CAMC

North Carolina Coal Ash Management Commission

Coal Ash: Waste or Resource

A Preliminary Report on the Beneficial Use of Coal Ash North Carolina Coal Ash Management Commission

June 2015

NORTH CAROLINA

COAL ASH MANAGEMENT COMMISSION

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EXECUTIVE OVERVIEW

Currently, there are an estimated 108 million tons of coal ash stored in 32 impoundments located at 14 active or retired power generation sites throughout North Carolina. In September, 2014, North Carolina enacted the Coal Ash Management Act ("CAMA" or the "Act"), the nation's first comprehensive legislation to manage the disposal of coal ash, and created the Coal Ash Management Commission (the "CAMC") to oversee that process. Over the next several years the CAMC will be responsible for approving the categorization of the impoundments and approving plans for disposing of this energy byproduct in a manner that preserves and protects our state's people and environment.

The Act requires the CAMC to prepare a report on the beneficial uses of coal ash (the "Report"). Specifically, the Act states that the CAMC "shall study how to promote, incentivize, and prioritize the beneficial use of coal combustion products over the disposal of coal combustion residuals." **This draft Report is a preliminary assessment which will be updated as we gather more information on the market dynamics and specific economics of various beneficial use applications.**

Based upon the CAMC's preliminary review, we believe that a new paradigm is needed to address the treatment of coal ash going forward. Rather than treating coal ash as waste and asking where and how all of it can be stored in landfills and impoundments in perpetuity, policy makers should be asking how we can *eliminate* as much coal ash as possible in an environmentally and economically sustainable manner by recycling it in commercially viable applications. There are sufficient scientifically, environmentally and economically acceptable beneficial uses for coal combustion residuals that the volume of coal ash currently stored in earthen impoundments can be reduced by recycling coal ash in sustainable applications.

If most of us were asked: "What is the best way to dispose of soda cans, newsprint, glass bottles and scrap metal in the ground?" we would scoff at the notion of burying discarded products in the earth when they can be economically recycled in an environmentally friendly manner. Similarly, coal ash has many potential commercial applications when it is recycled. This Report will describe economically viable applications for the beneficial use of coal ash that are more environmentally sustainable than discarding it in earthen impoundments.

The technology curve for recycling coal ash, rather than treating it as rubbish, is in its infancy. Only in recent years have the potential dangers of impounding coal ash received widespread attention, leading to heightened academic and industry research efforts on beneficial use. While clean-up plans should consider where technology is heading in the future so that North Carolina can adopt long-term solutions, in this Report we focus primarily on commercially viable and environmentally safe solutions that are proven and in use today.

The barriers to more effectively recycling coal ash are less scientific than they are market and regulatory imposed. Given years of uncertainty over whether the Environmental Protection Agency ("EPA") would categorize coal ash as a hazardous waste, industry participants were understandably reluctant to invest in beneficial use technologies. With the recent EPA decision to not categorize it as such, much, but not all, of the regulatory uncertainty has been eliminated.

Moreover, in North Carolina the enactment of CAMA should serve as a catalyst for incrementally larger beneficial use programs. The primary producer of coal power in North Carolina, Duke Energy, is incentivized by the Utilities Commission to produce electricity in a cost effective manner. Low cost power is a critical input to our state's economy and job base, not to mention its importance to low-income households. Given the alternative of disposing of coal ash in impoundments contiguous to power plants, or establishing a more sustainable treatment of residuals, Duke chose the lowest cost option that was acceptable to regulators at the time, as one would expect given the utility's incentives. Meanwhile, the risks to our environment and people compounded, which led to the adoption of CAMA. CAMA, in turn, has dramatically altered the economics of disposal options, which opens the door for beneficial uses that heretofore may not have been economically compelling.

In other words, the Act could be a game-changer for beneficial use applications in North Carolina. Compliance with the Act will require Duke Energy to invest billions into excavating and moving coal ash from unlined ponds to lined impoundments or landfills, generally further away from bodies of water, to prevent a repeat of the February 2014 Dan River ash spill and to minimize leaching of harmful metals into groundwater. As plans are drawn up to remove the ash from unlined impoundments, utilities and regulators should weigh recycling options more heavily than in the past and revisit assumptions about the economics of various alternatives now that the low-cost solution of using unlined impoundments is rightfully no longer an option.

To transform our approach from permanently *burying* coal ash, to *eliminating* as much as possible, however, will require a new paradigm. And leadership.

The beneficial use of coal ash in parts of Europe and Asia outpaces practices in the United States. And within the U.S., North Carolina lags many other states in its coal ash recycling efforts.

To date, none of the key stakeholders in North Carolina have shown significant leadership in promoting sustainable beneficial uses of coal ash. As the nation's largest electric utility, many believe Duke Energy should be more committed to sustainable solutions for recycling coal ash. State environmental regulators have not been charged with promoting beneficial use applications either. And environmental groups, which typically show leadership in promoting sustainability initiatives, have been pushing for coal ash to be categorized as hazardous waste, which would preclude most beneficial uses. Having prioritized the elimination of coal power, many environmental leaders have been largely on the sidelines in policy discussions of sustainable ways to recycle coal ash.

This Report examines current applications for beneficially using coal ash and focuses our attention on applications: 1.) with the greatest opportunity to absorb large amounts of coal ash; 2.) which are most environmentally sound; and 3.) which have the most compelling economics. Where science or practice indicates a potential use exists, but it has not been demonstrated to be commercially viable, or there are questions about the environmental ramifications, we identify those applications but do not prioritize them. In other words, the CAMC is focused not on what is possible, but what is safe and practical.

The two applications we determined to be the most commercially viable based on the criteria above are: 1.) using coal ash as an input into concrete and concrete products; and 2.) its use as structural fill. Structural fill projects such as the Asheville Airport, where coal ash is providing the base underneath a new runway, have the same general environmental considerations and economics as storing the ash in lined landfills. There are additional costs and safety risks of transporting the coal ash to the site of the construction project; however, there are offsetting benefits of using coal ash rather than dirt in that it costs less, reduces labor, compacts better, forms a stronger base, and preserves natural fill alternatives. Moreover, structural fill projects are less likely than current impoundments to be located near lakes or rivers that supply drinking water to a large number of residents.

We believe the greatest opportunity relates to the use of coal ash in producing concrete. In North Carolina, up to 30 percent of the Portland cement commonly used to mix into concrete can be replaced by coal ash. Concrete produced with coal ash is stronger, more durable and lasts longer. For example, California requires the use of coal ash in the construction of its highways because of its performance benefits. And the environmental benefits are numerous. The potentially dangerous toxins found in coal ash are encapsulated in the concrete, preventing them from leaching into water supplies. Additionally, less water is required to produce the concrete. And the carbon footprint of producing concrete with fly ash currently reduces greenhouse gasses by an estimated 10 million tons per year, as it reduces Portland cement production, which has a very high carbon footprint.

In 2014, Duke Energy reported that it used only 30 percent (approximately 570,000 tons) of the coal ash it produced in concrete and structural fill. The annual absorption rate for these applications could be materially greater if the various stakeholders chose to make it a priority.

The explanation commonly provided for why so little coal ash is beneficially used in concrete in North Carolina is that the carbon content of much of the ash produced in our state is not suitable. For coal ash to be an acceptable ingredient in concrete, it should have a carbon content of no greater than 4 percent. The byproduct of the coal burned in North Carolina often fails to meet these specifications. However, there are several technologies for reprocessing coal ash to alter the carbon content and render it suitable for use in concrete.

