategy*, 2011. <http://energy.gov/sites/prod/files/DOE_CMS2011_Final_Full.pdf>.
9. U.S. Energy Information Agency, *Monthly Energy Review* October 2014. Office of Energy Statistics, DOE/EIA-0035(2014/10).
10. U.S. Environmental Protection Agency, *Rare Earth Elements: A Review of Production, Processing, Recycling, and Associated Environmental Issues*, Office of Research and Development, EPA/600/R-12/572, 2012, 135p.



MINERAL RESOURCE TECHNOLOGIES, INC.



- CCP Marketing
- On-site Operations
 - Ash Handling and Loading
 - System Operations and Maintenance
 - Landfill Management
- Internal Ready Mix Demand
- Internal Consumption for Cement Production
- National Terminal Network
- Dedicated Logistics Department
- Cement and Concrete Reference Laboratory (CCRL)

1-800-99-CEMEX

www.cemexusa.com

mrt-bd@cemex.com

COAL COMBUSTION PRODUCT UTILIZATION IS LIMITED BY LACK OF RESEARCH AND LEGISLATION

By Brigitte Brown, Research Assistant, University of Wisconsin-Madison

SUMMARY

Disposal of CCPs is costly, land intensive, and may impact the environment. The disadvantages associated with disposal have led to initiatives to recycle coal combustion products (CCPs); however, CCP reuse currently only accounts for 37% of CCPs produced annually. Much of the reuse occurs in encapsulated applications (e.g. concrete, wallboard). Reuse in unencapsulated applications, such as stabilizing road subgrade or base course, has the potential to dramatically increase CCP reuse. Perceived risk of heavy metals leaching often prevents CCPs from being employed in unencapsulated conditions. Furthermore, recent events and survey results have shown that legislation greatly controls those possibilities. Research documenting acceptable uses of CCPs is required to pass such legislation, and is being solicited by the EPA. Increasing reuse can help the environment and economy.

ESSAY

The United States obtains 37% of its electricity from burning coal, resulting in the annual production of 120 million tons of coal combustion products (CCPs), i.e. fly ash, bottom ash, boiler slag, etc. (U.S. DOE, 2012). Fly ash comprises over half (52%) of CCPs produced (U.S. DOE, 2012), which is enough fly ash to fill standard hopper rail cars from New York City to Seattle and back. Disposal of CCPs is costly and land intensive, and suspended ash and heavy metals can have environmental impacts if disposal failure occurs. To avoid disposal, initiatives to recycle CCPs were created, which have annually reduced greenhouse gas emissions by 11 million tons, fossil fuel consumption by 162 trillion British thermal units, and

water consumption by 32 billion gallons, amounting to over \$11 billion total economic benefits (Fig. 1) (ACC, 2014; Carpenter et al. 2007; Lee et al. 2010, 2011, 2013). Because CCP reuse currently only accounts for 37% of CCPs produced annually, there is great opportunity for increased beneficial reuse (U.S. DOE, 2012).

Much of the reuse occurs in encapsulated applications (e.g. concrete, wallboard). Reuse in unencapsulated applications, such as stabilizing road subgrade or base course, has the potential to dramatically increase CCP reuse. Mechanical properties of CCPs, namely fly ash and bottom ash, increase strength and stiffness and reduce swelling in unencapsulated roadway applications while decreasing or eliminating the amount of other stabilizing materials required. This improves the service life of roads, reduces GHG emissions, and reduces energy and water consumption, making CCP-stabilized soils a less expensive and more sustainable alternative than virgin aggregate or

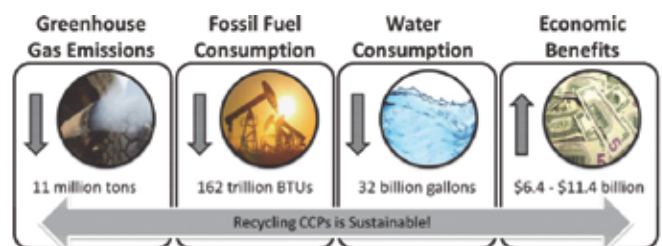


Fig. 1 Benefits of CCP Recycling Initiatives
(Adapted from ACC, 2014; Carpenter et al. 2007; Lee et al. 2010, 2011, 2013)

cement- stabilized soil (Bin-Shafique et al. 2004; Edil et al. 2006; Carpenter et al. 2007; Li et al. 2008, 2009; Lee et al. 2010, 2011, 2013; Tastan et al. 2011; Ebrahimi et al. 2012; Camargo et al. 2013; ACC 2014; Soleimanbeigi et al. 2014). However, perceived risk of metal leaching often prevents CCPs from being employed in unencapsulated conditions. Furthermore, other reuse applications no doubt exist, with their potential not yet realized. In fact, the EPA is focusing on gathering more information on the efficacy of CCP use in unencapsulated applications (US EPA Office of Inspector General, 2011).

A recent survey of state Departments of Transportation about their use of CCPs in roadway applications found that 46 states use fly ash, four use bottom ash, and two use boiler slag (Brown, 2014). When only unencapsulated uses are considered, only 18 states use fly ash and two use bottom ash. The potential for additional CCP reuse is made even clearer when the small proportions of fly ash used in unencapsulated applications are considered (Fig. 2). For example, out of 46 states using, 2 states use >90% of fly ash in unencapsulated conditions, 1 state uses 50% of fly ash in unencapsulated conditions, 28 states use <10% of fly ash in unencapsulated conditions, and 5 states use an unknown percent of fly ash in unencapsulated conditions. That amounts to 61% of states using a low percentage of fly ash in unencapsulated conditions, with an additional 11% of states reporting an unknown percentage of fly ash.

Although economics largely controls construction, legislation is one of the biggest players in controlling or alternatively motivating CCP use. The DOT survey found that the chance of CCPs being used in unencapsulated applications increased in states where fly ash authorization is explicitly included in legislation or regulation: 50% of states reporting unencapsulated fly ash use had legislation authorizing fly ash use, 39% had legislation authorizing fly ash with some sort of permission, and 75% of states reporting unencapsulated bottom ash use had no mention in legislation (Brown, 2014). Wisconsin DOT (WisDOT) is an excellent example. As part of a beneficial use of industrial byproducts initiative, Wisconsin has adopted fly ash-stabilization of soft subgrades as a preferred technology through NR 538 of the WI Administrative Code because of substantial reductions in construction time, which is important in regions that have a short construction season. Fly ash use is allowed in different soil and pavement applications based on ASTM C618 criteria for coal fly ash (NR 538). This legislation allows for the streamlined approval of fly ash. As a result, WisDOT has been able to take advantage of the material property enhancements and economic benefits of using fly ash, so much so that all fly ash meeting the ASTM criteria is used in Wisconsin (McMullen, 2014). The demand for fly ash is so high that WisDOT is actively seeking out-of-state sources within an economical shipping radius (McMullen, 2014). This demand was created by having legislation that facilitated safe reuse of CCPs.

There is much more recycling of CCPs that could be done in the United States, and recent events and survey results have shown that legislation greatly controls those possibilities. Research documenting acceptable uses of CCPs is required to

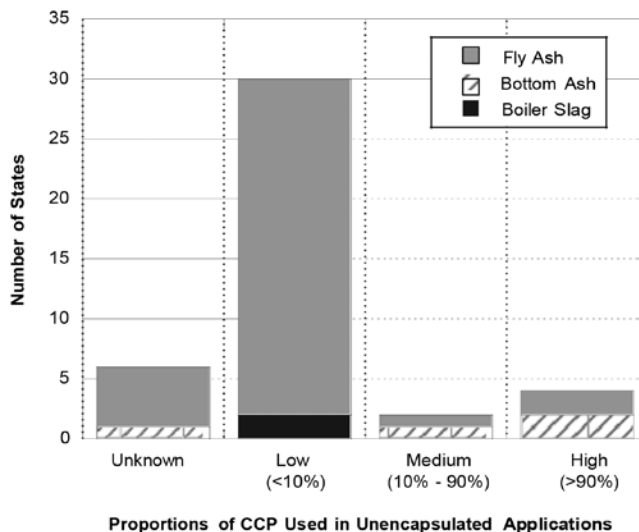


Fig. 2 Number of States Using CCPs and Number of States Using CCPs in Different Unencapsulated Proportions (Brown, 2014)

pass such legislation, and is being solicited by the EPA. The Proposed rule for CCP disposal will be finalized by the end of the year; now is the time to take action. Beneficial reuse can help the environment by being used in non-risky applications, by reducing the amount of virgin materials that would have otherwise been used, and by not filling up landfills; and can help the economy by reducing construction costs, construction times, and disposal costs, to name a few. I challenge all workers in the coal ash field and surrounding industries to do whatever they can to help bring together the expertise and research needed to increase CCP reuse in the United States. The results of many small projects can help shape the future. ♦

SOURCES

- American Coal Council (ACC). (2014). Coal Ash ~ Coal Combustion Products (CCPs). Retrieved October 10, 2014, from <http://www.americancoalcouncil.org/?page=ccp>
- Beneficial Use of Industrial Byproducts, Chapter NR 538 § 238.06 - 538.08, 538.14 (1998).
- Bin-Shafique, S., Edil, T., and Benson, C. (2004). Incorporating a Fly Ash Stabilized Layer into Pavement Design: Case Study, *Geotechnical Engineering*, 157(4), 239-249.
- Brown, Brigitte L. (2014, October 15). *Leaching from Roadways Constructed with Unencapsulated CCPs: Data Assessment and Synthesis (Interim Report)*. Rep. N.p.
- Carpenter, A., Gardner, K., Fopiano, J., Benson, C., and Edil, T. (2007). Life cycle based risk assessment of recycled materials in roadway construction. *Waste management* (New York, N.Y.), 27(10), 1458-1464. doi:10.1016/j.wasman.2007.03.007.
- Camargo, F., Edil, T., and Benson, C. (2013). Strength and Stiffness of Recycled Pavement Materials Stabilized with Fly Ash: A Laboratory Study, *Road Materials and Pavement Design*, 14(2) 1-13.
- Ebrahimi, A., Kootstra, B., Edil, T., and Benson, C. (2012). Practical Approach for Designing Flexible Pavements Using Recycled Roadway Materials as Base Course, *Road Materials and Pavement Design*, 13(3), 1-18.
- T. B. Edil, H. A. Acosta, and C. H. Benson, "Stabilizing Soft Fine-Grained Soils with Fly Ash," *Journal of Materials in Civil Engineering*, American Society of Civil Engineers, Vol. 18, No. 2, 2006, pp. 283-294.
- EPA. (2001, March 12). EPA to Hold Public Meeting Regarding the Martin County Coal Corporation Slurry Spill. Retrieved September 24, 2014, from <http://yosemite.epa.gov/opa/admpress.nsf/e51aa292bac25b0b85257359003d925f/e646c46e2b4bb13d852573450070aae5!OpenDocument>

EPA. (2009, January 6). Summary of Past and Current EPA Response Activities Regarding The TVA Kingston Coal Ash Spill. Retrieved September 25, 2014, from <http://www.epa.gov/region04/kingston/summary.html>

EPA. (2010, June 21). Hazardous and Solid Waste Management System: Identification and Listing of Special Wastes; Disposal of Coal Combustion Residuals from Electric Utilities. Retrieved October 10, 2014, from <http://www.regulations.gov/#!documentDetail;D=EPA-HQ-RCRA-2009-0640-0352>

Lee, J. C., Edil, T. B., Tinjum, J. M., & Benson, C. H. (2010). Quantitative assessment of environmental and economic benefits of using recycled construction materials in highway construction. *Transportation Research Board*, 2158(-1), 1–11. doi: 10.3141/2158-17.

Lee, J. C., Edil, T. B., Benson, C. H., & Tinjum, J. M. (2011). Evaluation of Variables Affecting Sustainable Highway Design With BE2ST-in-Highways System. *Transportation Research Record: Journal of the Transportation Research Board*, 2233(-1), 178–186. doi: 10.3141/2233-21.

Lee, J., Edil, T. B., Asce, D. M., Benson, C. H., Asce, F., Tinjum, J. M., & Asce, M. (2013). Building Environmentally and Economically Sustainable Transportation Infrastructure: Green Highway Rating System, 1–10. doi: 10.1061/ (ASCE) CO.1943-7862.0000742.

Li, L., Benson, C., Edil, T., and Hatipoglu, B. (2008). Sustainable Construction Case History: Fly Ash Stabilization of Recycled Asphalt Pavement Material, *Geotechnical and Geological Engineering*, 26, 177–187.

Li, L., Edil, T. B., & Benson, C. H. (2009). Mechanical Performance of Pavement Geomaterials Stabilized with Fly Ash in Field Applications. *Coal Combustion and Gasification Products*, 1(1), 43–49. doi:10.4177/CCGP-D-09-00018.1.

McMullen, Kevin (President of Wisconsin Concrete Pavement Association), Personal Communication, September 30, 2014.

Soleimanbeigi, Ali, Edil, T.B. (August 26, 2014). Settlement of Highway Embankments Constructed with Recycled Materials. *Mid-Continent Transportation Symposium*. Madison Concourse Hotel, Madison.

Tastan, E. O., Edil, T. B., Benson, C. H., & Aydilek, A. H. (2011). Stabilization of Organic Soils with Fly Ash. *Journal of Geotechnical and Geoenvironmental Engineering*, 137(9), 819–833. doi: 10.1061/ (ASCE) GT.1943-5606.0000502.

U.S. Department of Energy, the U.S. Energy Information Administration (2012). *Annual Environmental Information, Schedule 8. Part A. Annual Byproduct Disposition, 2013 Final Release*. [Data set]. Retrieved from <http://www.eia.gov/electricity/data/eia923/> >

U.S. EPA Office of Inspector General. (2011, March 23). EPA Promoted the Use of Coal Ash Products With Incomplete Risk Information (Report No. 11-P-0173). Retrieved September 17, 2014, from <http://www.epa.gov/oig/reports/2011/20110323-11-P-0173.pdf>

RESEARCH PART OF A LARGER SEPARATELY-FUNDED PROJECT

Information was presented from a separately-funded project, called the CCP Roadway Use Database Project. This information is cited as Brown, 2014.

Scope:

I am currently compiling and analyzing a database consisting of leachate information from more than 10 large-scale pan lysimeters that have been installed beneath roadways constructed with unencapsulated fly ash and bottom ash in Wisconsin and Minnesota. These lysimeters have been capturing the water emanating from the bottom of the pavement profile for analysis of volumetric flow rate and trace element concentrations from roadways constructed with CCPs for more than a decade. Data collected from these lysimeters constitutes the largest and longest data record on leaching from roadways in the world, and is held by the Recycled Materials Resource Center (RMRC) at the University of Wisconsin- Madison.

This study compares metal concentrations from water collected from roadways constructed with fly ash and in unencapsulated conditions to federal and state drinking and surface water limits (direct assessment). Leached elements were categorized as “no risk,” “no additional risk,” or “requires further evaluation.” Elements requiring further evaluation will be analyzed with flow and transport models (e.g., WiscLEACH) to conduct parametric model simulations to evaluate probable trace element concentrations at environmental receptor points (indirect assessment). The results of this study are intended to provide a conservative risk assessment associated with using CCPs in unencapsulated applications in roadways that will influence future projects and industry policy by ensuring sustainability and economic benefits are realized without adversely affecting the environment.