In order for the manufacturers of coal ash reprocessing equipment to make the investment, which has a payback period greater than a decade, they need assurance of a long-term supply of coal ash to sell. To date the reprocessors have not been able to secure such a commitment from Duke Energy. Whether Duke purchases and operates the equipment itself, or provides supply agreements to the equipment manufacturers for a sufficient duration to recoup their cost, the utility will need to make a commitment to transforming both production and impounded coal ash into a form where it can be beneficially reused if we are to materially expand the market for sustainable beneficial use applications.

With the state's plans to expand its highways, coupled with the nation's need to rebuild its crumbling infrastructure, the amount of concrete that will be purchased by government entities is expected to grow considerably in the coming years. The need for longer lasting and more durable concrete has never been greater in America. One avenue to expand the market for concrete produced with coal ash would be to require its use in state-funded projects.

At this point, the CAMC is not recommending government subsidies for reprocessing coal ash, as we believe further study is needed on the economics to determine if that is necessary. While historically the economics of reprocessing coal ash to supply beneficial use markets may not have been compelling, compared to the cost of some current plans that involve excavating coal ash; transporting it across the state; purchasing, lining and storing the ash in abandoned clay mines; and compensating communities where the ash is stored, the *relative* economics of recycling coal ash are far more compelling today than in the past.

There are many other beneficial use applications besides the two above which have promise, including production of a wide variety of products ranging from bricks to bowling balls. While the metals in coal ash are a liability when impounding it, there are sought-after metals being extracted from coal ash. For example, coal ash contains lithium, which is being extracted from coal ash in China. The ash also contains several rare earth elements. The fact that our country no longer produces many of these elements creates a national security vulnerability. The Report discusses early stage efforts to extract rare earth elements from coal ash, as well as a host of other niche applications. But the CAMC feels the focus needs to be more on market innovations to dramatically expand current beneficial uses, than scientific breakthroughs in areas where the demand is limited.

One consideration that may seem counterintuitive is that in order to implement programs for the sustainable treatment of coal ash, the end use markets need to know that there will be an adequate supply of coal ash in the future, while our country is reducing the production of coal power. As coal power plants are retired, such as the Asheville plant which is being shut down and replaced with natural gas and solar power, the supply of production ash will diminish. This will require producers of products using recycled ash to have access to impounded ash to meet market demands before they are going to be willing to make major investments to expand recycling programs.

North Carolina has the potential to be a world leader in the sustainable disposal of coal ash. The University of North Carolina at Charlotte has established the Energy Production and Infrastructure Center ("EPIC"), which is a state-of-the-art research center that provides applied research relating to the beneficial use of coal ash. Other universities in the state system are also engaged in research relating to coal ash. However, for EPIC and other academic researchers to have maximum impact on beneficial use applications, we recommend that a program at EPIC or another state university system institution be funded to supplement needed science-based studies with economic analysis to better understand and address the market barriers to expanded opportunities for beneficially using coal ash. To move the needle on beneficial use, the issue needs to be viewed through a business lens as well as a science lens.

There are competing objectives in addressing the clean-up of coal ash, some of which are mutually exclusive. The CAMC believes that protecting the safety of our state's residents is the number one priority, and that objective should never be compromised. Where there is an imminent risk to surface or groundwater, coal ash should be moved to lined storage facilities as soon as practical.

However, where possible, the CAMC believes that we should pursue sustainable solutions which *eliminate* coal ash from landfills and impoundments rather than *bury* coal ash. It will take many years for markets to absorb tens of millions of tons of coal combustion residuals. *Electric utilities and regulators need to explore environmentally sound ways to temporarily store some of the ash rather than permanently burying it all in order to implement meaningful recycling programs.* There are technologies for temporary storage such as in situ stabilization and others that should be examined. As is often the case, timing considerations and time horizons will impact the ultimate soundness of the solutions selected.

There are additional areas of study needed to identify market, regulatory and political barriers to and opportunities for expanding beneficial use programs, as well as the specific economics of recommended beneficial use applications, which the CAMC will pursue in the future. However, given the statutory requirement for the CAMC to provide input to the Environmental Review Commission on beneficial use, we have prepared this preliminary report to help further the dialogue on prioritizing beneficial use applications.

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DEFINITION OF TERMS

ACAA	American Coal Ash Association Website: http://www.acaa-usa.org/
Beneficial Use	Beneficial and beneficial use means projects promoting public health and environmental protection, offering equivalent success relative to other alternatives, and preserving natural resources.
Blended Cement	Cement with a fixed percentage of pozzolans replacing the Portland cement clinker portion of the cement mix. Blended cement is usually understood to be cement that is blended by a cement manufacturer rather than a ready-mix supplier.
Bottom Ash	Bottom Ash means the agglomerated, angular ash particles formed in pulverized coal furnaces that are too large to be carried in the flue gases and collect on the furnace walls or fall through open grates to an ash hopper at the bottom of the furnace.
CAA	The Clean Air Act, 42 U.S.C. §7401 et seq. (1970), is the primary federal law that regulates emissions of pollutants into the air.
CAMA	Coal Ash Management Act – The nation's first comprehensive legislation to manage the disposal of coal ash, which became law September 20, 2014, as enacted in Part II of NC Session Law 2014-122.
CAMC	Coal Ash Management Commission – Commission established pursuant to CAMA to oversee the management of coal ash residuals throughout the state of North Carolina.
CCPs	Coal combustion products – means fly ash, bottom ash, boiler slag, or flue gas desulfurization materials that are beneficially used, including use for structural fill.
CCRs	Coal combustion residuals – means residuals, including fly ash, bottom ash, boiler slag, mill rejects, and flue gas desulfurization residue produced by a coal-fired generating unit destined for disposal. Note: The EPA's term "coal combustion residuals" when referring to beneficial use is synonymous with coal combustion products as defined herein.
Cement	The binder in concrete. Common materials used to manufacture cement include limestone, shells, and chalk or marl combined with shale, clay, slate, blast furnace slag, silica sand, and iron ore. These ingredients, when heated at high temperatures form a rock-like substance that is ground into the fine powder that we commonly think of as cement.
Cementitious	To have the qualities and properties of cement.

Clinker The main ingredient in Portland cement manufactured largely from limestone, clay and a variety of minerals and metals at high temperatures.

Coal Ash For purposes of this Report, coal ash will include both fly ash and bottom ash.

Concrete A mixture of gravel, broken stone, other particles and water in a cement or mortar mix.

CWA The Clean Water Act, 33 U.S.C. §1251 et seq. (1972), is the primary federal law that regulates discharges of pollutants into water. Primary sections of the CWA that may apply in the coal ash context include Section 401 (wetlands rules), 402 (the NPDES permitting system) and 404 (dredge and fill rules).

DA&CS NC Department of Agriculture and & Consumer Services
Website: http://www.ncagr.gov/

DEMLR NC Division of Energy, Mineral and Land Resources
Website: http://portal.ncdenr.org/web/lr/oilgas

DENR NC Department of Environment and Natural Resources
Website: http://portal.ncdenr.org/web/guest

DWM NC Division of Waste Management
Website: http://portal.ncdenr.org/web/wm/

DWR NC Division of Water Resources
Website: http://portal.ncdenr.org/web/wq/dwr-home-page

E&SC Erosion and Sedimentation Control Plan under the DEMLR sediment program.

Final EPA Rule EPA's Federal CCR Rule, 40 CFR Parts 257 and 261, Hazardous and Solid Waste Management System; Disposal of Coal Combustion Residuals From Electric Utilities; Final Rule as published in the Federal Register, Vol. 80, No. 74, Friday, April 17, 2015. This rule regulates coal combustion residuals impoundments, but does not regulate beneficial uses, except to provide a definition of beneficial use.

Fly Ash (Class C) Fly ash produced from the burning of younger lignite or sub-bituminous coal. In addition to having pozzolanic properties, it also has some self-cementing properties. In the presence of water, Class C fly ash ("C-ash") hardens and gets stronger over time. C-ash generally contains more than 20 percent lime (CaO). Unlike F-ash, self-cementing C-ash does not require an activator. Alkali and sulfate (SO4) contents are generally higher in C-ashes.

Fly Ash (Class F)	The burning of harder, older anthracite and bituminous coal typically produces Class F fly ash (“F-ash”). The fly ash is pozzolanic in nature, and contains less than 20 percent lime (CaO). Possessing pozzolanic properties, the glassy silica and alumina of Class F fly ash requires a cementing agent, such as Portland cement, quicklime, or hydrated lime mixed with water to react and produce cementitious compounds. Alternatively, adding a chemical activator such as sodium silicate (water glass) to an F-ash form a geopolymer. F-ash is the most prevalent class of fly ash in North Carolina.
LOI	Loss on Ignition – A test used in inorganic analytical chemistry, particularly in the analysis of minerals. It consists of strongly heating a sample of the material at a specified temperature, allowing volatile substances to escape, until its mass ceases to change. For purposes of this Report, LOI represents the amount of unburned carbon in coal ashes.
NPDES	National Pollutant Discharge Elimination System - The permitting scheme, created under Section 402 of the CWA, which covers discharges of point source pollution into waters of the United States. The NPDES program, while a federal program, is administered by the State.
Portland cement	Portland cement has traditionally been the basic ingredient in concrete.
Pozzolan	A mineral admixture that acts as a supplement to “standard” Portland cement hydration products to create additional binder in a concrete mix.

REGULATORY OVERVIEW

The use and disposal of coal ash triggers a number of different federal and state statutes and regulations. This section is intended to provide a brief overview of some of the primary laws and regulations that will be referenced later in this Report. It is not intended to be a comprehensive list. It is for educational purposes only, and is not intended to be, nor should it be, used as legal advice.

Currently, states are primarily responsible for regulating the various beneficial uses of coal ash.

Primary North Carolina laws include:

- Session Law 2014-122, which established the Coal Ash Management Act and Coal Ash Management Commission, defines "beneficial use" in North Carolina and sets forth liner, leachate collection, groundwater monitoring and permitting requirements for certain beneficial uses of coal ash in North Carolina.

- 15A NCAC 13B .1700 sets forth definitions relevant to the use of coal combustion products in North Carolina and regulates certain structural fills and use or reuse of by-products. Under 15A NCAC 13B .1701:

  (1) "Beneficial and beneficial use" means projects promoting public health and environmental protection, offering equivalent success relative to other alternatives, and preserving natural resources.
  (2) "Coal combustion by-products" means residuals, including fly ash, bottom ash, boiler slag and flue gas desulfurization residue produced by coal fired electrical or steam generation units.
  (3) "Jurisdictional wetland" means those areas that meet the criteria established by the United States Environmental Protection Agency for delineating wetlands and are considered by DWR to be waters of the United States.
  (4) "Structural fill" means an engineered fill with a projected beneficial end use constructed using coal combustion by-products properly placed and compacted.
  (5) "Use or reuse of coal combustion by-products" means the procedure whereby coal combustion by-products are directly used as follows:
    (a) As an ingredient in an industrial process to make a product, unless distinct components of the coal combustion by-products are recovered as separate end products; or
    (b) In a function or application as an effective substitute for a commercial product or natural resource.

- 15A NCAC 02T .1200 applies to the "treatment, storage, transportation, use, and disposal of coal combustion products (CCPs) that are defined as wastewater treatment residuals."

The NC Department of Environment and Natural Resources (NCDENR) is the principal state agency tasked with enforcing these rules. Within that agency, several divisions have jurisdiction over aspects of coal ash and its reuse.

Division of Waste Management (DWM)
Division of Water Resources (DWR)
Division of Energy, Mineral and Land Resources (DEMLR)

Certain beneficial uses may also trigger regulatory and permitting requirements from other state agencies such as NC Department of Transportation (DOT), NC Department of Health and Human Services (DHHS), and NC Department of Agriculture and Consumer Services (DA&CS).

Primary Federal Laws include:

- The Federal CCR Rule (referred to in this Report as the Final EPA Rule), published April 17, 2015, sets forth the federal definition of beneficial use (discussed below) and establishes rules governing coal combustion residuals impoundments. In this Final Rule, the EPA determined that coal ash would not be regulated as hazardous waste, but shall be treated as a Subtitle D solid/non-hazardous waste under the Resource Conservation and Recovery Act.

- The Clean Water Act (CWA) regulates the discharge of pollutants from sources such as coal-fired power plants and coal ash impoundments. The discharge of pollutants will generally trigger permitting requirements under the National Pollution Discharge Elimination System (NPDES).

- The Clean Air Act (CAA) regulates emissions from sources such as coal-fired power plants, cement kilns and other manufacturing facilities.

Each section will end with a brief discussion of the permitting and approval considerations specific to that particular beneficial use. Additionally, a comprehensive (but non-exhaustive) regulatory overview is provided in Appendix A. The regulatory information included throughout this Report was compiled in partnership with several state departments and divisions.

BENEFICIAL USES

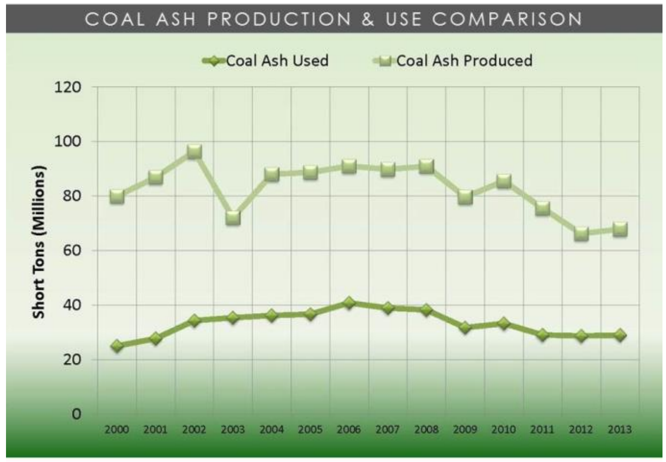


Figure 1 – Coal Ash Production & Use Comparison (ACAA)

Coal ash (fly ash and bottom ash) has been beneficially used throughout the world for over 70 years. During the 1990s, approximately 20 percent of coal ash produced in the United States was recycled. In 2000, the recycling rate reached 29 percent. That same year, the EPA issued its Final Regulatory Determination that regulation of coal ash as a "hazardous waste" was not warranted.[1] The regulatory certainty prompted the beneficial use industry to expand markets and develop new applications. Although the EPA's support of the beneficial use of fly ash dates back to the 1970s, if not earlier, the Agency began actively promoting the beneficial use of coal ash after its 2000 determination. Since 2004, the percentage of fly ash that is beneficially used each year has remained steady at around 40 percent (Figure 1). Historically, and still today, coal ash has predominately been used as an additive in concrete and concrete products (Figure 2).