Besides containing RMRC data, the database will also contain leachate data collected from DOTs across the country. This data is being obtained through a survey distributed to every state in the US in order to determine how CCPs in roadway applications are used nationally. Leachate data from national sources will undergo the same comparisons to water standards and same parametric model simulations to evaluate risk. Based on my findings, recommendations will be made for using CCPs in unencapsulated roadway applications. The final report detailing the database, risk assessment findings, and recommendations is expected to be published by EPRI by May of 2015.

Funding Source: Electrical Power Research Institute (EPRI)

Funding Amount: \$141,085

Major Milestones and Schedule:

1. Nationwide Review of Data Sources – September 2014
 - a. Create CCP Roadway Use Survey
 - b. Disperse CCP Roadway Use Survey
 - c. Obtain all CCP Roadway Use Survey Responses
 - d. Compile and Synthesize Survey Results
2. Compilation and Synthesis of Recycled Material Resource Center Field Data – to be completed by September 2014
3. Interim Report – September 15, 2014
4. Direct Assessment of Leaching Data – December 2014
5. Indirect Assessment of Leaching Data – December 2014
6. Recommendations for Using CCPs in Unencapsulated Roadway Applications – May 2015
7. Reporting – May 2015

BEST PRACTICE

**SMART LONG-TERM
SOLUTIONS**

SUSTAINABLE



STAR[®] Technology transforms 100% of coal ash into usable products

For almost 40 years SEFA has proven to be a powerful partner in discovering the best solutions for coal ash utilization.
Please contact us to consult with our highly qualified and experienced team of experts.

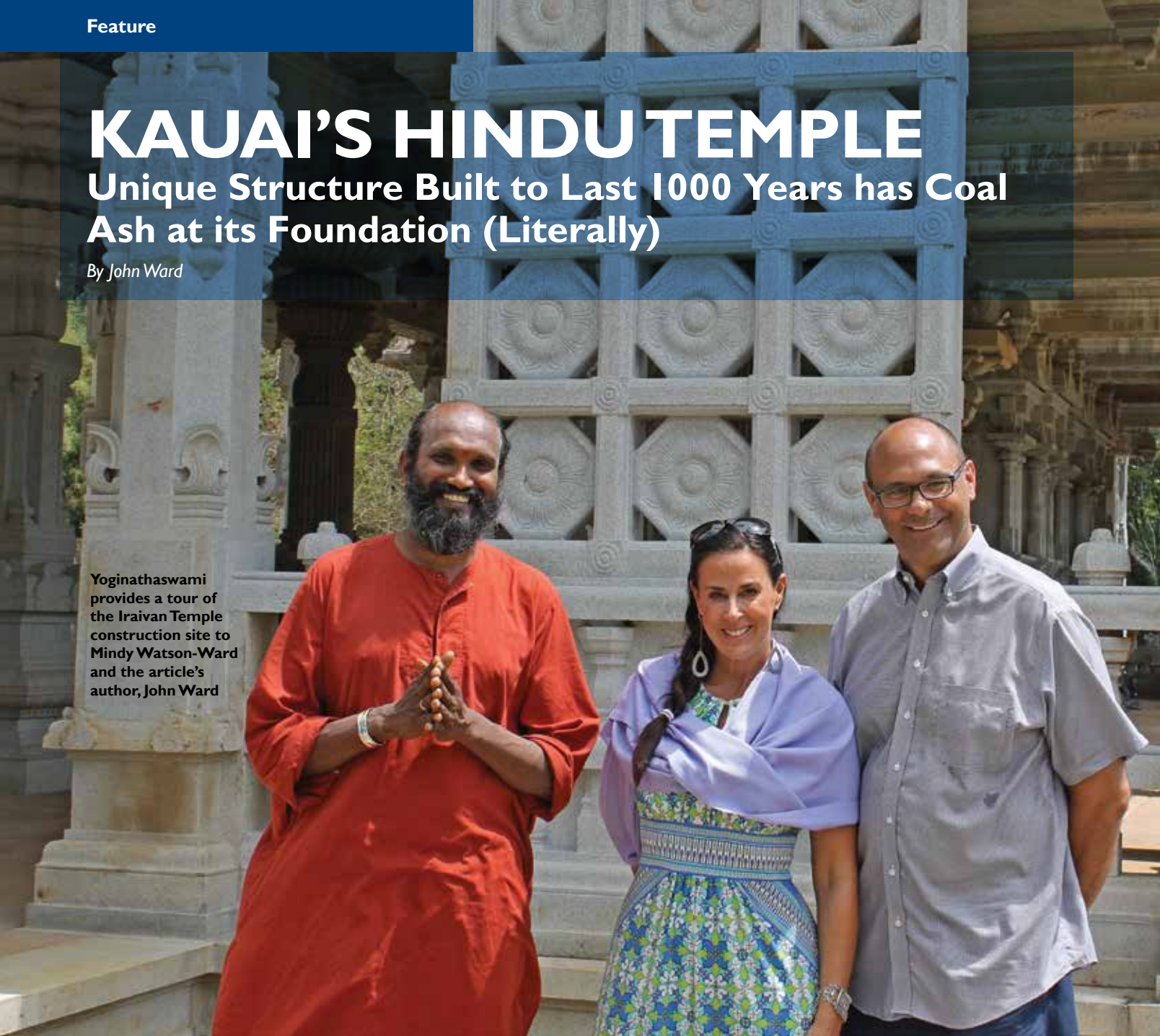
www.sefagroup.com / 800-884-7332

KAUAI'S HINDU TEMPLE

Unique Structure Built to Last 1000 Years has Coal Ash at its Foundation (Literally)

By John Ward

Yoginathaswami provides a tour of the Iraivan Temple construction site to Mindy Watson-Ward and the article's author, John Ward



Nestled in a verdant jungle on the garden island of Kauai, HI, construction workers patiently assemble a structure reminiscent of an ancient era that is designed to last until our own generation fades into antiquity. At the foundation of this project, quite literally, lies fly ash.

The San Marga Iraivan Temple is located on the grounds of Kauai's Hindu Monastery, a 363-acre patch of paradise that is home to Satguru Bodhinatha Veylanswami and his order of 21 swamis, yogis, and sadhakas from six nations. The monastery serves as headquarters and

theological seminary of Saiva Siddhanta Church and is home to the Himalayan Academy, *Hinduism Today* magazine, and the Hindu Heritage Endowment.

Kauai's Hindu Monastery was Founded in 1970 by Satguru Sivaya Subramuniyaswami (1927-2001), who was affectionately (and fortunately for Western tongues) known as "Gurudeva." Early in the morning on February 15, 1975, Gurudeva had a vision in which he saw Lord Siva seated on a large boulder that was later discovered on the then -overgrown monastery property. A series of subsequent mystical visions revealed

a plan for a temple to be built there and even the locations of some materials enshrined in the temple. The temple's name "Iraivan" is an ancient Tamil word for God meaning "He who is worshiped."

Mystical visions do not always mesh well with local geology, however. The site chosen for the temple was comprised of soft clay and the island did not have equipment necessary to characterize the soils deeper underground. Furthermore, the temple itself was to be constructed of heavy granite stone—3000 blocks of it, hand-carved in Bangalore, India, and then assembled on Kauai.



The Iraivan Temple rests on a 4 ft thick, unreinforced, high-volume fly ash concrete mat that remains uncracked after the first 15 years



“...materials like fly ash and slag are complementary to portland cement, because without them, it would not be possible to build durable and sustainable concrete structures.”



Hand-carved stone elements of the temple include pillars shaped like lions that contain freely rotatable (but unremovable) balls in their mouths



“Mystical visions do not always mesh well with local geology...”



The finished temple is comprised of 3000 granite blocks weighing more than 2000 tons

Then there was the issue of design life. The temple is designed to last 1000 years, ruling out the use of steel-reinforced concrete for the foundation. (In fact, nothing that can rust is used anywhere in the temple structure.) Designing an unreinforced concrete foundation resting on potentially unstable soils to support 2000 tons of stone for 10 centuries presented a design challenge.

Enter P. Kumar Mehta and his colleague, Wilbert S. Langley. Mehta, Professor Emeritus of Civil Engineering at the University of California, Berkeley, is

one of the pioneers of coal fly ash use in concrete. Langley, at the time President of W.S. Langley Concrete & Materials Technology Inc., was an expert in high-performance concrete and high-volume fly ash mixture proportioning.

Drawing on his knowledge of Roman pozzolanic concretes that remain in good condition after 2000 years, Mehta proposed a fly ash-based concrete mixture to be employed in a monolith mat foundation. Fly ash would be imported from the United States mainland at a cost of approximately \$200 per ton in 1999.

Design of the mat foundation had to be modified to accommodate ready mixed concrete production capacity available on the island. Only one ready mixed concrete plant was available. The plant had never used fly ash and it could furnish only 500 yd³ of concrete in an 8- to 10-hour period. So the foundation—originally designed as a single 4 ft thick monolith—was altered to be placed in two courses as concrete slabs each measuring 117 x 56 x 2 ft thick.

A high volume fly ash mixture design was developed incorporating 240 lb/yd³

of Class F fly ash with 180 lb/yd³ of portland cement. The site was prepared by heavily compacting the clay soils and adding a 3.28 ft thick base course of well-compacted gravel. Placement of concrete began at 7:00 a.m. on August 21, 1999, when the first concrete truck arrived to be greeted by “sounds from a Balinese gong and Sanskrit chants from a fire ceremony, saffron-robed monks and a host of onlookers.” All 54 trucks arriving to place a total of 500 yd³ of concrete that day were greeted the same way.

Details of the concrete mixture design and meticulous care taken during the curing process are recounted in a fascinating article by Mehta and Langley in the July 2000 edition of *Concrete International*. Published just over 9 months following completion of the foundation placement, the article notes that “The slabs look beautiful; careful examination of the exposed surface has shown no evidence of any cracking.” Fifteen years later, the condition of the concrete is the same.

The temple itself is now nearly finished. Stone carving began in India in 1990 and assembly began in Kauai in 2001. The structure was designed by renowned Indian temple architect V. Ganapati

Stapathi following Vastu architecture principles aimed at creating a space that will elevate the vibration of the individual to resonate with the vibration of the built space, which in turn is in tune with universal space. The temple is defined in multiples and fractions of one unit, 11 feet and 7-1/4 in. Pillars through the temple are spaced and structured to serve as energy points for the building and Iraivan Temple is completely free of electricity for mystical reasons.

A number of unique design features are included in the temple. Two sets of “musical pillars” resonate precise musical tones when struck with a mallet. Six stone lions are carved into the pillars, each of which contains a stone ball freely rotatable in its mouth but not removable. The temple features a large stone bell and 10 ft long stone chains with loose links. The temple’s main murti (a worshipful object) is a rare spathika sivalinga, a pointed, six-faced 700-pound clear quartz crystal found in Arkansas after visions by Gurudeva and a local Kauai shopkeeper.

For fly ash beneficial use aficionados, the conclusion from the *Concrete International* article about this remarkable project still resonates today: “Many in the concrete

construction industry still suffer from an old myth that fly ash is a cheap substitute for portland cement. This simply is not true with modern fly ashes if one pays proper attention to materials, mixture proportions, and the curing of concrete. Without fly ash, the workability and durability of concrete in the structure described in this article could not have been achieved. If fly ash was a cheap substitute or only a supplement to cement, why would someone pay three times as much for it to replace cement? This indeed is the most convincing argument that materials like fly ash and slag are complementary to portland cement, because without them, it would not be possible to build durable and sustainable concrete structures.”

If you go (and you really should!), tours of the monastery and temple grounds are available 1 day each week. The schedule changes frequently, so call ahead. More information can be found on the Himalayan Academy website: www.himalayanacademy.com/monastery ♦

About the Author: John Ward serves as chairman of the American Coal Ash Association Government Relations Committee.



these companies and individuals who contributed financially to a recent project to develop model coal combustion products Safety Data Sheets and guidance for using them.

Ameren Missouri
Boral Material Technologies
Headwaters Resources
Wisconsin Public Service
American Electric Power
Charah, Inc.
Great River Energy
MRT Cemex
Muscatine Power & Water
Talen Energy
Southern Company
Salt River Material Group
Separation Technologies

The Safety Data Sheets materials are available on ACAA's website.
www.acaa-usa.org

COAL ASH UNDERGROUND MINE STABILIZATION

Kansas City's Briarcliff Project Sets Standard for Enabling Development over Historic Mine Sites

Casual visitors to Kansas City, MO, likely never realize that the city and its surroundings have an unseen feature below the surface—about 100 ft below the surface in many areas. Decades of underground limestone mining have created hundreds of miles of empty mine workings that prevent development of the land above.

Some entrepreneurial companies have begun using the mine workings for light commercial activities such as storage and warehousing. But those applications can only use a fraction of the space that has been mined. Meanwhile, thousands of surface acres are rendered off-limits for residential and other development because, over time, portions of the mine workings can collapse and cause subsidence at the surface.

ACAA member USC Technologies developed an innovative solution using coal ash to stabilize underground mine workings. The company is now wrapping up 25 years of activity at its flagship Briarcliff

project, where more than \$460 million of commercial and residential development has occurred on a site that was previously unusable.

Briarcliff is located about 5 miles north of downtown Kansas City along a ridge with a panoramic view of the city skyline. The area under 169 Highway and the Briarcliff commercial area was mined for limestone starting in the 1940s and ending in the 1960s. The Bethany Falls limestone that was mined was used for aggregate in construction to make concrete, asphalt, and cement.

The underground mining method used in the Briarcliff area is called room and pillar mining. Limestone to a thickness of 11 to 14 ft was extracted around pillars that were left to provide the support for 100 to 130 ft of rock and earth above. But over time, shale in the rock above the voids deteriorated and in some cases collapsed. Surface subsidence of a few feet to several feet are eventually possible.

To stabilize the mine and prevent subsidence, USC Technologies developed

techniques for completely filling the voids with coal fly ash. Crews would enter the mine and build dikes to section off portions of the mine workings. Holes would then be drilled from the surface into the sectioned-off areas and a fly ash slurry mixture would be pumped in. The superior flowability of fly ash allowed it to completely fill the voids, while the cementitious nature of the ash produced material with strength sufficient to prevent subsidence.

All of the site work and use of fly ash for stabilization purposes was permitted by the Missouri Department of Natural Resources Water Quality branch, which also required monitoring of the groundwater. Monitoring data shows no indication of elevated metals for the operation, which is consistent with the naturally low levels of metals in the coals from which the ash was derived. In addition, because the fly ash used is self-cementing, the fly ash locked any foreign particles or metals within it as it hardened into a solid, rock-like mass. Furthermore, the bedrock strata of the



Subsidence known as “dome-out” inside mine workings prior to stabilization



Fly ash slurry flows into mine void through borehole from surface above



Worker crouches on solidified fly ash slurry in partially filled mine void



Layers of fly ash slurry fill are seen after retaining berm is removed



Kansas City skyline is seen behind 123-room hotel constructed over stabilized mine workings

mine are very restrictive to groundwater flow. The bedrock acts as a second line of protection with impermeability equal to or better than compacted soil liners in many landfills.