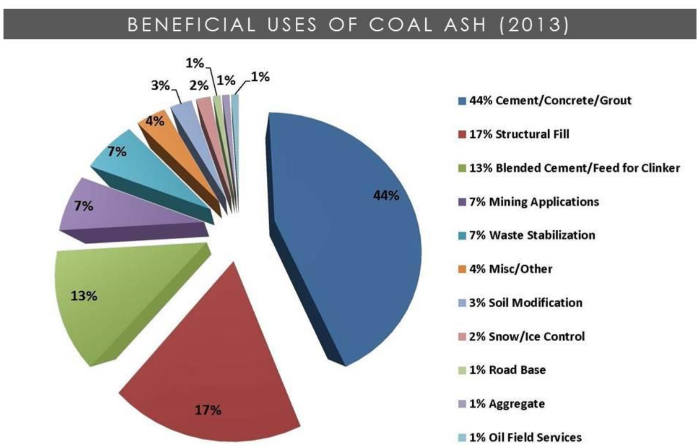


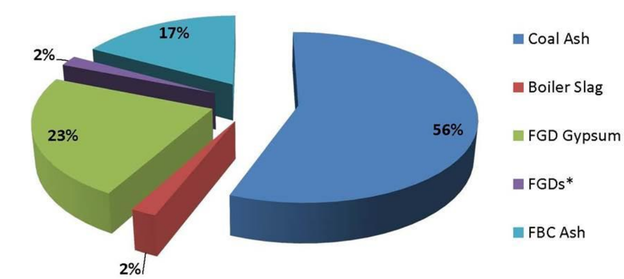
Figure 2 – Beneficial Uses of Coal Ash (ACAA)

In 2008, the failure of a coal ash disposal facility in Tennessee reopened the hazardous versus non-hazardous waste debate. With the door reopened, EPA once again considered whether coal ash (and all other coal combustion residuals) should be classified as a hazardous waste. In 2015, the EPA issued its second regulatory determination that regulation of coal ash and other CCRs as a "hazardous waste" is not warranted (the "Final EPA Rule"). Today, coal ash is classified as a Subtitle D solid/non-hazardous waste under the Resource Conservation and Recovery Act. Under the Final EPA Rule, the beneficial use of coal ash is still permitted. To be considered a beneficial use, an application must meet four criteria: (1) The coal ash must provide a functional benefit; (2) It must substitute for the use of a virgin material, thus conserving natural resources; (3) The use of coal ash must meet relevant product specifications, regulatory standards or design standards when available. If standards are not available, coal ash must not be used in excessive quantities; and (4) Un-encapsulated use involving placement on the land of 12,400 tons or more, except for road projects, must demonstrate that releases to groundwater, surface water, air and soil are comparable to or lower than those from analogous products made without coal ash, or that such releases will be at or below regulatory and health-based benchmarks.[2]

The North Carolina Coal Ash Management Act, which was enacted in the summer of 2014, also sets out criteria for what constitutes "beneficial and beneficial use". In North Carolina, a beneficial use of coal ash is a project that promotes public health and environmental protection, offers equivalent success relative to other alternatives, and preserves natural resources.

The beneficial use of coal ash, when conducted in an environmentally sound manner, can contribute significant environmental and economic benefits. Environmental benefits can include reduced greenhouse gas emissions, reduced need for disposing of coal ash in landfills, and reduced use of virgin resources. Economic benefits can include reduced costs associated with coal ash disposal, increased revenue from the sale of coal ash (and coal ash products), savings from using coal ash in place of other more costly materials, and job creation in the beneficial use industry.

RECYCLING RATES OF TOTAL CCPs USED (2013)



**FGD Material Wet Scrubbers, FGD Material Dry Scrubbers, and Other FGDs*

Figure 3 - Recycling Rates (ACAA)

This Report discusses the various beneficial uses of coal ash, and sets out to educate the state on how coal ash is and/or can be recycled. Although coal production generates multiple byproducts, as Figure 3 shows, coal ash is produced and used more than any other CCR, and as Figure 4 shows, fly ash is (and has been) the primary resource for coal ash recycling. With over 108 million tons of coal ash in North Carolina, we believe it to be vital to focus on the market for and science of the beneficial use of fly ash in the state. As such, this Report will focus primarily on the beneficial uses of fly ash, but will also address applications that utilize bottom ash in meaningful quantities.

COAL ASH RECYCLING (2013)

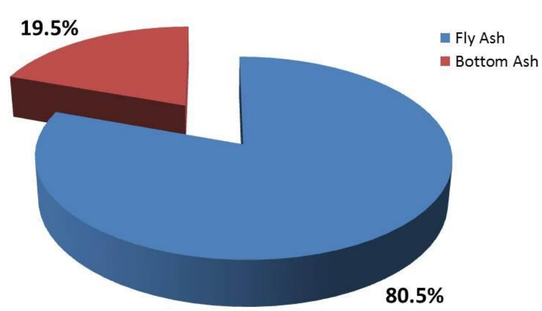


Figure 4 - Coal Ash Recycling in 2013 (ACAA)

CONCRETE

The most common and widespread beneficial use of fly ash is as a supplementary cementitious material in the manufacture of concrete and concrete products. As an admixture, fly ash can function as a partial replacement for, or a supplement to Portland cement. Fly ash and Portland cement share similar chemical properties, including constituents such as silica, alumina, iron and other oxides, which allows for the substitution of fly ash in concrete. Until fly ash interacts with other materials it possesses little to no cementitious value. However, when mixed with calcium hydroxide and water it chemically reacts to form compounds having cementitious properties. These specific pozzolanic reactions significantly enhance the strength, durability and long-term performance of the concrete, especially as compared to concrete made with typical percentages of Portland cement.

Fly ash concrete finishing (www.fhwa.dot.gov)

ENERGY SAVINGS AND LIFE CYCLE IMPACTS OF ONE TON OF FLY ASH IN CONCRETE	
Metric Measurement	**Amount**
Energy savings in dollars	$129.10
Water savings	376.3 liters or 99.4 gallons
Avoided total CO2 equivalent greenhouse gases (average)	718,000 grams or approximately .80 tons per ton of Portland cement
Equivalent passenger cars not driven for a year	.2
Equivalent avoided gasoline consumption	310 liters or 82 gallons
Equivalent avoided oil consumption	1.7 barrels or 53.5 gallons

Figure 5 - June 3, 2008 EPA Report to Congress (EPA 530-R-08-007)

The use of fly ash concrete yields a number of economic and environmental benefits. By altering the properties of concrete, fly ash increases strength, reduces permeability, decreases segregation and bleeding, improves workability and lowers heat of hydration (thus reducing the risk of cracking). The production of fly ash concrete requires less water and energy than its Portland cement counterpart. Estimates indicate that concrete made with fly ash requires between 3 to 10 percent less water to produce, and results in energy savings equal to 24 days electricity consumption of an average home for every ton produced.[3] In 2004 and 2005, this equated to energy savings valued at approximately $700 million, and water savings valued at approximately $1.2 billion.[4]

There are several important environmental benefits of using fly ash in concrete that have been identified by the EPA and are highlighted in the Final EPA Rule. When used in concrete and other cementitious construction materials like flowable fill (a beneficial use discussed in further detail later), the potential for leaching of heavy metals constituents to groundwater is greatly reduced. And it has been determined that even if a cement structure is demolished, the metals in coal ash will not leach. In EPA's Methodology for Evaluating Encapsulated Beneficial Uses of Coal Combustion Residuals,[5] the Agency highlights the benefits of the encapsulated use of fly ash in concrete and mentions that there is no merit for further regulating this type of beneficial use. Additionally, in February 2014, the EPA released a report in which it expressly announced its support of the beneficial use of fly ash in concrete.[6]

The substitution of fly ash results in benefits at every stage of concrete construction projects. The improved workability, short and long-term performance benefits, and energy and natural resource savings contribute to the reduction of production and construction costs. Using fly ash is estimated to reduce the cost of concrete by 17 to 25 percent compared to the price of traditional Portland cement.[7] The American Road and Transportation Builders Association approximates that for those states that can identify the use of fly ash in their transportation and construction markets, the total savings between 2006 and 2011 from fly ash concrete was roughly $2.3 billion.[8] The replacement of Portland cement with fly ash in concrete production in turn reduces the consumption of water and energy that is necessary to produce large volumes of cement. In addition, the use of fly ash decreases the need for virgin materials such as clay and limestone, and, by reducing the amount of manufactured cement needed to produce concrete, this beneficial use of fly ash accounts for *10 million tons of greenhouse gas emissions reductions each year*.[9] As with any encapsulated use of fly ash, the health and leachate concerns are minimal.

Photograph of the Hoover Dam (formerly Boulder Dam) from Across the Colorado River; from the series Ansel Adams Photographs of National Parks and Monuments, compiled 1941 - 1942, documenting the period ca. 1933 - 1942.

Fly ash was first recognized as a "suitable pozzolanic material" a century ago. The first major application of fly ash in concrete in the United States occurred in 1942 during the repair of a Hoover Dam spillway.

Globally, countries such as China, India, Canada and many European nations have been adding fly ash to concrete mixes since the 1950s. Worldwide, utilization of fly ash in concrete expanded in the 1970s and has generally increased over the past four decades. To date, this continues to be the most prevalent beneficial use of coal ash. Between 12 and 15 million tons of fly ash is used in concrete and concrete products nationally each year, and more than 50 percent of all ready mixed concrete placed in the United States contains fly ash.[10] Fly ash has traditionally been used as an additive in concrete at levels ranging from 15 to 30 percent by weight of the cement. Cement demand and current capacity in the United States is approximately 100 million tons per year, which would subsequently translate to 20 to 30 million tons of fly ash per year when the economic and supply market is favorable. However, with the noted crumbling of roads and bridges throughout the country, the demand for fly ash in concrete is expected to grow considerably in the years to come.

Projects with high cement replacement rates utilizing fly ash are on the rise. This is partly due to the reduced cost of fly ash versus Portland cement, but an equally important reason is the increased durability and resistance to environmental degradation. Projects utilizing concrete with fly ash are known to be less vulnerable to impacts from salt water and sulfates, and the negative impacts caused by freeze and thaw cycles. For example, the Olivenhain Dam in

California had a 65 percent fly ash replacement, using 152,000 tons of fly ash. The Olivenhain Dam was the first roller compacted concrete (RCC) dam in California and is the tallest in North America at 318 feet high. The use of fly ash was less expensive than conventional RCC; it reduced heat of hydration and thermal cracking, sped up dam construction (workability), and was denser and less permeable.

At 318 feet tall, the Olivenhain Dam is the largest roller-compacted concrete dam of its kind in North America.

Other high fly ash content replacement projects include: the Gulf Coast Waterway West (51 percent), a bridge abutment in Texas (70 percent) and several LEED hospital projects across the United States (50 percent).

Hungry Horse Dam, Montana, is a thick-arch structure that was built between 1948 and 1953 with concrete containing 120,000 metric tons of fly ash. The use of coal fly ash in concrete displaces Portland cement. Photograph from U.S. Bureau of Reclamation.

Although there continues to be some debate as to how much fly ash can be mixed without diminishing its performance and cost benefits, the current consensus suggests that utilizing fly ash in concrete at levels beyond 30 percent may impact the rate of construction and impair the long term performance of the final product. At rates above 30 to 50 percent, the properties of the concrete change. For example, an excess of fly ash in concrete products has been shown to extend set times and slow strength development. The same is true if poor quality fly ash is selected. However, these concerns can be largely addressed through the effective use of chemical admixtures, the reduction of carbon content to acceptable industry levels, and the testing of fly ash properties. For dams and other RCC projects, a slower set time and delayed strength are preferred, thus the reason for using higher replacement rates in those applications.

Replacement of cement with fly ash material continues to become a more common practice as technology advances and such advances are commercialized. The replacement of Portland cement for fly ash has been deployed since 2005 in Texas in over 700 miles of highway, Houston's Intercontinental Airport, Houston's Hobby airport and the Port of Houston. Houston's Intercontinental Airport is the 11th busiest airport in the United States for total passenger traffic and 5th for scheduled destinations resulting in the need for a highly reliable concrete product. These projects demonstrate over a 10-year track record of successfully using fly ash in runways and roadways that were also certified for use by the Federal Highway

Administration, Federal Aviation Administration and the Texas Department of Transportation. Fly ash has been utilized in some of these examples at replacement rates up to 40 percent.

In Texas, 750 lane-miles of paved road equates to the use of 200,000 tons of fly ash per year. Testing is being done to validate up to a 60 percent replacement for use in roadway applications. Other non-road applications have used fly ash products to replace ordinary cement up to 80 percent. Texas has made a concerted effort to increase the amount of fly ash in its state-funded construction projects to increase durability and reduce maintenance of its highways.

Innovative technologies and processes have been developed and are being commercialized that utilize processed fly ash in concrete. The benefits of these new technologies reduce the cost of production by 40 percent, capital cost by 60 to 90 percent, and greenhouse gas emissions by 90 percent by creating a new type of cement plant utilizing fly ash a raw material for a capital investment of approximately $25 million.

Carbon Content and Beneficiation of Fly Ash

Fly ashes typically contain some level of unburned carbon that can negatively impact the strength and durability of concrete materials. Specific limitations on the maximum allowable carbon content ("loss on ignition" or "LOI") in fly ashes destined for use in concrete are generally set by individual states. Many state transportation departments, such as the North Carolina Department of Transportation, and ready-mix concrete producers, specify that to be used in cement production, fly ashes must have a maximum LOI value of 4 percent. Carbon contents above 4 percent can have an adverse effect on air entrainment, which in turn can impact the quality and performance of the concrete products. Many fly ashes stored in wet ash basins have too high of an LOI or have reduced pozzolanic qualities to be beneficially used in concrete without being processed.

Three commercial technologies have been developed to "treat" such high LOI fly ashes: triboelectric (or electrostatic) separation (ST), carbon burn out (CBO) and stage turbulent air reactor (STAR). The ST process creates a triboelectric field, which imparts different electrical charges to the carbon and mineral particles. These particles are then separated with the aid of a conveyor belt into high-carbon and low-carbon product streams. The low-carbon stream is marketed as pozzolan in concrete, and the high-carbon stream is usually disposed of in landfills (although research is being conducted to identify the opportunities for the high-LOI product stream, including re-burning it in the utility's boiler). This process is typically implemented at the end of the utility generation process in order for "fresh" production ash to achieve an LOI within specifications to be sold for further beneficial use in concrete. Currently, there are eight ST plants in the United States, one of which is located in North Carolina.

In order to utilize an ST process, coal ash from ponds would have to go through a drying process prior to being further processed to reduce the LOI content. In North Carolina, Duke Energy's Roxboro plant has an electrostatic system at the end of the production line that processes 200,000 tons of fly ash per year. The capital investment necessary for an ST system ranges from a minimum of $10 to $15 million, up to $35 million, depending on the size of system.

CBO is a thermal process that burns the carbon in high-LOI fly ash. The resulting fly ash is a low-LOI fly ash that is used as pozzolan in concrete. There is no solid waste stream from this process. And since the resulting fly ash must be cooled before sending it to the marketplace, hot water can be generated as a byproduct of the CBO process, which the utility can beneficially use in their turbine cycle to improve power plant efficiency.