Since initiating the project in 1990, a total of 80 acres of mine workings have been stabilized, enabling the development of 400 acres overall. Development at the site includes:

- Two full diamond highway interchanges built to access the area.
- Commercial Square Footage: Just over 630,000 ft²: 550,000 ft² office, 90,000 ft² retail.
- Hospitality Space: 123-room Courtyard Hotel with 7200 ft² of meeting/event space.
- Single-Family Homes: 310 (BC West-156; Villas-87; Ravello-56; Briarcliff Hills-11).
- Apartment Units: 723 (Province-120; City Apts.-263; The Landing-340).
- Senior Living: 168 units, 40 of which are assisted living.

Approximately 74 acres remain available for future development and developers are currently completing the most recent project, a 340-unit luxury apartment complex.

The USC Technologies Briarcliff project is a prime example of safely and beneficially using large volumes of coal ash that otherwise would likely be disposed.



High-end retail shops are part of Briarcliff mixed-use development



Large commercial office building development also occurred following stabilization

COMPARATIVE LIFE CYCLE ASSESSMENT OF TRADITIONAL CONCRETE AND CONCRETE MADE WITH FLY ASH

By Christa Heavey, Angelica Hernandez, Shea Hughes, and Lindsay Willman

INTRODUCTION

In 2009, cement manufacturing was the fourth-largest source of carbon dioxide emissions in the United States.¹ On average, about 1,850 pounds of CO₂ are emitted for every ton of cement produced.² Depending on the end-use and performance requirements, concrete contains between 7% and 15% cement by weight. According to the National Ready Mixed Concrete Association, current construction standards and specifications require higher quantities of Portland cement than are actually needed. Additionally, there are limits on the use of supplementary cementitious materials (SCMs) that can be used to replace a portion of the cement used in concrete. Using SCMs to replace cement has been shown to reduce the environmental impact of concrete by decreasing mining requirements and raw material processing for the manufacturing of Portland cement. SCMs have also been shown to increase the long-term strength and durability of concrete.³

One common SCM is fly ash, which is one of the main byproducts of the coal combustion process. When coal is burned at a power plant to generate electricity, the non-combustible minerals in coal form bottom ash and fly ash. The bottom ash falls to the bottom of the boiler and the fly ash is carried off with the flue gases and can be collected for use. If the fly ash is not used, it is disposed of in landfills. When fly ash is used as a partial replacement of Portland cement, replacement rates are usually between 20% and 30%, although they can be higher.⁴ Headwaters Resources is America's leading supplier of coal combustion products to the concrete industry, specifically fly ash. They provide these products to the construction industry with the goal of improving the performance of concrete products while making use of products that would otherwise be discarded.

This report documents the Life Cycle Assessment (LCA) performed for Headwaters Resources. This study analyzed the environmental impacts associated with concrete pavement made with fly ash as a partial replacement of Portland cement. This included an inventory analysis, impact assessment, life-cycle cost analysis, and sensitivity analysis. These results were

then compared to those for traditional concrete pavement made exclusively with Portland cement.

GOAL AND SCOPE

The goal of this study was to perform a comparative LCA of concrete pavements made with fly ash as a partial replacement of Portland cement versus traditional concrete made exclusively with Portland cement. To limit the number of potential data sources, the analysis was limited to highway pavement in Palo Alto, California. In order to capture life cycle impacts, the functional unit for this LCA was a one mile stretch of highway pavement for a time frame of 50 years.

This study considered the entire life cycle of concrete, from material acquisition through disposal and recycling. The material acquisition and manufacturing stages were the most important for this analysis since the traditional concrete pavement requires more materials and material processing. For the construction of the highway pavement, only the concrete was considered. Construction costs and other material requirements for the highway structure, such as the base and steel bars, were assumed to be the same for both products and were not included in the analysis. Additionally, this LCA also assumed the use phase was the same for both products. Differences in highway pavement surface degradation and the resulting emissions from vehicles were not considered. In the initial analysis, the maintenance periods and requirements were considered the same for both types of pavement. However, the sensitivity analysis includes results for various maintenance schedules, including the potential for less maintenance for the pavement made with fly ash to account for increased durability. For the end of life phase, recycling and landfill disposal percentages and the resulting transportation emissions and costs for these were also assumed to be the same for both products.

INVENTORY ASSESSMENT AND RESULTS

The principal data sources for this analysis are SimaPro databases and Headwaters Resources, Inc. The analysis primarily

uses company specific data, and when not available local industry averages were used for highway construction in Palo Alto, California. A summary of data inputs and assumptions for both systems, traditional Portland cement concrete and concrete with 25% replacement of Portland cement with fly ash, is provided in more detail in the following sections.

The general concrete mix design used industry standard volumetric percentages: 40% coarse aggregates, 26% fine aggregates, 14% total cementitious material, 14% water, and 6% entrained air. The highway design consists of a bi-directional two-lane highway with a thickness of 10 inches and a length of 1 mile. The highway width included standard 12-foot lanes, with a total shoulder width of 15 foot and a median width of 18 ft.⁴ The total volume of concrete required for the stretch of highway in the analysis was 13,200 cubic yards. This set volume of concrete represents the functional unit metric and is used as a basis for all life cycle calculations.

The coarse aggregates used in concrete are generally gravel and crushed stone between the sizes of 9.5 and 37.5 millimeters. This analysis assumes gravel as the coarse aggregate input into SimaPro, with 0.8% moisture content, and a specific gravity of 2.63.⁵ To find the total mass of coarse aggregate needed in one cubic yard of concrete, the absolute density was multiplied by 40%, giving 1760 pounds of coarse aggregate per cubic yard of concrete. The coarse aggregates were transported from Sunol, CA 29 miles by truck to Palo Alto.

The fine aggregates used are typically sand or pulverized stone that can pass through a 9.5-millimeter sieve. This analysis assumes sand as the fine aggregate input into SimaPro. A moisture content of 3.5% and a specific gravity of 2.60 was assumed.⁵ The absolute density was multiplied by 26% to give 1100 pounds of fine aggregates per cubic yard of concrete. The fine aggregates are also transported by truck from Sunol to Palo Alto.

Portland cement is a carefully balanced chemical mixture of calcium, aluminum, iron, and small amounts of other elements. In physical form, the raw materials in Portland cement production include mined limestone, shale, clay, slate, silica sand, iron ore, and gypsum. In SimaPro, the Portland cement input was used, which includes averages for all of the upstream processes associated with Portland cement production. The first step in this process is the initial grinding and blending of limestone and clay. After the raw materials are thoroughly mixed, they are fed into the kiln for firing, where the gases are driven from the raw materials and their physical and chemical properties are altered. This step is referred to as calcination, and it is where the vast majority of the carbon dioxide is released. The product that is recovered after baking in the kiln is called clinker, which is then cooled and stored. During the final step of Portland cement production, the clinker is mixed with gypsum and sent through multiple grinders where it emerges as a finely pulverized powder.

For Palo Alto, Portland cement comes from the Lehigh plant in Cupertino, and is transported 15 miles by pneumatic truck. Calculating the weight per cubic yard of concrete using the same

methods described above resulted in 560 pounds of Portland cement for traditional concrete, and 397 pounds of Portland cement for concrete with 25% fly ash replacement by weight.

The water used in concrete production was assumed to be readily available on-site for the 'central coast' region of California. Therefore, there are no associated transportation costs. Generally, the water to cement ratio by mass is 0.45. For traditional concrete, 14% by volume resulted in 236 pounds of water per cubic yard of concrete production. For concrete with 25% Portland cement replacement with fly ash, a 10% reduction in water use was assumed, resulting in about 212 pounds per cubic yard of concrete. This reduction is significant because concrete with less water is generally considered stronger and more durable.⁶ It is also worth noting that the moisture content of the aggregates was accounted for in this calculation.

For the admixtures associated with concrete production, the 'organic chemical' input into SimaPro was used. The water reducing agent Pozzolith 200N made by BASF Chemicals, Inc. was used to determine the dosage required for the mixture.⁶ The volume was measured in milliliters per 100 kilograms of cement and considered negligible in total volume calculations. However, it is important to note that the dosage is measured per kilogram of cement; concrete containing 25% fly ash requires less cement and therefore less admixtures.

Fly ash is a natural waste product of coal combustion. Depending on the source and composition of the coal being burned, the components of different classes of fly ash vary considerably. Generally, fly ash contains substantial amounts of silica dioxide and calcium oxide. Since there are no local coal plants near Palo Alto, the fly ash used in the study comes from the Jim Bridger coal plant in the Powder River Basin, Wyoming, and is transported 960 miles to Palo Alto. The fly ash is transported 950 miles by train and the last 10 miles by truck.

The coal in the Powder River Basin is considered sub-bituminous, which becomes class C fly ash after combustion. Fly ash is a pozzolanic material, meaning that in the presence of water it will have cementitious properties.⁵ Class C fly ash also has self-cementing properties and will gain strength over time. Because fly ash is a toxic waste of coal-fired power plants, no emissions associated with fly ash production were allocated in the study. Therefore, the only emissions associated with fly ash replacement in the stretch of pavement were the transportation distances. A 25% replacement of Portland cement by weight results in a ~25% increase in volume of cementitious material and a total of 132 pounds of fly ash in a cubic yard of concrete produced. A summary of the raw material inputs for both concrete pavement alternatives is shown in Table 1.

All of the raw materials listed above are transported to the construction site in Palo Alto where they are mixed on-site in a rotary drum batch plant and hardened through hydration. For this step, the input 'plaster mixing' in SimaPro was used. The study did not account for other construction labor and machinery costs because the inputs to this phase were assumed to be identical for both systems; the same amount of equipment and

TABLE 1: SIMAPRO INVENTORY INPUTS FOR ICY OF CONCRETE FOR BOTH SYSTEMS

Material	Traditional Concrete (lbs)	Concrete with fly ash (lbs)
Portland Cement	560	397
Fly ash	0	132
Water	290	252
Fine aggregate (sand)	1,100	1,040
Coarse aggregate (gravel)	1,760	1,663
Admixtures	1.4	1.0

labor are assumed for both traditional concrete and concrete with a 25% fly ash replacement.

For structures that are intended to have a relatively long life, the use phase is considered very important. This study assumed both pavements have a 50-year life with regularly scheduled maintenance, and the initial installation of the pavement at year zero. Although reports state the increased strength and durability of concrete using fly ash replacement, it was important to establish a baseline for this initial assessment of the difference between impacts of the two systems. Therefore the maintenance schedule was assumed as follows: minor repair at year 12, major rehabilitation at year 25, and a minor repair again at year 37.⁷ For this study, a minor repair constitutes a 2-inch concrete overlay and a major rehabilitation constitutes an 8-inch concrete overlay.⁵

It is important to note that the assumptions for the use phase of the highway have a high degree of uncertainty. There are numerous studies showing increased strength and durability of concrete containing 20% or more fly ash,⁴ however there have been no definitive studies over the lifetime of a concrete pavement containing fly ash that could result in accurate quantitative predictions. Any increase in the lifetime of concrete with 25% fly ash replacement will result in significantly lower use phase energy use and emissions, mainly due to decreased traffic congestion during maintenance periods and reduced material use.⁷

At the end of the 50-year lifetime of both concrete pavements, a 50% recycling rate was assumed for both systems for reuse in future projects as road base or other aggregates. Reports have shown this recycling rate to be as high as 85% in some cases.⁸ The highway is excavated, and either taken to a landfill or recycling plant via truck. End of life procedures for both pavement systems are considered equivalent, and thus the energy and emissions associated are also considered equivalent.

IMPACT ASSESSMENT RESULTS

The total life cycle inventory results for both concrete pavement alternatives are shown in Table 2. These were obtained by first quantifying the impacts for the initial installation and then scaling these values on a volume basis depending on the adopted maintenance schedule. At a glance, using fly ash as a cement replacement in concrete pavement results in overall lower life cycle energy consumption and emissions. This means that no matter how the resulting emissions are characterized in terms of environmental indicators, using fly ash as a cement replacement

TABLE 2: SIMAPRO LIFE CYCLE INVENTORY RESULTS FOR ENERGY USE AND CRITERIA EMISSIONS FOR BOTH CONCRETE ALTERNATIVES

Inventory	Traditional Concrete	Concrete with fly ash
Energy MJ LHV	79,327,967	69,246,157
kg CO ₂ e	7,282,561	5,532,240
kg CO	2,420	2,266
kg PM	182	170
kg NO _x	18,370	16,852
kg SO ₂	4,268	3,454
kg Pb	1.54	1.27

TABLE 3: SUMMARY OF ECO-INDICATOR 95 RESULTS FOR BOTH CONCRETE PAVEMENT ALTERNATIVES BY IMPACT CATEGORY

Impact Category	Unit	Initial Installation		Initial Installation + Repairs	
		Traditional Concrete	Concrete with Fly Ash	Traditional Concrete	Concrete with Fly Ash
Greenhouse	kg CO ₂	3,310,255	2,514,655	7,282,561	5,532,240
Ozone layer	kg CFC11	0.38	0.34	0.84	0.75
Acidification	kg SO ₂	8,459	7,498	18,609	16,495
Eutrophication	kg PO ₄	1,192	1,087	2,622	2,391
Heavy metals	kg Pb	9.27	8.06	20.40	17.74
Carcinogens	kg B(a)P	0.07	0.07	0.16	0.15
Pesticides	kg act. subst.	-	-	-	-
Summer smog	kg CH ₄	843	768	1,854	1,690
Winter smog	kg SPM	2,895	2,434	6,368	5,355
Energy resources	MJ LHV	36,058,167	31,475,526	79,327,967	69,246,157
Solid waste	kg	-	-	-	-

will always yield lower impacts.

The results from the inventory analysis were characterized into environmental impacts for both concrete pavement types. Translating the inventory results into environmental metrics would more clearly show the environmental implications associated with the implementation of each concrete pavement alternative.

SimaPro, Eco-Indicator 95 V2.05 was used to characterize the inventory results into the various environmental indicators. Table 3 provides values for all the impact categories included in Eco-indicator 95. Graphing these results as shown in Figure 1 shows the reduction capacity for using fly ash as a 25% replacement of Portland cement.

The life cycle energy consumption of traditional concrete pavement is about 79.3 million MJ (LHV) compared to about 69.2 million MJ (LHV) for concrete made with fly ash. This is a total life cycle energy reduction potential of about 10TJ, which is about 13%. To put these results into context, a comparison can be made with the annual energy consumption of the average U.S. household. According to the U.S. Energy Information Administration, in 2011, the average annual electricity consumption for a U.S. residential customer was 11,280 kWh.⁹ Using data from Ecobalance, the equivalent energy per kWh of electricity from the U.S. grid is about 40,608 MJ per year. This means that installing a four lane, one mile stretch of Portland cement concrete pavement uses 888 times the energy of one household in a year; whereas using concrete with fly ash as a partial replacement for cement uses more than 775 times as much energy.

SimaPro network flow diagrams were then used to qualitatively depict the most energy intensive material inputs or processes.¹⁰ From the network flow diagrams shown in Figure 2, the primary contributors to energy consumption are Portland cement

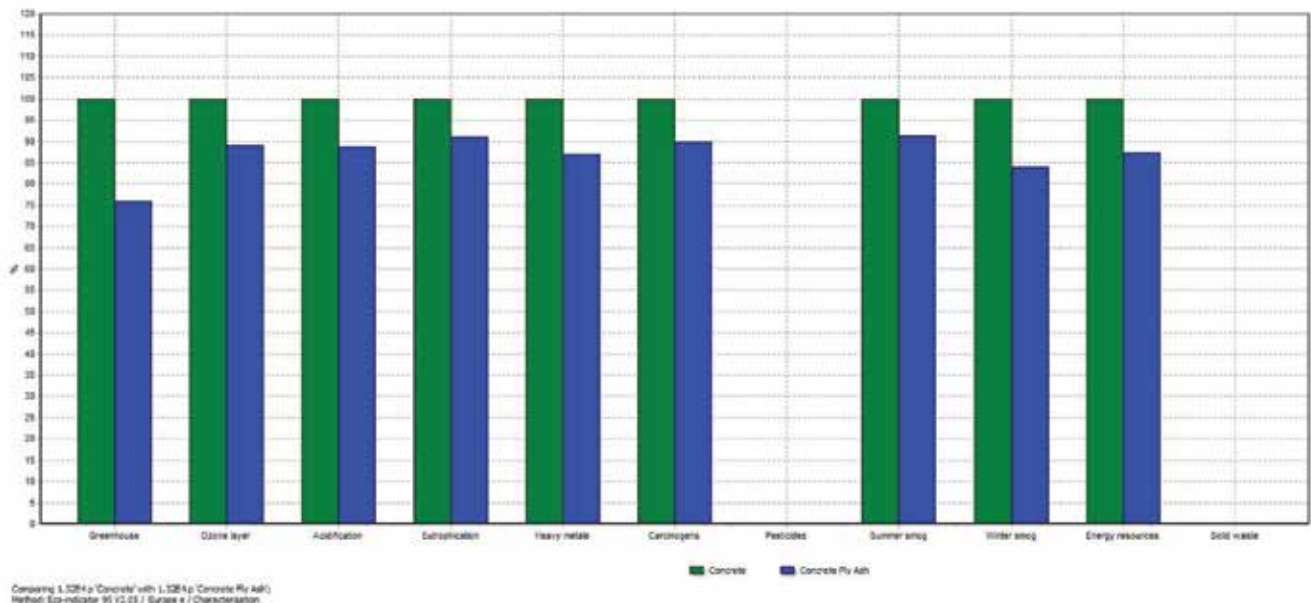


Figure 1: Reduction potential for using fly ash in concrete (blue) compared to traditional concrete (green)

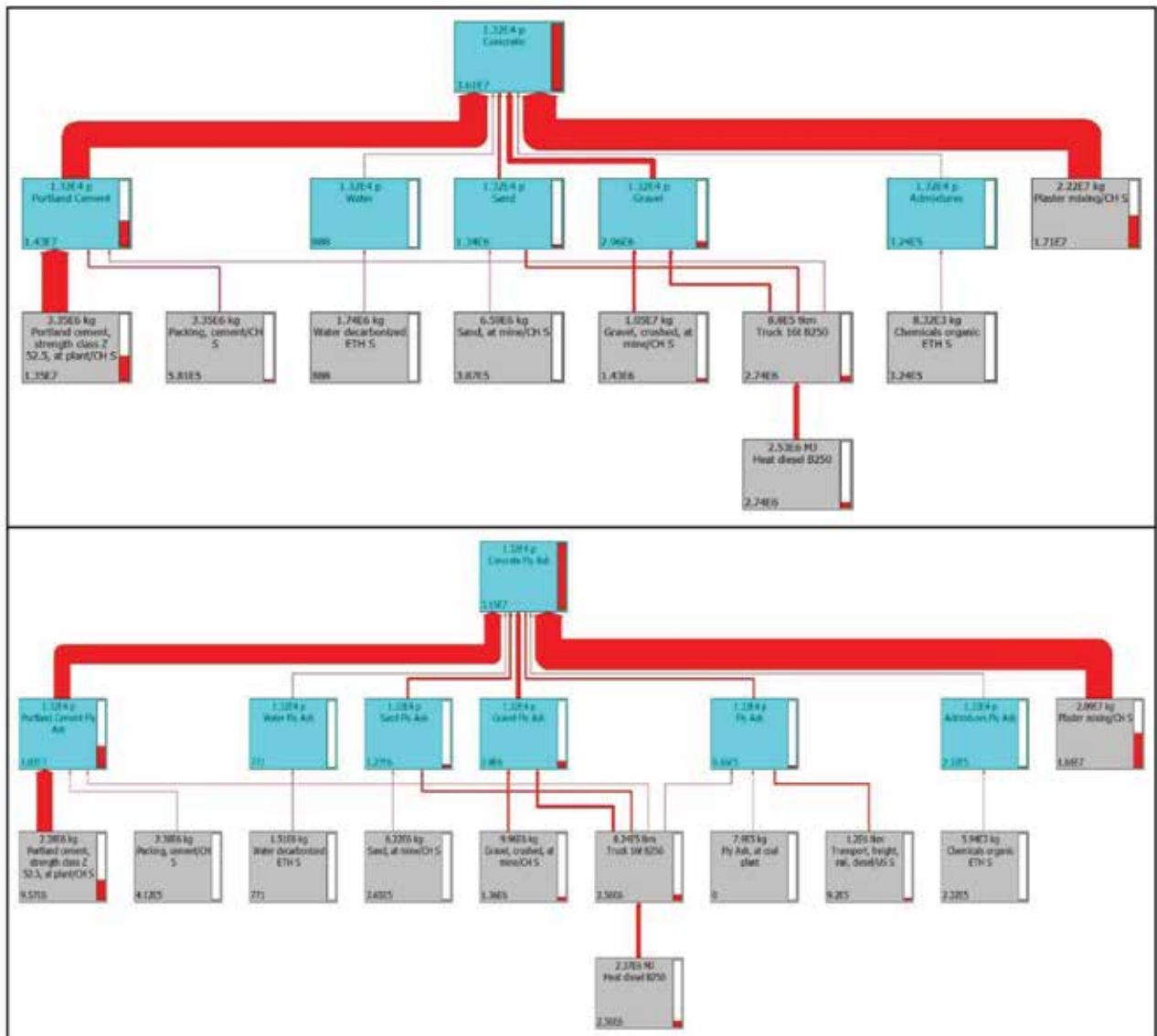


Figure 2: SimaPro energy network flows for traditional concrete (top) and concrete with fly ash (bottom)

and plaster mixing. As expected, Portland cement was a major energy contributor due to its very energy intensive kiln heating process. However, the contribution of plaster cement was surprising. Although there is electricity used to mix the concrete on-site, the group suspects the large contribution may be due to uncertainties in the SimaPro database. Since the energy used for concrete mixing will always be required, decreasing the use of Portland cement would achieve the highest energy savings. A quantitative characterization of these results is shown in Figure 3.

Given that globally, cement production accounts for 5% of global carbon dioxide emissions, the main environmental indicator considered was global warming potential (GWP).⁹ Anthropogenic greenhouse gas emissions, such as carbon dioxide (CO₂), methane (CH₄) and nitrous oxides (N₂O), are a major driver for global warming and hence climate change. Global warming has a predominant effect on the environment and its growing effects have made it a principal area of interest in greenhouse gas reduction discussions.

In order to characterize these impacts, GWP was measured in kg of carbon dioxide equivalent (CO₂e) based on normalization factors derived by the Intergovernmental Panel on Climate Change (IPCC).¹⁰ From Table 3 above, traditional concrete

produces 7.3 million kilograms of carbon dioxide equivalent, compared with 5.5 million kilograms of carbon dioxide equivalent from concrete made with fly ash. Using fly ash would offset about 1.75 million kg CO₂e, which is a significant 25% reduction compared to traditional concrete.

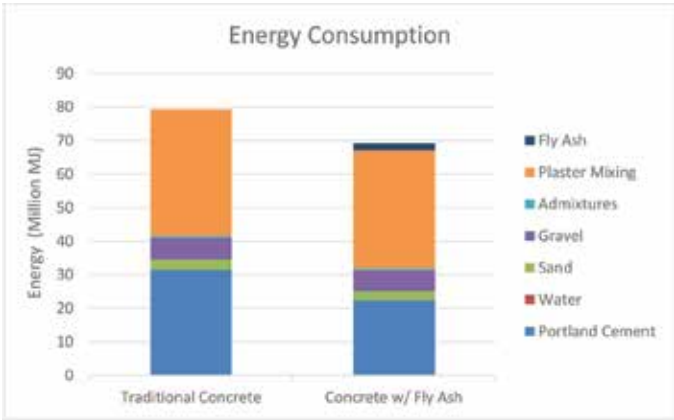


Figure 3: Breakdown of life cycle energy consumption for both concrete alternatives

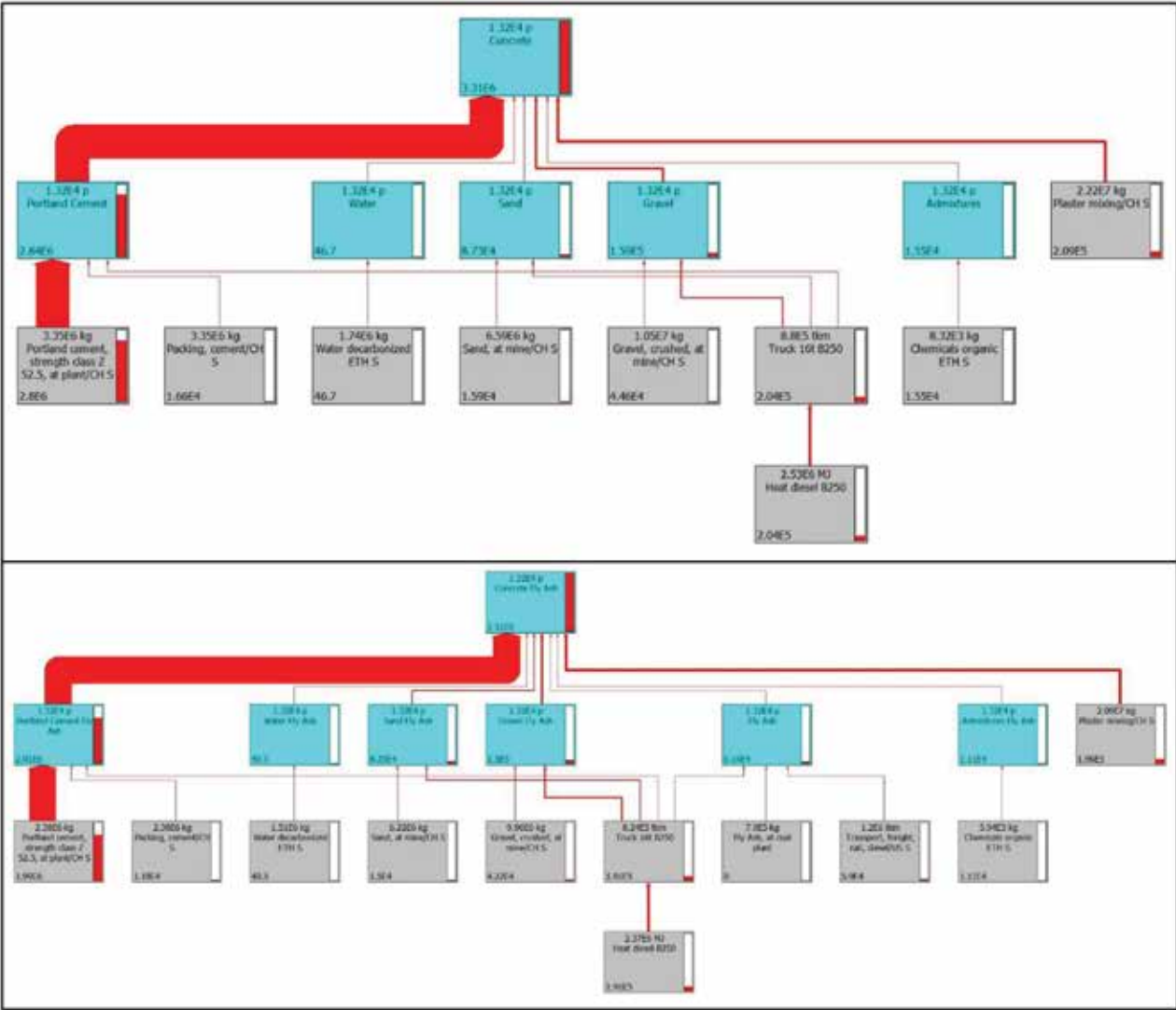


Figure 4: SimaPro CO₂e network flows for traditional concrete (top) and concrete with fly ash (bottom)

Similarly, CO₂e network flow diagrams from SimaPro were used to qualitatively assess the contribution of each product/process in the overall system impact. From Figure 4, Portland cement is by far the largest contributor to lifecycle CO₂e emissions for both concrete pavement alternatives.

A quantitative account of these results is shown in Figure 5. Portland cement production accounts for an overwhelming 80% and 85% of the total greenhouse gas emissions for each alternative. According to the IEA, the about 60-65% of CO₂ is directly emitted during the calcination process alone, while the remainder is indirectly emitted through fossil fuel use in the cement production process.⁹

Other environmental indicators in Eco-Indicator tool that were worth noting were acidification, ozone depletion, eutrophication and carcinogenic health effects. Fly ash used in concrete results in lower values across all environmental indicators. Graphs for these indicators can be found in Appendix A.

It is important to note that the impact assessment is limited to energy and emission flows for the construction of concrete alone. Other waste products and emissions resulting upstream or outside of the scope of the study are not fully accounted for.

Additionally, growth in the demand of concrete production will increase raw material resource depletion, energy consumption and environmental impacts. The impact assessment results showed that using fly ash as a partial replacement of concrete yields overall lower environmental impacts. Hence, continued use of fly ash in concrete pavement poses a unique opportunity for overall impact reductions in the concrete industry.