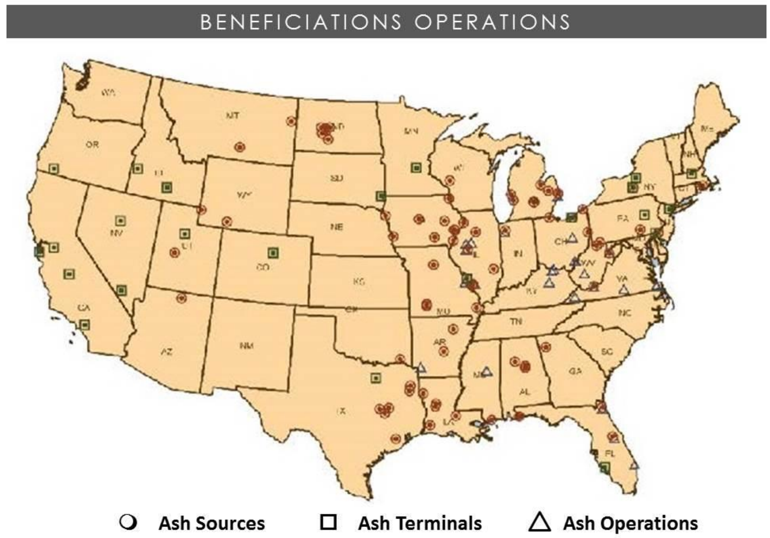


Figure 6 – Headwaters Resources Beneficiation Site Locations

In addition to being able to lower the LOI of fly ash, the STAR process, which is also a thermal process, can remove all the carbon in fly ash so that the purified mineral matter can be used as raw feed material in other products and processes that historically have been unable to use fly ash as raw feed material because of the deleterious effect of residual carbon in fly ash. The STAR process does not generate any solid waste stream and generates hot water as a byproduct, which could potentially be beneficially used. Preprocessing can be reduced with the STAR process, as compared to an ST process, since the STAR process is able to take ash with 40 percent moisture content (other process tolerate less than a 20 percent moisture content) and LOI over 20 percent (the highest LOI reprocessed to date was 26 percent).

The STAR facility at NRG's Morgantown Station is sized to process up to 360,000 tons of ash per year, which represents 100 percent of the ash generated at NRG's Morgantown and Chalk Point Stations. The facility sells 100 percent of the processed ash to the concrete industry. As a result of the beneficiation facilities in Maryland, in 2013, nearly 80 percent of the Class F fly ash produced in the state was beneficially used. The STAR facility is one of five thermal processing plants in the United States, none of which are located in North Carolina.

The upfront start-up costs associated with the construction of a CBO or thermal processing plant typically range from $40 million to $50 million in addition to operating and maintenance costs. However, these processes produce viable products with real market demand not only domestically, but also globally. To achieve an acceptable return on investment for a thermal beneficiation type of process requires operating it over 15 to 20 years depending on the demand of fly ash for use in cement replacement.

Preprocessing of ponded ash material broadly entails dewatering an ash pond, excavating and drying the material before the ash can be transported, stored or further processed for beneficiation. The state of the ash pond, contents other than coal ash, and the embankment integrity are all factors that influence the time and cost for preprocessing, which ranges from about $12 per ton to $36 per ton. The wide variation in the range of cost for preprocessing and dewatering of wet ash basins and saturated ash materials is a reflection of the fact that the "state of the practice" is still evolving.

Various states set out different minimum and maximum requirements for the use of coal ash in concrete. In California, the state DOT (Caltran) has a mandate to replace about 25 percent of its cement with fly ash. Texas allows for 40 percent replacement. States may also regulate the percentage of carbon that can be present in the coal ash. On May 1, 2015, NCDOT revised its standard specifications for roads and structures to increase the limit of replacement of cement by fly ash to 30 percent (up from 20 percent) and to replace the cement with fly ash at a rate of 1 lb. of fly ash for each 1 lb. of cement. In North Carolina, to be used in concrete products, the LOI of the fly ash must not exceed 4 percent.

In 2013, 12,356,726 tons of fly ash and 494,074 tons of bottom ash were beneficially used in concrete and concrete products in the United States.[11] According to NCDOT, since 1989, North Carolina has used, on average, only 14,271 tons of fly ash per year as an additive in concrete mix.[12] Between July 1, 2013 and June 30, 2014, use was higher than the average at 21,159 tons.[13]

There is clearly room to grow the fly ash concrete market in North Carolina. The state currently uses over 7 million cubic yards of concrete a year in a combination of roadway, building and civil work construction projects. *Rough estimates suggest that by increasing the percentage of cement replacement to be up to 30 percent, approximately 450,000 tons of fly ash could be utilized each year, all while increasing the durability and strength of the concrete mixtures*.

Permitting and Approval Considerations

The use of coal ash in concrete products is deemed permitted under 15A NCAC 02T, and no permit is required under 15A NCAC 13B. However, NCDOT and the State Construction Office should be consulted, and industry guidelines should be followed.

For more detail, see Appendix A.

PERMITTING AND APPROVAL FOR CONCRETE APPLICATIONS					
DWM	DWR	DEMLR SEDIMENT PROGRAM	DEMLR STORMWATER PROGRAM	DEMLR DAM SAFETY PROGRAM	DEMLR MINING PROGRAM
PROJECT DEPENDENT	**DEEMED PERMITTED**	**PROJECT DEPENDENT (e.g., size)**	**PROJECT DEPENDENT (e.g., size)**	**-------- (unless Jurisdictional Dam built for project)**	**-------**

STRUCTURAL FILL

Structural fill or embankment material is the second largest use of fly ash after concrete production and the largest use of bottom ash. In 2013, approximately 3 million tons of fly ash and 1.9 million tons of bottom ash were placed in structural fill and embankment projects in the United States.[14]

Fill projects are typically constructed by compacting earthen materials such as local soil and rock to form a strong, relatively impermeable base layer. Some soils and rock types cannot provide a suitable foundation without expensive modification or additional design requirements. If local soil is too weak to support a structure, compacted coal ash can serve as a replacement for native materials and can help reclaim otherwise undevelopable land. Due to its high shear strength, particularly relative to its low unit weight, fly ash is well suited for placement over soft or low bearing strength soils which could not otherwise provide a strong, stable base. The use of fly ash as structural fill material results in minimal settlement and provides sufficient bearing support for construction of commercial or industrial projects. In embankment projects, the use of coal ash can improve soil conditions, increase plant growth, reduce runoff and prevent erosion.

To avoid settlement over time, fill material must have low compressibility and have consistent permeability. These requirements can be addressed through the proper compaction of fill material. The compaction of soil or soil alternatives is critical. Compaction properties of the material, such as optimum water content and maximum dry density (i.e., that point where there is little potential for additional compaction) greatly impact performance.

For fly ash in particular, moisture control is essential. In order to achieve the level of compaction required for a fill project, prevent flash setting or hardening, and reach its maximum shear strength potential, fly ash must be placed at or near its optimum moisture content as determined by industry guidelines. The optimum point and required control measures differ depending on the type (i.e., F-ash vs. C-ash) and source of the fly ashes (e.g., landfilled or ponded). However, optimum moisture content is typically between 20 and 30 percent. Maintaining the proper moisture content generally requires some moisture conditioning of the fly ash prior to loading for transport (either watering or dewatering), and once again after delivery to the structural fill project site. Such measures are, however, not uncommon in fill projects and are minimal, particularly when compared to the processing requirements for use of fly ash in concrete.