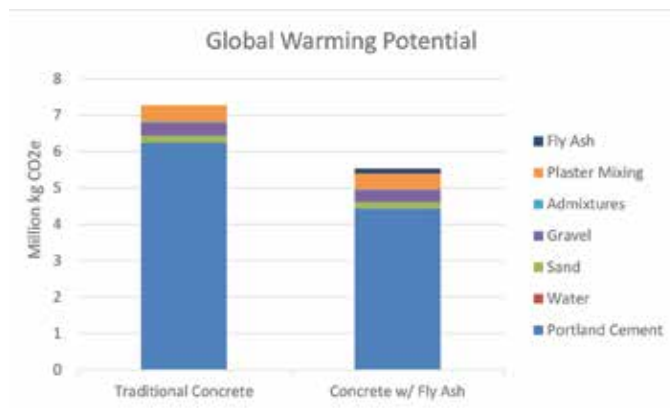


Figure 5: Breakdown of life cycle global warming potential for both concrete alternatives

TABLE 4: SUMMARY OF MATERIAL AND TRANSPORT COSTS USED IN LIFE CYCLE COST ANALYSIS

Material Input	Material (\$/ton)	Transport (\$/ton)	Total Cost (\$/ton)
Portland Cement	95	13	108
Fly ash	74	36	110
Water	0.41	0	0.41
Aggregate	24	13	37
Admixtures	3.15	0	3.15

LIFE CYCLE COSTS

The life cycle cost assessment allows for a total costs comparison of the two concrete alternatives. Such an assessment is important because it provides additional insight that can influence the overall decision-making process. In order to quantify the total life cycle costs, the same assumptions outlined in the inventory analysis section were followed. The life cycle cost analysis included both agency and social costs.

The agency costs included material costs, scheduled maintenance over the lifetime of the concrete pavement and end of life costs. The material costs included the costs of the concrete mix materials and transport of each to the installation site. The material input and transportation costs were provided by Headwaters Resources. The total lifetime material costs included initial installation materials as well as materials used for each maintenance event. The values used to calculate the initial installation material costs are shown in Table 4. Notice that the transport cost for water is set to zero as it is assumed to be obtained on-site and similarly, assumed to be negligible for admixtures.

The maintenance schedule for both concrete alternatives was assumed to be the same; two minor repairs and one major rehabilitation. The costs for these were obtained from historical averages of highway maintenance projects in California.¹¹ A modified maintenance schedule to account for the increased durability of concrete made with fly ash is used in the sensitivity analysis portion of the study.

At end of life, it was assumed that up to 50% of the concrete is recycled and the rest sent to a landfill in Palo Alto. The salvage value of recycled concrete was found to be \$7-10 per ton.¹² Additionally, according to the City of Palo Alto, disposal costs are \$28 per cubic yard of concrete.¹³ Costs associated with transportation to the landfill were not included as it was assumed to be the same for both alternatives. Construction and user related costs were assumed to be the same for both alternatives and hence not included in this assessment.

Social costs associated with life cycle emissions were also included. These were based on the emissions inventory quantities found previously. The same methodology as material costs was used to determine the emissions resulting from the initial installation and each scheduled maintenance activity. Although there is no price on carbon, environmental costs were quantified using suggested damage costs given in \$/ton for each emission

TABLE 5: DAMAGE COSTS FOR CRITERIA EMISSIONS, GIVEN IN 2013\$

Criteria	Damage Costs (\$/ton)
CO ₂	26.65
PM	7798.41
NO _x	198.01
SO ₂	215.78
CO	2.39
Pb	5019.97

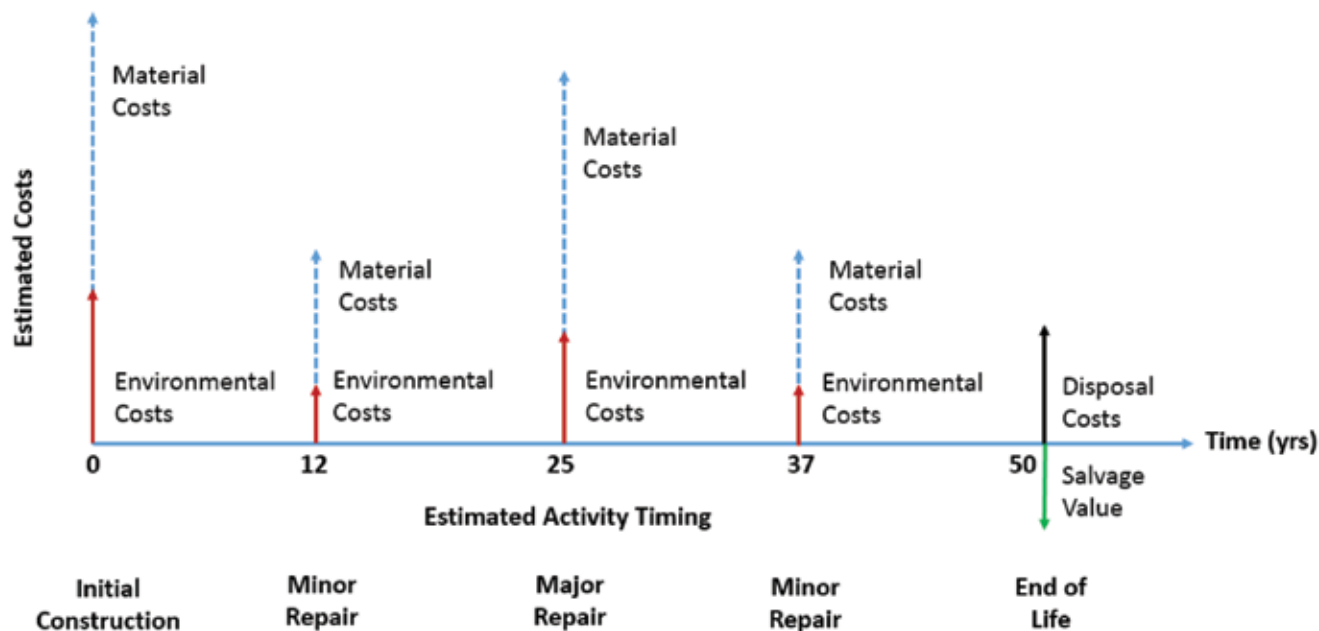


Figure 6: Estimated cash flow over lifetime of concrete pavement

type.⁷ The damage cost values for the criteria emissions were given in 1990-1993 dollars and converted to 2013 dollars using producer price index values; these are shown in Table 5.

The general life cycle cash flow used for both alternatives is shown in Figure 6. In order to account for time value of money, all cash flows were discounted to present value. According to the US Federal Highway Administration (FHWA), typical real discount rates range from 3-5%.¹⁴ For this present worth analysis, a discount factor of 5% was used.

The results of the present worth life cycle costs are shown in Table 6. Traditional concrete resulted in total life cycle costs of \$3.04 million compared to \$2.93 million for concrete using fly ash. Fly ash use results in a total life cycle savings of about \$133,838, equivalent to about 4%. The difference in costs results from the materials and environmental emissions costs; with the material costs contributing more than 70% of the total savings. This makes sense because using fly ash reduces the amount of Portland cement, water, aggregates and admixtures used. Additionally, cement has a higher cost compared to fly ash. Based on the life cycle costs, concrete made using fly ash is the better alternative.

SENSITIVITY ANALYSIS

In order to test the strength of these results, two different scenarios were considered for the concrete made with fly ash. First, it was assumed that the highway pavement made with fly ash may require less maintenance due to the increased durability and strength from the fly ash. Second, different transportation distances for the fly ash were considered to analyze the effect of transportation energy use and emissions. For each analysis, the inputs to SimaPro were changed in the specified way while keeping all other inputs constant, then compared with the original results for regular concrete.

Because concrete made with fly ash is reported to be more durable,¹⁵ it could require less maintenance over the lifetime of the

TABLE 6: LIFE CYCLE COST RESULTS FOR BOTH CONCRETE ALTERNATIVES. FLY ASH USE IN CONCRETE SAVES OVER \$100,000

	Traditional Concrete	Concrete with Fly Ash	Concrete with Fly Ash Opportunity Savings
Materials & Transport	\$1,515,992	\$1,434,812	\$81,180
Portland Cement	\$551,050	\$390,655	
Fly Ash	0	\$132,296	
Water	\$1,084	\$941	
Aggregate	\$963,818	\$910,891	
Admixtures	\$40	\$28	
Maintenance	\$1,381,552	\$1,381,552	\$0
End of Life	\$5,442	\$5,442	\$0
Environmental	\$138,388	\$105,730	\$32,657
TOTAL COSTS	\$3,041,374	\$2,927,536	\$113,838

highway pavement. For this scenario, two different changes were made to the maintenance schedule. The concrete made with fly ash may only need the one major repair and no major repair, or it may require only the two minor repairs and no major repair. The results of the sensitivity analysis reduced the emissions and costs for concrete with fly ash even further below traditional concrete. The results are shown in Table 7.

For the second sensitivity analysis, different transportation distances for the fly ash were considered. Fly ash is a waste product from coal and generally does not require any processing, so it was assumed that fly ash had no energy or emissions associated with it except for its transportation. Because the highway pavement is located in Palo Alto, California, where there are no coal plants nearby, the fly ash must come from other states. In the original analysis, the fly ash came from a coal plant in Wyoming, requiring 944 miles of transportation by rail. In order to see how the impact of fly ash concrete could change with varying transportation distances for the fly ash, distances of 50% closer (472 miles by rail) or 50% further away (1,416 miles) were considered. For each changed distance, all other inputs stayed the same, including the original maintenance schedule (two minor repairs and one major repair).

TABLE 7: INVENTORY RESULTS FOR DIFFERENT MAINTENANCE SCHEDULE SCENARIOS FOR CONCRETE WITH FLY ASH

Inventory	Regular concrete	Concrete with fly ash	Concrete with fly ash - no minor repair	Concrete with fly ash - no major repair
Energy MJ LHV	79,327,967	69,246,157	56,655,947	44,065,736
kg CO ₂ e	7,282,561	5,532,240	4,526,378	3,520,517
kg CO	2,420	2,266	1,854	1,442
kg PM	182	170	139	108
kg NO _x	18,370	16,852	13,788	10,724
kg SO ₂	4,268	3,454	2,826	2,198
kg Pb	1.54	1.27	1.04	0.81

TABLE 8: INVENTORY RESULTS FOR DIFFERENT SCENARIOS INVOLVING THE TRANSPORTATION DISTANCE OF FLY ASH

Inventory	Decrease distance by 50%	Increase distance by 50%
Energy MJ LHV	68,233,796	70,258,714
kg CO ₂ e	5,467,388	5,597,105
kg CO	2,266	2,266
kg PM	170	170
kg NO _x	16,016	17,688
kg SO ₂	3,366	3,542
kg Pb	1.24	1.29

For each alternative distance, there were only slight changes in energy consumption and emissions of the fly ash concrete, with both situations still using less energy and generating fewer emissions than the regular concrete. The results are shown in Table 8. Since the transportation distance did not have a significant effect on the impact, concrete made with fly ash is still a better choice for lower energy consumption and emissions even when coal plants are not close to the highway pavement site.

With transportation as the only source of energy consumption for the fly ash, the distance that fly ash could be transported by rail in order to make the energy consumption of fly ash concrete equal to the energy use of regular concrete was calculated. The fly ash would need to travel 5,644 miles by rail in order for the two concretes to have the same energy consumption. As this distance is longer than the width of the United States, any site in the country would have a coal plant close enough to make the use of fly ash worthwhile.

REGULATORY REQUIREMENTS

Different requirements can impact the use of fly ash in concrete for highway pavements. The fly ash must meet certain quality requirements, as the fly ash may change depending on the characteristics of the coal and the combustion process. While the fly ash provided by Headwaters typically does not require processing in order to meet quality requirements, certain particle sizes of fly ash may need some processing.⁴ The additional processing would increase the energy consumption, emissions, and costs of the concrete made with fly ash. If processing is required, it is important to evaluate how the increased impacts compare with the impacts of regular concrete.

Since the highway is located in California, certain parties involved in the concrete production may be subject to Assembly

Bill 32, the California Global Warming Solutions Act. The agency building the pavement may be compelled to use fly ash to lower its greenhouse gas emissions and meet AB32 requirements. Additionally, cement manufacturers are included in AB32 due to the high emissions from cement. If cement manufacturers are able to reduce their emissions with technological improvements or other changes, the emissions from both types of concrete will be lower than shown in this report.

It is also important to consider the decommissioning of coal plants due to stricter regulations on air pollution. While the supply of fly ash is dependent on the use of coal plants, the decline of coal plants will not be a problem in the near future. Not all of the fly ash available is currently recycled for concrete or other purposes, so there is still potential for increased recycling and utilization of fly ash. Furthermore, even though the number of coal plants is declining, coal generation will still be a sizeable portion

of the energy mix for the foreseeable future, thereby providing enough fly ash to meet demand.

OPPORTUNITIES FOR REDUCING ENVIRONMENTAL BURDEN

The results from this comparative LCA indicate that using fly ash as a partial replacement for Portland cement in concrete will reduce the environmental impact of highway pavement. However, there are still several strategies that could be used to further reduce the environmental impact of concrete highway pavement. Currently, only about 32% of fly ash is recycled in the United States. Of this recycled fly ash, about 61% is used in concrete production.¹⁶ As a result, there is a large potential for additional recycling and higher amounts of fly ash utilization. Additionally, fly ash can be used to replace a larger portion of Portland cement. Current replacement rates are typically between 20% and 30%, although they can be higher. However, some current regulations and industry specifications limit the amount of fly ash or other supplementary cementitious materials that can be used in concrete. In response, the U.S. concrete industry recently implemented the P2P Initiative, with the goal of providing more flexibility for concrete mixtures.³ Similar regulations that require the use of fly ash or other materials as partial replacements for Portland cement could be used to further reduce the environmental impacts associated with the concrete and cement industries.

In addition to regulations, further testing that quantifies the strength and durability of fly ash concrete could encourage the industry to use fly ash concrete rather than traditional concrete. If numerous examples show fly ash concrete to be stronger, more durable, and less expensive than traditional

concrete, a larger amount of fly ash may be used as a replacement for cement. Many construction projects around the world may be able to see immediate economic and environmental benefits from using fly ash concrete. In this analysis, the transportation impact was relatively large for fly ash since it was transported from Wyoming to California. However, transportation impacts can be reduced by using fly ash for construction projects that are located closer to coal-fired power plants.

CONCLUSIONS AND RECOMMENDATIONS

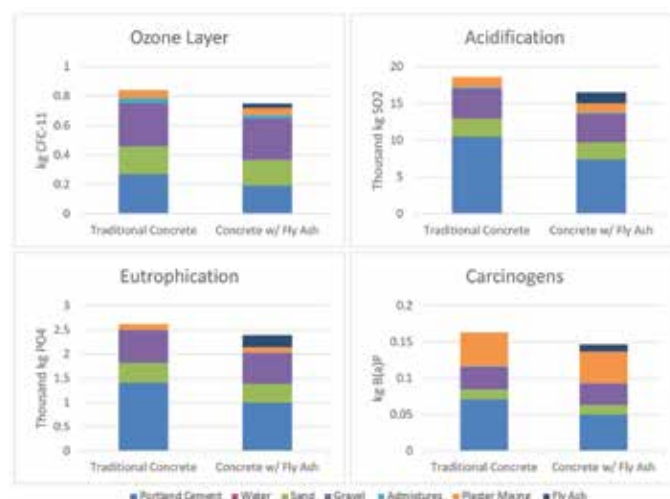
This comparative life cycle assessment has shown that concrete made with fly ash as a partial replacement for Portland cement consumes less energy and produces fewer emissions than traditional concrete made exclusively with Portland cement. Additionally, concrete made with fly ash has lower life cycle costs. When the increased strength and durability is considered, the concrete made with fly ash may require less maintenance, which would further increase the reduction potential for energy consumption, emissions, and costs compared with traditional concrete. The transportation distance of the fly ash should be minimized in order to decrease the energy consumption and emissions of the concrete made with fly ash. It is recommended that concrete pavements include greater utilization of fly ash with the goals of increased strength and reduced environmental impact.

REFERENCES

1. U.S. Energy Information Administration. Emissions of Greenhouse Gases in the United States 2009. Rep. U.S. Department of Energy, 31 Mar. 2011.
2. Marceau, Medgar L., Michael A. Nisbet, and Martha G. VanGeem. Life Cycle Inventory of Portland Cement Manufacture. Rep. no. 2095b. Portland Cement Association, 2006.
3. National Ready Mixed Concrete Association. Concrete CO₂ Fact Sheet. Publication no. 2PCO₂. National Ready Mixed Concrete Association, Feb. 2012.
4. Headwaters Resources, Inc. Rafic Minkara and Jim Johnson. 2013. <http://www.flyash.com/index.asp>.
5. Portland Cement Association. Concrete Technology. 2013. <http://www.cement.org/tech>
6. BASF Admixtures. 2010. Pozzolith 200N Data Sheet <http://www.basf-admixtures.com/EN/Pages/default.aspx>
7. Michael Lepech. Life Cycle Impact Assessment for Complex Systems. Lecture Slides. 2013.
8. Alex Loijos. Life Cycle Assessment of Concrete Pavements: Impacts and Opportunities. June 2011. <http://dspace.mit.edu/bitstream/handle/1721.1/65431/746765257.pdf?sequence=1>
9. International Energy Agency, Cement Technology Roadmap 2009 - Carbon Emissions Reductions up to 2050. 2009
10. SimaPro 7.2, Eco Indicator 95 V 2.05. Accessed 2013.
11. California Department of Transportation Division of Maintenance Pavement Program. 2011 State of the Pavement Report. December 2011. http://www.dot.ca.gov/hq/maint/Pavement/Pavement_Program/PDF/2011_SOP.pdf
12. Hafner & Sons, Inc. Recycled Aggregate Prices. 2013. <http://www.hafners.com/cincinnati-landscaping-supplies/recycled-aggregates.html>
13. City of Palo Alto Landfill & Composting Facility. Rates & Fees Schedule. December 2010. <http://www.cityofpaloalto.org/civicax/filebank/documents/8251>
14. US Department of Transportation Federal Highway Administration. Life-Cycle Analysis Primer. August 2002.

15. Collin D. Johnston. Alberta Transportation and Utilities. Fly Ash Utilization in Bridge Works. Rep. no. ABTR/RD/RR-96/04. June 1996. <http://www.transportation.alberta.ca/Content/docType241/Production/RR9604.pdf>
16. U.S. Environmental Protection Agency. Background Document for Life-Cycle Greenhouse Gas Emission Factors for Fly Ash Used as a Cement Replacement in Concrete. Rep. no. EPA530-R-03-016, 7 Nov. 2003.

APPENDIX A





HILLTOP

ENTERPRISES

**Innovative Solutions
&
Support For All Your CCP Management**

⇒ **CCP Beneficial Reuse**

⇒ **Landfill Management and Closure**

⇒ **Transportation**

⇒ **Environmental Remediation**

⇒ **Plant Services**

www.Hilltopenterprises.com

(610) 430-6920

Editor's Note: Welcome to ASH at Work's newest feature, in which leaders with unique insight affecting the coal ash beneficial use industry will be asked to answer six questions.

Terry Holland is a Consulting Engineer who specializes in concrete materials and concrete durability. He is an Honorary Member and Past President of ACI. During his year as ACI President (2002-2003), Terry spoke to many groups about sustainability in the concrete industry and made the first outreach from ACI to USGBC. Terry received his BS from the United States Military Academy at West Point, West Point, NY, and his master's and doctorate in civil engineering from the University of California, Berkeley, Berkeley, CA.



ASH at Work (AW): In your opinion, how effective has the concrete industry been in defining and applying sustainability concepts? Please give a letter grade, if possible.

Terry Holland (TH): Regarding defining concepts, I would grade the industry with a D (note that I have always been a hard grader!). The industry has not been a real leader in defining sustainability—it has been forced into pursuing sustainability by the rating systems, such as LEED. Unfortunately, I still see some of the industry pretending that we do not have a carbon problem. There is still nearly a one-to-one correlation between clinker and CO₂ production. We have to face the fact that as our cement usage returns to pre-recession levels and higher, we will be releasing more CO₂ because we are not yet replacing enough cement with suitable materials or we have not found an alternative binder or we have not improved the production of portland cement.

For applying sustainability as defined by others, I would rate the industry higher with a B. Some concrete producers are doing an outstanding job preparing innovative concrete mixtures to achieve a higher rating, but that is not yet the norm. In other cases, even though there is no rating system involved, concrete producers are supplying “greener” mixtures simply because it makes good business sense.

AW: What would you regard as the greatest success of the industry and the greatest failure?

TH: The greatest success is that the concrete industry is now largely familiar with sustainability. When I first began making presentations on sustainability, this was not the case. The biggest failure is lack of wide-scale implementation of a means of significantly reducing the carbon footprint of the industry. The recent debacle with the EPA actually set us back for fly ash acceptance and usage.

AW: Is greenhouse gas reduction the best measure of progress in creating more sustainable construction practices? Are there other measurements we should be monitoring?

TH: I am a firm believer in climate change and that human activities are contributing to this change. I do think that measuring CO₂ is an appropriate approach. Measuring other attributes is primarily looking at second or higher order effects that may have a contribution, but they are far overshadowed by CO₂.

AW: Fly ash use in improving concrete performance has evolved over several decades. Can you point to a significant event or events that brought fly ash use to be regarded as an important tool for designers?

TH: The first uses of fly ash were in reducing concrete temperature for mass concrete. This was “high-performance” concrete, but we had not yet invented that term. I think that fly ash really came into its own with the overall interest in high-performance concrete. When users began to look at developing concrete mixtures for properties other than compressive strength, and particularly for durability applications, fly ash became an important tool. Because the use of fly ash or other cement replacement materials is the only current means of reducing CO₂ in concrete, it is now an important tool for both sustainability and performance.

AW: Do you believe fly ash and other supplemental cementitious materials have hit their maximum value as of yet?

TH: Absolutely not. As long as we are throwing away any of these materials, we cannot consider that we have achieved the maximum value or benefit. We are only beginning to scratch the surface with concrete mixtures that use high amounts of replacement materials—high-volume fly ash for an example.

AW: Is there a technology lurking that you see as “the next big thing” in sustainability?

TH: We all keep seeing information about this or that process that will make a difference in our industry. However, on close inspection, the technology is either doubtful or has very small impact. I recently reviewed a paper on such a process where the carbon accounting that was presented indicated very minor reductions. A minor change in the assumptions and the entire benefit would disappear. I haven't seen anything lately that really excites me.

I was heavily involved with a new technology for several years that could have helped to make a difference. Unfortunately, we could not refine the process adequately to bring it to market for several reasons, including cost and lack of committed customers. I don't have a feel for whether there is as much venture money being pumped into the green sector as there was previously. I do remain hopeful that successful technologies will be developed and deployed. However, we should not be hoping for a “miracle cure” while we have not yet completely applied the replacement approach, which we know works.

AW: Thank you, Dr. Holland.

ASH CLASSICS

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

ASH at Work in 1982

ASH AT WORK

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

Printed on recycled paper.

Vol. XIV

1982

No. 1



FINALIZE PLANS FOR SYMPOSIUM—Ash industry officials are shown as they completed final arrangements for the 6th International Ash Utilization Symposium with the MGM Grand Hotel in Reno. Those pictured with Ms. Julie Powers (Seated), Director of Sales for MGM; are (Left to right) NAA President Gerald Bowdren, Executive Director James Covey, Ms. Kathy Davis of Meeting Planning Associations, and John Gillis of the NAA staff.

66 Papers Are Selected For Symposium

WASHINGTON—Sixty-six papers have been accepted for presentation at the Sixth International Ash Utilization Symposium to be held at the MGM Grand Hotel in Reno on March 7-10, 1982.

Program Chairman Jack Weber said 11 separate sessions have been scheduled during the three-day event. Aside from a single general program on Monday morning there will be concurrent sessions on Monday afternoon, Tuesday and Wednesday morning.

Topics cover a wide range of subjects with the primary focus on ash applications. Ash management, research, and marketing techniques are other major categories.

Special features will be the premiere showing of a documentary film titled "Power Plant Ash: A Resourceful Alternative" and a live demonstration

of the placement of fly ash concrete. The NAA produced the 27-minute film in cooperation with the Federal Highway Administration.

The registration fee for the Reno Symposium has been set at \$150. The package includes three luncheons, wine/cheese and cocktail socials, pre-print abstracts of papers, and a bound copy of the proceedings.

For the first-time the symposium is encouraging spouse attendance with side trips to Reno museums, ski areas at Lake Tahoe, and San Francisco. Spouse registration has been set at \$50.

Attendees will also have an opportunity to view exhibits of products and services available to the ash industry. A handbook outlining these items will be a part of the registration kit.

Tuesday's buffet luncheon and cocktail hour will be served in the exhibit area.

Space commitments have been received from the following exhibitors: National Ash Association, American Fly Ash Company, Fillite Disposal Services, Oh-Kay Chemical Corp., Monier Resources, Inc., Free Flow, Inc., Lytag Ltd., and Production Eng. Products, Inc.

(See 66 PAPERS, Page 3)

DOE, FHWA, EPA Reps Head Reno Program

WASHINGTON—Representatives of three Federal agencies will play vital roles in the 6th International Ash Utilization Symposium at Reno in March.

NAA President Gerald Bowdren identified the trio as Ray Barnhart, administrator, Federal Highway Administration; Ms. Penny Hansen, solid waste specialist, Environmental Protection Agency; Augustine A. Pitrolo, director, Department of Energy's Morgantown Energy Research Center.

Their remarks are expected to center on the theme of '82 Symposium—The Challenge of Change.



Mr. Pitrolo

Pitrolo, who is serving as co-chairman with Mr. Bowdren, will officially welcome the delegates in opening ceremonies on Monday. He came to the DOE from a career in the aerospace and coal industries.

The FHWA official, keynote speaker for the three-day event, will address Monday's luncheon. Before assuming the top post in the highway agency, Barnhart served as a college professor and commissioner of the Texas Highway and Public Transportation Department.

An eloquent speaker, Mr. Barnhart appears as a narrator in the FHWA/NAA film to be shown to the public for the first time in Reno. Individuals wishing to order copies of color documentary may do so at the registration desk, Co-chairman Bowdren explained.

Ms. Hansen will review new Federal procurement guidelines for cement and concrete products containing fly ash



Mr. Barnhart

(See DOE, FHWA, EPA, Page 3)

IN THIS ISSUE

66 Papers Selected.....	1,3
DOE, FHWA, EPA Reps.....	1,3
Arundel County Bill.....	2
Benza Profile.....	2
VEPCO Converts Four.....	3
Ohio Is Premier User.....	4

No Longer Refuse

Anne Arundel County Council Passes Bill To Permit Fly Ash Use in Structural Fill

BALTIMORE—The County Council of Anne Arundel County, Maryland, by a vote of 6 to 1, has approved a bill allowing the Baltimore Gas & Electric Company to place fly ash as a structural fill in industrially zoned areas.

More particularly, the legislation will permit B. G. & E. to utilize fly ash from its Brandon Shores Station on a 260-acre tract on Marley Neck. The utility wants to develop the property for use as an office building and warehouse.

A company spokesman, Gary Fuhrman, says the bill requires "the responsible placement of fly ash and sets forth the compaction requirements, moisture control, handling criteria, monitoring wells, and provides for a 12-inch cover over the fill."

"This is a very well controlled bill and sets out what needs to be done by everybody"—McGuirk

"The passage of this legislation paves the way for exciting economic development opportunities in the county," he added.

The new measure redefines fly ash as a fill material instead of refuse and permits its use in three industrially zoned areas.

Councilman Ronald C. McGuirk stated "This is a very well-controlled

bill and sets out what needs to be done by everybody."

The Maryland Gazette, in reporting the action, noted "McGuirk said, after visiting the West Virginia operation (AEP's John Amos Station), he was assured the coal residue could be recycled instead of dumped in a landfill."

"This is the type of bill we should be looking forward to with many wastes," he added. "The idea of recycling resources is something we need to get into more and more."

The lessons learned from this Maryland project are applicable anywhere."—Covey.

The NAA, with a major assist from American Electric Power Company's staff personnel in Charleston, helped develop and present the public relations campaign that led to a change in ash views by county officials.

Executive Director James Covey complimented the utility on the effectiveness of its "awareness program" and stated "the lessons learned from this Maryland project are applicable anywhere."

The B. G. & E. story will be one of the highlights of the upcoming 6th International Ash Utilization Symposium in Reno on March 7-10.

Personal Profile

Stephen T. Benza

Stephen T. Benza is serving as Ash Marketing Specialist for Pennsylvania Power & Light Company and is headquartered in Allentown.



The 30-year-old utility official also directs investigation of prospective fossil fuel reserves and transportation systems for PP&L.

In his prime area of responsibility, Benza supervises all ash disposal operations and directs the firm's ash marketing program.

Prior to joining P.P.&L, he spent four years on the staff of J. E. Baker Company of York, PA—a manufacturer/processor of mineral products for metallic/agricultural, aggregate, and other smokestack industries.

Benza is a member of the NAA Board of Directors and served as a member of the Steering Committee for the 6th International Ash Utilization Symposium Steering Committee.

He is a graduate of Pennsylvania State University with a B.S. in Mineral Economics and has taken continuing education courses in Earth and Mineral Sciences at Millersville State University. His wife, Donna, is a speech pathologist.



KEY TO CHANGE IN ASH VIEWS—An on-site visitation to American Electric Power Company's John Amos Power Station near Charleston, WV to view the placement of fly ash in a structural fill near AEP's coal-fired facility helped erase governmental and community skepticism from Anne Arundel County in Maryland that Baltimore & Gas & Electric Company's plan to develop a 260-acre site was environmentally and economically practical. The visitors saw first-hand the loading and transportation of the fly ash from the station, shown in the background, to the compaction of the material in the structural fill before reviewing and approving B.G. & E.'s plan and adopting a bill redefining ash as a fill material rather than refuse.

American Fly Ash Purchases All Stock of Penn-Virginia

American Fly Ash Company, Inc. of Des Plaines, Ill. has purchased all the stock of Penn-Virginia Materials Corporation headquartered in Willoughby, OH.

President Craig Cain said the transaction, which was effective Dec. 31, will make his firm one of the largest fly ash marketing agencies in the United States with sales coverage from Iowa into Pennsylvania including Tennessee.

"We hope to bring our experience into the picture to further enhance the services now being offered to Penn-Virginia's customers," Cain added.