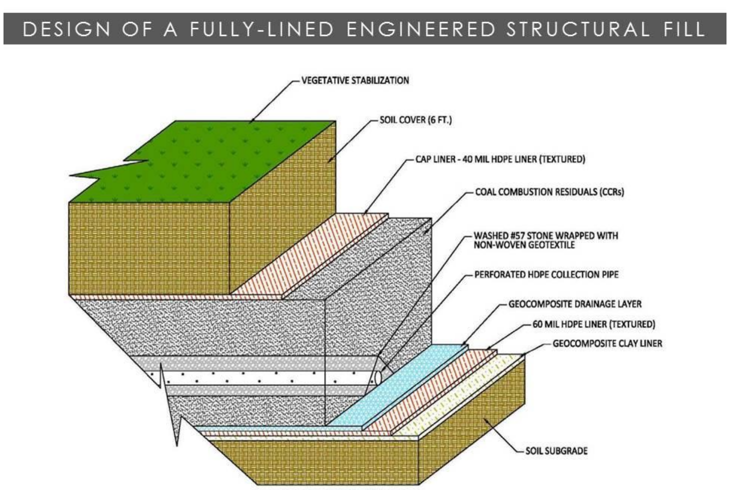


Figure 7 - Fully-lined Engineered Structural Fill (Charah)

The cementitious and pozzolanic qualities of the coal ash used for structural fill are less restrictive than other beneficial uses; *nearly all fly ashes can be utilized in fill projects, including ponded ash that has been reclaimed from an ash lagoon and ashes with a LOI* *greater than 4 percent. That is why we believe combining structural fill programs with concrete initiatives is an effective complement for beneficial use.* The ash that can economically be used in concrete would be sold into that end use market, while much of the balance could be deployed as structural fill. However, despite the reduced processing requirements, the unique physical and chemical properties of coal ash must still be considered when engineering and designing the beneficial use projects discussed in this section. Industry guidance is widely available.

In addition to its performance benefits, the ease with which fly ash can be placed and compacted (at the proper moisture content) results in reduced construction time and decreased equipment costs. Its use as a replacement for soil, rock and sand also conserves virgin materials that are not as readily available in bulk quantities. The Asheville Airport (discussed below) provides an example of the cost and material savings associated with structural fill projects.

Across the United States there are two primary types of structural fill approaches, both of which have been used with no documented environmental impacts. The first type involves placement and compaction of a pre-tested and approved fly ash-cement or fly ash-lime mixture. The mixture is placed above the water table and designed to control the pH and other material properties so that the potential leaching of heavy metal constituents is contained. This type of fly ash structural fill has been effectively used beneath roadways, airport runways and large embankment projects, and is applicable when a combination of strength and reduced permeability of the entire fly ash matrix is required. The second type of structural fill is one where a liner and leachate collection system is used to create a Subtitle D-like structure for the fly ash materials. This lined structural fill method is the main type of fly ash placement, and was the structural fill strategy utilized at the Asheville Airport.

Both unlined structural fills with cement/lime additives and lined structural fills with a leachate collection system require a low permeability final cover system consisting of either a liner or clay-like material. The purpose of the cover system is to shed excess water off the surface and prevent infiltration of water into the structural fill after construction is complete. Both of these methods, if properly designed according to industry standards and applicable NCDENR requirements provide suitable protection of the environment and groundwater resources.

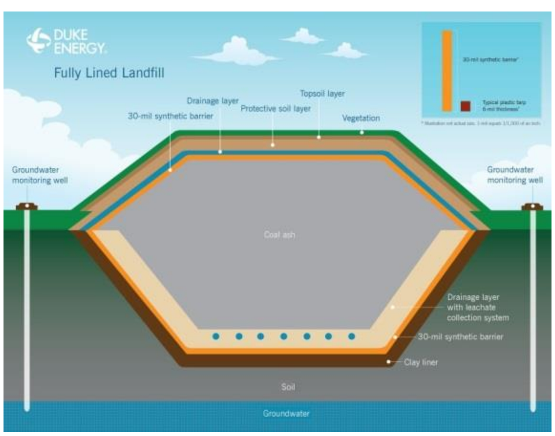
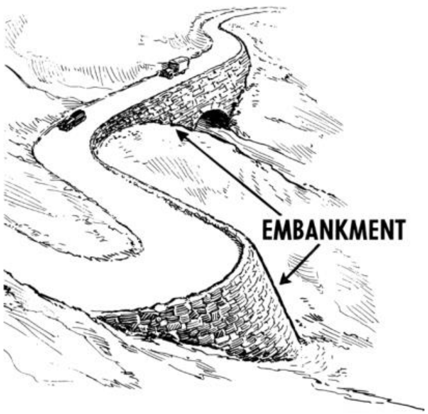


Figure 8 – Fully- lined Landfill (Duke Energy)

In a fully lined structural fill, the ash is placed in controlled lifts over an engineered liner and leachate collection systems, with the top and bottom impermeable liners being heat-welded together to encapsulate the ash. In an unlined but additive amended structural fill, the fly ash is encapsulated by the cementing of the fly ash in reaction with the cement or lime additives. The permeability is greatly reduced throughout the fly ash matrix, and the structural strength and stability of the material is increased. Since the passing of the Final EPA Rule and the NC Coal Ash Management Act, both of these methods would need to be designed to meet the requirements of the EPA Methodology for Evaluating Encapsulated Beneficial Uses of Coal Combustion Residuals and guidelines provided by NCDENR. The requirements for both lined and cement/lime additive stabilized structural fills will require a complete site characterization, leachability testing of the fly ash and stabilized ash mix, and documentation that infiltration is controlled and the groundwater is protected.

For both types of structural fill methods, after the required cover liner has been placed, the site is covered with a thick layer of soil to promote vegetative growth. The type of cover liner system and the depth of vegetative cover soils are typically determined by state requirements and/or design considerations of the project's Professional Engineer. As shown in Figure 8, a properly constructed structural fill project has the same containment qualities as a lined landfill or cement stabilized embankment, but there are added commercial benefits as well as the environmental benefits from moving the coal ash away from surface water supplies, where many current wet ash basins are located.



Coal ash has successfully been used as fill material in embankment and structural projects around the world. The types of embankment and structural fill projects differ. Embankments are commonly found along highways and next to bridges. In embankment projects, coal ash serves as both a soil alternative and soil additive. The use of compacted coal ash reduces runoff, prevents erosion, improves soil conditions and increases plant growth (as explained in further detail in the Agriculture section). According to T, since 1989 North Carolina has used, on average, 34,607 cubic yards of fly ash and 108 cubic yards of bottom ash in embankment fill each year.[15] By comparison, as of 2009, over 1.3 million tons of ash had been placed in highway embankment projects across the state of Wisconsin. Wisconsin's beneficial use success can largely be attributed to the partnership between Wisconsin Public Service and the Wisconsin Department of Transportation, and the state's NR 538 rules (which save time for both regulators and byproduct generators by describing when and how coal ash can be used in a project).

Coal ash has been used as structural fill in constructing foundations for industrial facilities, commercial buildings, airport runways and athletic fields in North Carolina. In 2011 at least 73,500 tons (dry tons) of local coal ashes were distributed for intended use in structural fill; in 2012, at least 65,000 dry tons were distributed; in 2013, at least 665,000 dry tons were distributed; and in 2014, at least 83,500 dry tons of local coal ashes were distributed for intended use in structural fill projects. To date, a total of 61 regulated coal ash structural fills have been constructed across the State.

Fully-lined engineered structural fill at Asheville Airport (Charah)

For example, fly ash is being used as structural fill material in the construction of a new taxiway at the Asheville Regional Airport. As part of the airport expansion project, over 4 million tons of fly ash have already been placed in a fully lined engineered structural fill, with approximately 1-2 million tons more expected to be used during additional phases of the expansion. The project also includes a leachate collection system and groundwater monitoring.