Dennis Casamatta will remain in charge of firm's Ohio office.

DARN!

We really
knew better,
but just
goofed

EDITOR'S NOTE: Our last issue (No. 3, Vol. XIII) contained mistakes which we are pleased to correct with apologies to Pozzolanic Northwest, Inc., Basin Electric Power Cooperative, and North Dakota Highway Department.

Pozzolanic Northwest Erects Ash Warehouse

(Page 2, last paragraph)

The reference to Class F ash was erroneous. ASTM standards list Class F as "Fly ash normally produced from burning anthracite or bituminous coal..." and Class C as "fly ash normally produced from lignite or sub-bituminous coal..."

Pozzolanic's Class F fly ash is 4% calcium and 0.2% LOI.

North Dakota Accepts Use of Basin Electric Ash on Highways

(Page 4)

The news article, re-written from information supplied by Basin, had five errors which we now correct:

(1) Olds fly ash is not "highly reactive Class F material" but a Class C ash.

(2) The use of Olds ash on the ND 83 Project had "no influence" on the decision to use Neal Station ash on the road project near Velva.

(3) Ponded ash from Neal Station cannot be used as cement replacement. The reference by Mr. Grosz was applicable to Olds fly ash.

(4) The Water and Power Resources Service in Wyoming is not "known" to be taking a long look at using fly ash to stabilize irrigation banks.

(5) A cost savings to Basin on the use of ash in a railroad structural fill at Neal Station was realized but it was not termed "substantial."

VEPCO To Convert Four More Units Over To Coal

Virginia Electric & Power Company, the newest utility member in the National Ash Association, has announced plans to convert four more of its oil-fired generating units to coal.

A company spokesman said the units, having a total generating capacity of 345,000 kilowatts, have been in "cold reserve" since September 1980. The stations are located in Virginia.

The cost of the conversions has been set at \$85 million and are expected to save VEPCO about 400,000 barrels of oil a year. Of this amount, \$80 million will go into the design and installation of environmental protection equipment. The units are expected to be back in service by 1986.

The facilities were identified as Units 1 & 2 at the Portsmouth Power Station and Units 1 & 2 at the Possum Point Station near Quantico.

VEPCO began its oil-to-coal conversion program in 1975. Six units have already been switched to coal with another four scheduled for completion by 1984.

The NAA is working with the utility in the formulation of an ash management and utilization program. Executive Director James Covey recently met with engineering and operating personnel in Richmond to outline guidelines for these programs.

Two other NAA affiliates, Baltimore Gas & Electric and American Electric Power Service Corporation, are assisting the Virginia based firm in developing an environmentally acceptable plan for the establishment of a fly ash structural fill at its Yorktown Station to meet county zoning standards.

66 Papers Selected

(Continued from Page 1)

Chairman Weber also disclosed that papers were accepted from authors in eight (8) foreign countries including the United Kingdom, British Columbia, Australia, Ontario and Calgary in Canada, Netherlands, Romania, Jordan, Japan, and Denmark.

Overall the committee reviewed 93 papers before making the final selections. "Those not chosen for presentation at Reno were given the option of preparing the text for inclusion in the printed proceedings," Weber stated.

The spokesman noted that the Department of Energy had once again agreed to publish all papers delivered at the Reno Symposium. The Government Printing Office will mail the bound volume directly to all registrants.

RESEARCH PROJECT

The Texas Highway and Public Transportation department and Federal Highway Administration recently completed an in-depth examination of five fly ashes produced in Texas.

The major objective was to develop laboratory procedures to quickly ascertain those characteristics of fly ash important to their utilization in soil stabilization and concrete.

Conclusions: There is a wide range of chemical compositions and physical characteristics between the different ashes and to a lesser extent within a given source of time.

Recommendations: Consideration should be given to checking fineness of random shipments using No. 200 Sieve.

Consideration should be given to "source qualifying" fly ash produced for Texas highway markets on a random schedule.

Results detailed in Research Report 240-1, "Analyses of Fly Ashes Produced in Texas."

DOE, FHWA, EPA Reps

(Continued from Page 1)



Ms. Hansen

which will soon be implemented. Ash is the first by-product to be recognized in this manner. Her presentation will conclude the Symposium at Wednesday's luncheon.

Ms. Hansen and John Heffelfinger were the chief architects of the new EPA regs. The latter served as a member of the Symposium Steering Committee.

The Manager-Technical Support for Public Service Electric & Gas Company, Bowdren has directed the overall development of the Symposium program in cooperation with the NAA's Executive Director James Covey and other staff members.

He noted detail arrangements have been coordinated by Ms. Kathy Davis of Meeting Planning Associates of Menlo Park, CA and John Gillis of the NAA's Washington office.

Eight other agencies are co-sponsoring the program with the NAA including American Public Power Association, DOE, Edison Electric Institute, Environmental Protection Agency, Electric Power Research Institute, Federal Highway Administration, National Coal Association, and New York Power Pool.

A Major Ash Producer, Ohio Is Emerging As Premier User

COLUMBUS, OH—For many years the State of Ohio has been a major producer of power plant ash and the Buckeye State is now emerging as one of the premier users of these coal by-products.

The prime thrust at the moment is centered on the use of fly ash in the reclamation of abandoned mine lands although applications in the highway and building industries continue at a high level.

Both the Soil Conservation Service and the Ohio Department of Natural Resources have approved the use of ash as a soil amendment in the re-vegetative process.

A 17-acre tract in Gallia County, identified as the Little Kyger Creek Reclamation Project, has been successfully treated with fly ash and final engineering work is being completed on two other projects. One is on an adjacent tract in Gallia County and the second is in the Duck Creek Watershed in Noble County south of Caldwell.

In addition to specifying ash, the ODNR also permitted portions of the Kyger Creek spoil to be mixed with paper pulp sludge, municipal compost, composted municipal garbage, lime only, and borrow material.

Rusty Nida, an AEP engineer who coordinated the ash delivery from OVEC's Kyger Creek Station near Pomeroy, said the ash was applied at the rate of 800 tons per acre and disced into the spoil to a depth of 6 to 8 inches. The seed and fertilizer were added by an hydroseeder.

"When viewed in early June the fly ash area had a ground cover equal to or better than any of the other sections," Nida asserted.

Much of the data that has been assembled on use of fly ash in such applications came from earlier demonstration plots near Powhattan Point and Caldwell. These programs were coordinated by John P. Capp of the U.S. Bureau of Mines.

Additionally, Dr. Paul Sutton of the Ohio Agricultural Research and Development Center, has provided lab work and follow-up research on these two projects. His published work on the treatment of the toxic spoils found in Eastern Ohio has been widely circulated and accepted.

Persistence by the National Ash Association and member companies over the past nine years in promoting the concept with Federal and State agencies here at the capital has now paid off.

Ready-mix producers and concrete block manufacturers throughout Ohio have been using fly ash as a pozzolan for



Ash Recovery



Stockpiling of Ash



Re-vegetated Area in Gallia County

years. The Ohio Department of Transportation now allows the use of power plant ash in many highway applications such as Type 1P cement, unstabilized bottom ash base and sub-bases, and lime-fly ash base courses.

Engineers in Toledo pioneered the development of a controlled density fill using fly ash under the trade name of K-Krete in 1974. Another enterprising businessman in the same community, J. Patrick Nicholson, is now producing and marketing pozzolanic concrete using both fly ash and kiln dust under the N-Viro trademark.

In 1972, Chevron Asphalt Company of Cincinnati mastered the formulation for ASHPHALT—a road base material utilizing power plant boiler slag and emulsified asphalt—in conjunction with William E. Morton of Highway Materials, Inc., and others.

Expressways here and in Cincinnati were among the first roadways to experiment with the use of Black Beauty boiler slag as an anti-skid additive in asphalt overlays.

The DOT has utilized fly ash in the construction of structural fill of a bridge approach in Belmont County and have been using bottom ash for ice control during the winter for many years.



Viewing Noble Site



Philo Ash Pond



Our Industry is Changing. Is Your CCP Management Program Ready for the Challenge?

With 50 years experience in heavy construction and CCP management, Trans Ash is prepared to provide state of the art, creative, cost effective, and environmentally acceptable CCP management alternatives.

- Landfill Design
- Landfill Construction
- Landfill Management
- Ash Pond Management
- Ash Pond Closure and Remediation
- Dredging Services
- Environmental Remediation

To learn more, call Trans-Ash at 1.800.829.8214 or visit us online at www.transash.com

NEW COAL ASH REPORT PUBLISHED

CCP Beneficial Use: Where We Have Been and Where We Are Going

Perhaps you have heard this saying: “You cannot know where you are going unless you know where you have been.” There is a lot of truth to this old saw.

As the American Coal Ash Association (ACAA) looks forward to the future for beneficial use of coal combustion products (CCPs), the association commissioned the American Road and Transportation Builders Association (ARTBA) to provide historical context to the efforts to beneficially use CCP and forecast the future for the industry.

Since 1974, ACAA has annually tracked the production and use of CCP. The intent of this survey has been to demonstrate trends in the beneficial use of CCP over time. Over the last four decades, this information has been cited by a wide

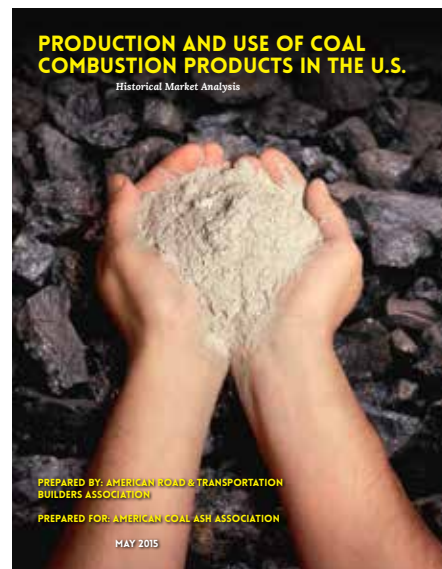
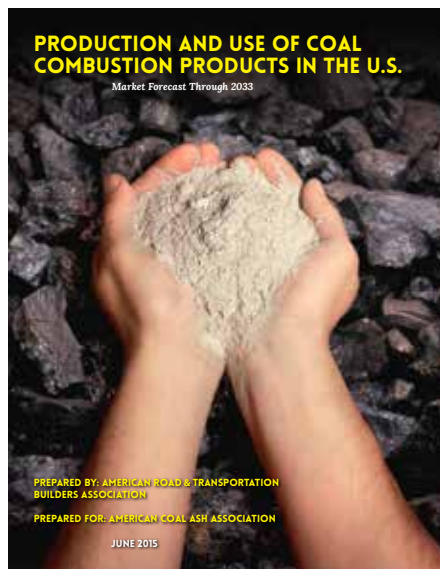
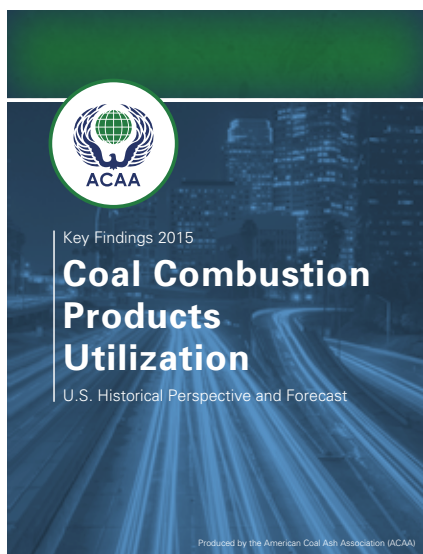
variety of public and private entities. The ARTBA analysis of the history of production and use considers the impacts of primary factors that affect production and use—regulations and economic conditions. Regulatory requirements on stack emissions and regulatory uncertainty have had major impacts on CCP production. Economic conditions—both boom and bust—have changed the demand for CCP over the decades.

Knowing what has affected the beneficial use industry provides context for looking to the future. The U.S. Environmental Protection Agency (EPA) has proposed numerous regulations that will affect the use of coal to generate electricity. While there is serious debate on the final form of these regulations, there can be no doubt that the combustion of coal will be significantly affected in the coming years. With

the advent of large quantities of natural gas at low prices, coal-fueled electricity has lost market share. Renewable energy technologies are also capturing market share largely due to subsidies from the federal government.

ARTBA has taken these factors, data from public and private energy industry resources, and economic data to provide the first-ever forecast for the availability of CCP. This forecast is intended to provide users of CCP with a realistic portrait of the future supply for the materials on which they rely.

The two ARTBA reports and a summary of the Key Findings of the report are available from the American Coal Ash Association at www.acaa-usa.org. ♦



A COLLABORATIVE PARTNER

BROAD-BASED EXPERIENCE

A TURNKEY APPROACH

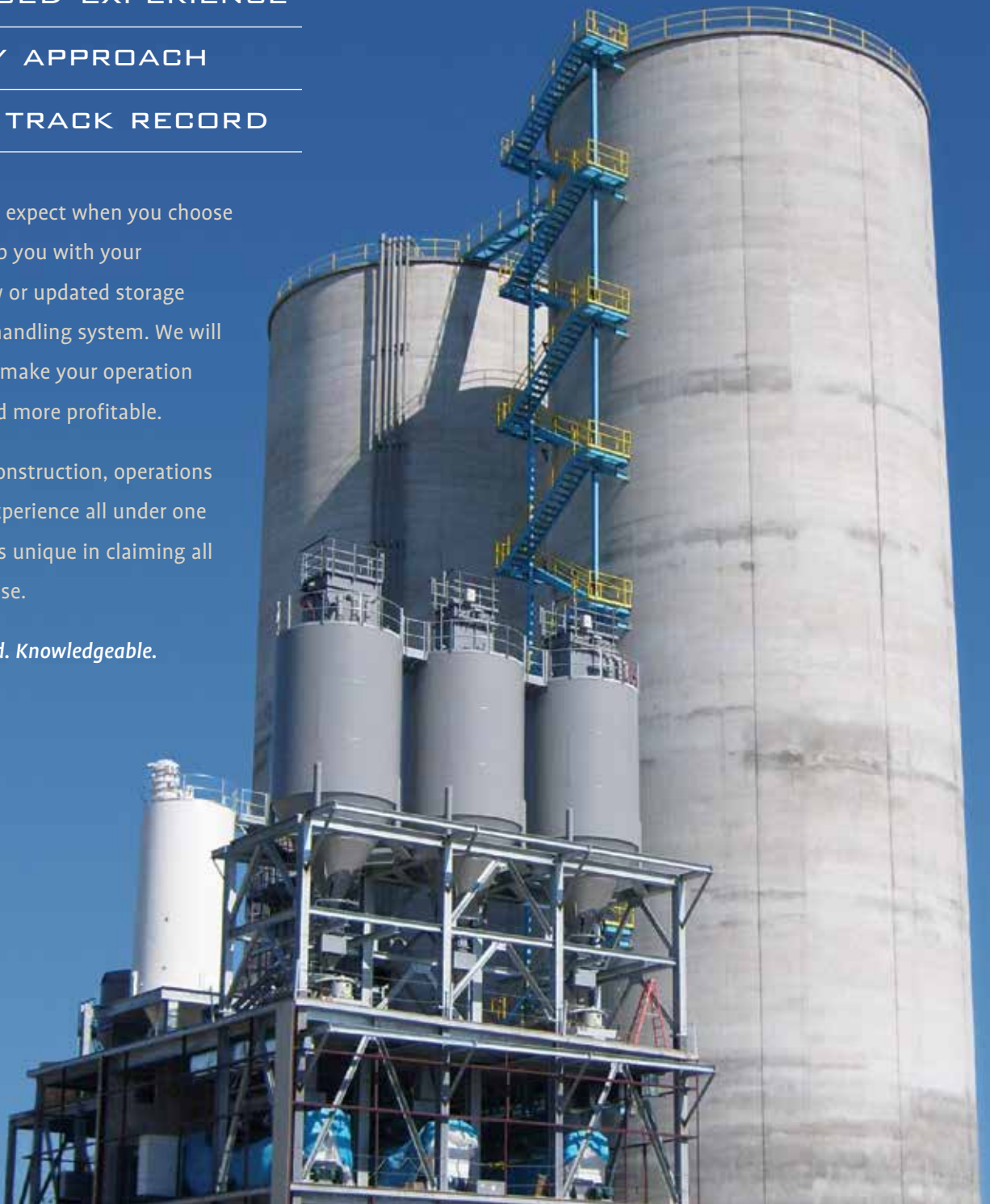
A PROVEN TRACK RECORD

That's what you can expect when you choose WL Port-Land to help you with your investment in a new or updated storage facility or material handling system. We will partner with you to make your operation more productive and more profitable.

With engineering, construction, operations and maintenance experience all under one roof, WL Port-Land is unique in claiming all four areas of expertise.

Committed. Talented. Knowledgeable.

Let us help you.



WLPORT-LAND
SYSTEMS, INC.

DESIGN / BUILD ENGINEERING RENOVATION



ACAA



— BENEFICIAL USE OF COAL COMBUSTION PRODUCTS —

AN AMERICAN RECYCLING SUCCESS STORY



***The American Coal Ash Association** was established in 1968 as a trade organization devoted to recycling the materials created when we burn coal to generate electricity. Our members comprise the world's foremost experts on coal ash (fly ash and bottom ash), and boiler slag, flue gas desulfurization gypsum or "synthetic" gypsum, and other "FGD" materials captured by emissions controls. While other organizations focus on disposal issues, ACAA's mission 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.*

AN AMERICAN RECYCLING SUCCESS STORY

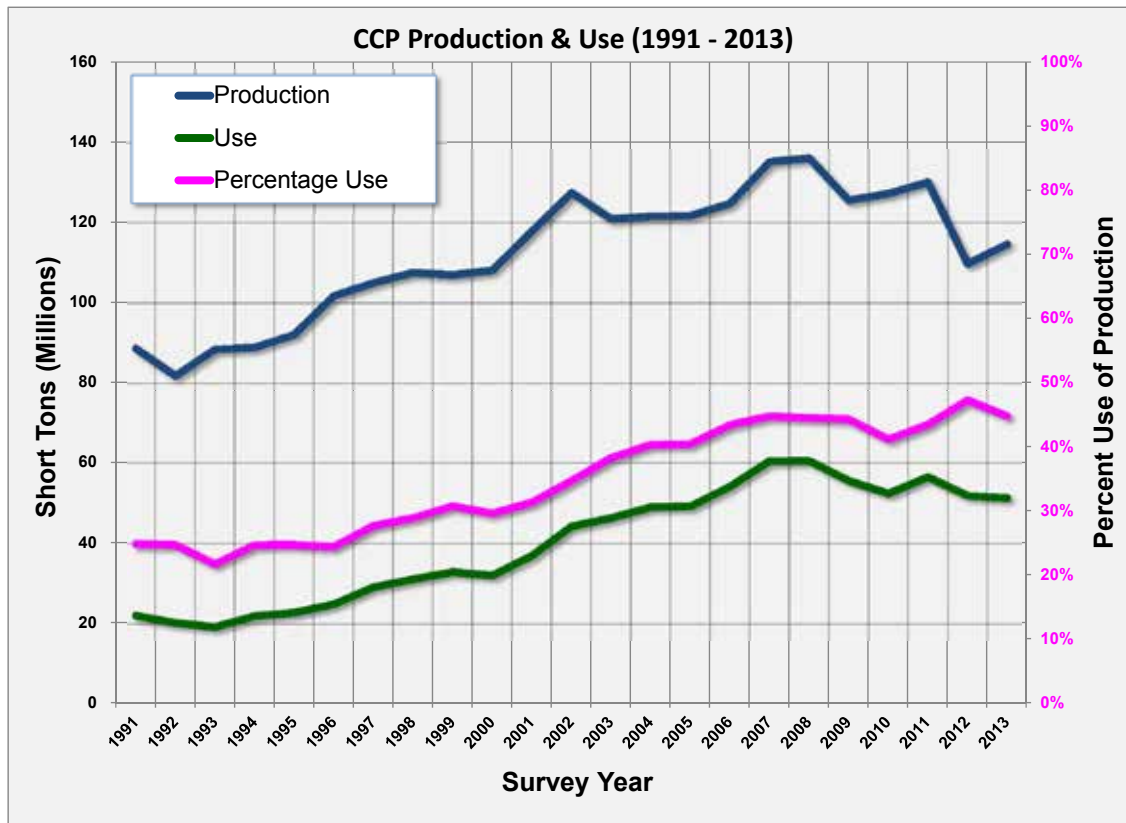
Coal Combustion Products – also referred to as “coal ash” – are solid materials produced when coal is burned to generate electricity. There are many good reasons to view coal ash as a resource, rather than a waste. Recycling it conserves natural resources and saves energy. In many cases, products made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

As coal continues to be the largest energy source for electricity generation in the United States, significant volumes of coal ash are produced. Since 1968, the American Coal Ash Association has tracked the produc-

tion 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.

In 2013, coal ash utilization remained below 2008 levels for a fifth consecutive year in the face of decreasing coal use, general economic stagnation, and regulatory uncertainty regarding the federal classification of ash. This follows eight years of dramatic growth in coal ash beneficial use during a period of regulatory certainty.

CCP Production & Use (1991 - 2013)



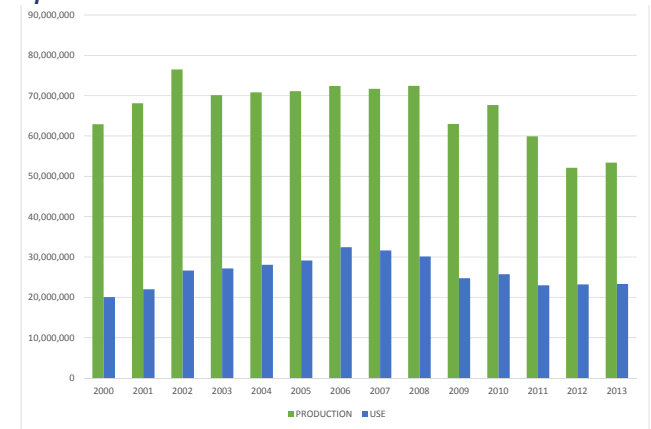
Fly Ash

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 more than 11 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 – 2013



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



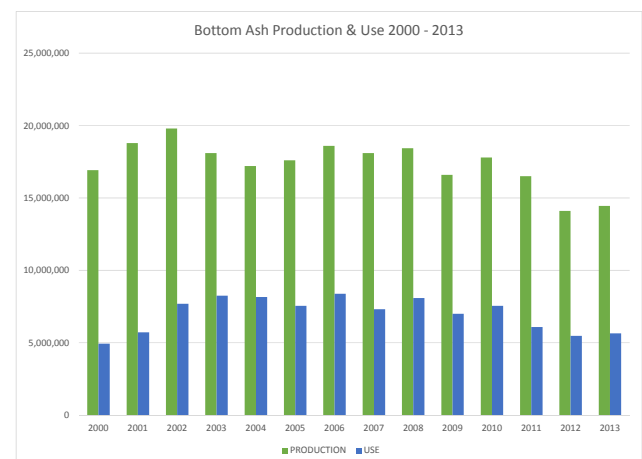
The American Road & Transportation Builders Association estimates coal fly ash use in roads and bridges saves \$5.2 billion per year in U.S. construction costs.

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 – 2013



Bottom ash can be used in asphalt paving.



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

Synthetic Gypsum

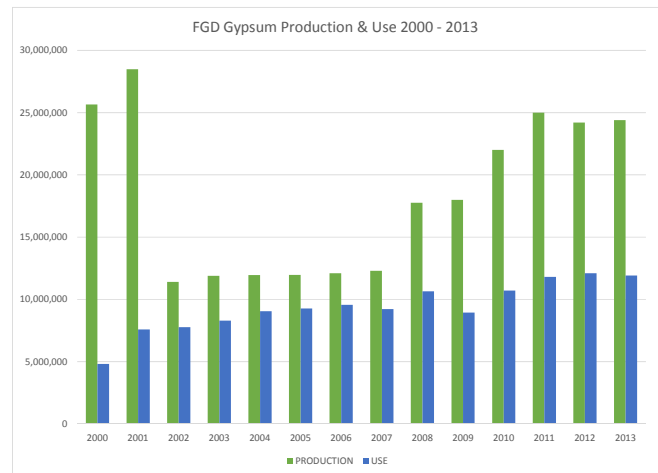
Power plants equipped with flue gas desulphurization (“FGD”) emissions controls, also known as “scrubbers,” create byproducts that include synthetic gypsum. Although this material is not technically “ash” because it is not present in the coal, it is managed and regulated as a coal combustion product.

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 2000 – 2013



Synthetic gypsum is often more pure than naturally mined gypsum.



Approximately 40 percent 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.



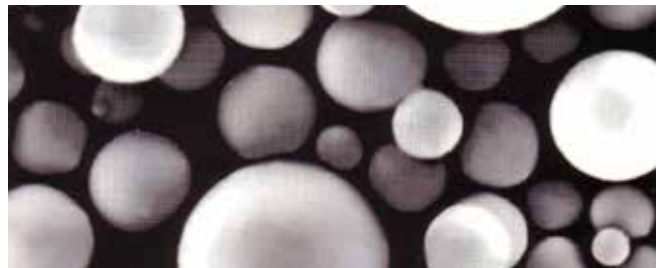
Other Products and Uses

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 reclaiming 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.





American Coal Ash Association
38800 Country Club Drive
Farmington Hills, MI 48331

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

2013 Coal Combustion Product (CCP) Production & Use Survey Report

Beneficial Utilization versus Production Totals (Short Tons)										
2013 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	53,400,000	14,450,000	1,355,939	24,400,000	8,514,789	687,706	1,557,431	10,326,745	114,692,610	
Total CCPs Used by Category	23,321,230	5,640,693	897,185	11,921,154	830,872	189,218	0	8,583,877	51,384,229	
1. Concrete/Concrete Products /Grout	12,356,726	494,074	0	263,742	0	5,710	0	0	13,120,252	
2. Blended Cement/ Feed for Clinker	2,286,144	1,324,131	0	1,080,832	83,817	0	0	0	4,774,924	
3. Flowable Fill	41,841	2,301	0	0	0	0	0	0	44,142	
4. Structural Fills/Embankments	3,005,136	1,912,283	0	966,334	268,816	0	0	0	6,152,569	
5. Road Base/Sub-base	136,318	228,517	0	0	0	2,026	0	0	366,861	
6. Soil Modification/Stabilization	268,462	457,070	1,000	3,827	0	102	0	92,556	823,017	
7. Snow and Ice Control	0	421,087	11,797	0	0	0	0	0	432,884	
8. Blasting Grit/Roofing Granules	4,150	17,672	884,861	0	0	0	0	0	906,683	
9. Mining Applications	1,843,292	250,113	0	1,562,373	478,239	139,244	0	8,403,003	12,676,264	
10. Gypsum Panel Products	0	0	0	7,446,839	0	0	0	0	7,446,839	
11. Waste Stabilization/Solidification	2,034,182	59,751	727	0	0	3,948		88,318	2,186,926	
12. Agriculture	15,644	217	0	582,244	0	0	0	0	598,105	
13. Aggregate	3,976	293,932	10,681	0	0	5,136	0	210,363	524,088	
14. Oil Field Services	313,373	73,883	0	0	0	25,954	0	0	413,210	
15. Miscellaneous/Other	1,011,986	105,662	0	14,963	0	0	0	0	1,132,611	
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	23,321,230	5,640,693	897,185	11,921,154	830,872	189,218	0	8,583,877	51,384,229	
Category Use to Production Rate (%)***	43.67%	39.02%	66.16%	48.85%	9.97%	27.51%	0.00%	83.12%	44.79%	
2013 Cenospheres Sold (Pounds)	16,167,431	Data in this survey represents 241,053 MWs Name Plate rating of the total industry wide approximate 331,091 MW capacity based on EIA data								

The data received this year represents approximately 60.3 % of the coal consumed in 2013 by electric utilities and IPPs (516,170,379 tons)

* These are actual tonnages reported by utilities responding and do not reflect estimates for utilities that did not respond this year.

**These numbers are derived from previous, current and applicable industry-wide available data, including Energy Information Administration (EIA) Reports 923 and 860 and other outside sources.

***Utilization estimates are based on actual tons reported and on extrapolated estimates and other sources only for fly ash, bottom ash, and FGD gypsum.



720-870-7897 • www.ACAA-USA.org



The power to support all your environmental needs.

When dealing with Coal Combustion Products (CCPs), you have to make smart business decisions and responsible environmental ones. At Waste Management – North America's leading environmental services company – we can assist you with handling CCPs safely, responsibly, and in full regulatory compliance.

Waste Management offers the most comprehensive range of sustainable solutions in the marketplace:

- CarbonBlocker™ technology for treating and neutralizing high carbon levels
- Fly ash marketing and beneficiation
- Ash pond conversion and closure
- Remediation services including closure, decontamination and demolition
- Landfill design, construction, management and closure
- Construction, engineering and design of new CCP disposal facilities

**To learn more, contact an Energy specialist at 877 747 3775
or visit wmsolutions.com/utility.**

**To review our qualifications
and experience document,
please download it at
wmsolutions.com/utility.**



©2014 Waste Management, Inc.



THINK GREEN.®

SYNMAT

Synthetic Materials

*The Proven Leader in
Synthetic Gypsum Processing
and Management*



Specializing in ...

- Design and Build Services for Gypsum Dewatering Systems
- Management of Gypsum Slurry to Eliminate Production Risks to Utilities
- Production of Quality Gypsum Cake for Commercial and Agriculture Applications
- Operation and Maintenance Services for all FGD Systems
- Comprehensive FGD Laboratory Services
- Market Development and Transportation of Synthetic Gypsum



Contact SYNMAT at: info@synmatusa.com

6009 Brownsboro Park Blvd., Louisville, KY 40207

Phone: 502-895-2810 **Fax:** 502-895-2812 **Website:** SYNMAT.com



DELIVERING INDUSTRY LEADERSHIP

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

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

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

www.flyash.com