A liner is laid out at the Asheville Regional Airport as part of a structural fill that has used approximately four million tons of coal ash in the airport expansion project. (NC Department of Environment and Natural Resources)

Ash placement over lined fill at Asheville Airport (Charah)

Duke Energy is providing the ash at no charge to the airport. By avoiding the need to purchase its own fill material, the Asheville Airport will save an estimated $12 million on material alone. The availability of low cost high quality fill material in close proximity to a large civil works project like the Asheville Airport project is often the most important financial consideration. In mountain regions or locations with shallow bedrock like those prevalent near Asheville, fill material can cost between $4 to $6 per cubic yard and be located in multiple borrow areas, increasing the distance between material site and project site. In the case of the Asheville Airport project, the power plant was located within a 2 mile roundtrip. In addition to the cost savings, this beneficial use resulted in the reclamation of land that, without the use of a soil alternative such as coal ash, could not have been used in the airport's reconstruction and expansion. The airport also plans to use the ash in the reconstruction of its main runway.

Asheville Airport, April 29, 2015 (Photo by Dr. Rubin, Environmental Management Commission)

In the Final EPA Rule, the EPA expressed concerns about unencapsulated uses. For clarification, these types of uses would include the placement of fly ash (and other CCRs) without the use of bottom liners or cement/lime additives. Open placement of coal fly ash in unlined fills or without additives can raise legitimate concerns about leachate, groundwater contamination and dust, and should be adequately considered prior to, during and after fill projects. The leaching of heavy metal constituents appears to be the primary concern associated with the use of coal ash as fill material. Coal ash is known to contain common elements, such as silicon, iron, and calcium and certain ashes have trace elements of potentially dangerous metals such as arsenic, selenium or mercury, among others. The Final EPA Rule, NCDENR regulations and the NC Coal Ash

Management Act all require that the design, placement and construction of structural fills involving any type of coal ash provide protection for groundwater and surface water by the use of appropriate liner systems or cement/lime additives.

During the design and construction of any type of structural fill that utilizes coal ash, the potential contamination of surface water, groundwater and drinking water should not be overlooked. While there are a number of studies which demonstrate that trace element concentrations in fly ashes are similar to those found in naturally occurring soils, concerns about leachate can be mitigated by stabilizing the fly ash with a reasonable amount of lime or cement, and proper design by a registered Professional Engineer and/or Geologist. There have been numerous field and laboratory studies that have demonstrated that the addition of a relatively low percentage of hydrated lime in the range of 2 to 3 percent can result in significant improvements in leachate quality and/or eliminate the potential for leaching of heavy metal constituents. The addition of a cementitious material such as lime or cement as part of a carefully designed structural fill can serve to encapsulate the ash and achieve both environmental and constructability objectives. The potential for infiltration can also be addressed by assuring adequate compaction, grading to promote surface runoff, and daily proof-rolling of the finished subgrade to impede water infiltration during the construction process.

Given its particle size and light weight, fly ash is susceptible to wind erosion. As with any earthwork operation, to control for dust the following preventative measures can be undertaken to mitigate the risk of airborne particulates during transport and at the project site:

- the use of covered dump trucks or pneumatic tankers,
- moistening the fly ash prior to delivery,
- utilizing proper ventilation and extraction procedures, and,
- once placed at the site, regularly wetting or covering the surface with a compactor.

As with any process that involves potentially hazardous substances, employees should be trained, protocols should be developed, emergency procedures should be identified and monitoring should be conducted.

Permitting and Approval Considerations

Structural fill projects are specifically excluded from the definition of beneficial use under the Final EPA Rule, unless they meet the four criteria set forth for beneficial use under that rule and address the encapsulation guidelines provided in the EPA Methodology for Evaluating Encapsulated Beneficial Uses of Coal Combustion Residuals. If a project fails to qualify as a beneficial use and/or an encapsulated product or method, then it must comply with all other requirements of the Final EPA Rule for disposal of CCRs. Those projects using greater than 8,000 tons per acre or 80,000 tons for the entire project will be subject to permitting requirements under CAMA, as well as liner, leachate collection and cap requirements. State law also sets forth buffer requirements, and other siting, design, construction and operations rules under CAMA and 15A NCAC 13B .1700 for all structural fill projects. Surface water runoff and dust control measures will also apply.

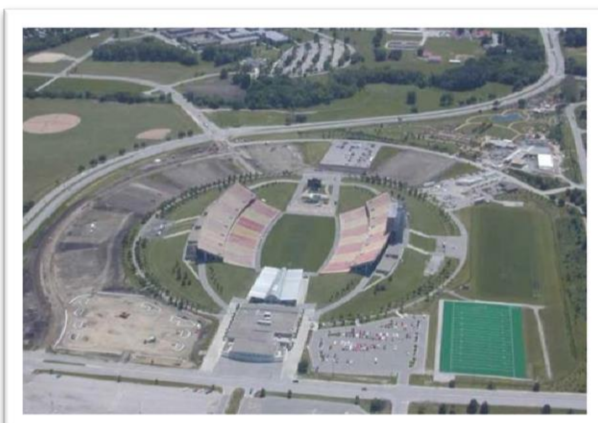
For more detail, see Appendix A.

PERMITTING AND APPROVAL FOR STRUCTURAL FILL APPLICATIONS						
DWM	DWR	DEMLR SEDIMENT PROGRAM	DEMLR STORMWATER PROGRAM	DEMLR DAM SAFETY PROGRAM	DEMLR MINING PROGRAM	FEDERAL
PERMIT REQUIRED	--------	PROJECT DEPENDENT (e.g., size)	PROJECT DEPENDENT (e.g., size)	--------	PROJECT DEPENDENT	FEDERAL LANDFILL RULES APPLY

ASPHALT

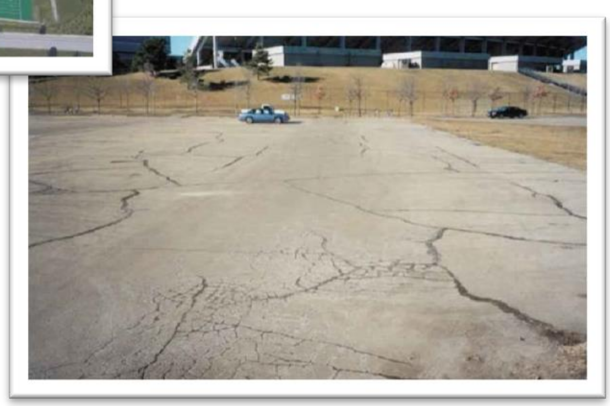
Fly ash can be used as mineral filler in hot mix asphalt concrete. Mineral fillers, such as fly ash, hydraulic lime and limestone, are used to fill any voids in asphalt mixes, increase asphalt mortar mix stiffness, improve rutting resistance and increase mix durability. Asphalt pavements with coarse gradations have been shown to perform well under heavy traffic conditions; therefore, asphalt mixture gradations are becoming increasingly coarser. As a result, mineral fillers are now more prevalent. Fly ash can also serve as a partial replacement of asphalt cement. Due to the lower specific gravity of fly ash and its ability to perform comparably to other fillers, less material is needed, and because fly ash is generally cheaper than asphalt, the use of fly ash can be an economical alternative in asphalt paving applications. Costs can be further reduced when fly ash is available locally.

Research over the years has shown that fly ash is a suitable filler material in terms of mixing, placing and compaction, stability, resistance to water damage and flexibility. Additions of fly ash to asphalt mixtures can improve asphalt hardening, fatigue life, moisture and freeze-thaw resistance, and tensile strength (i.e., the maximum stress it can withstand before failing). Typically, fly ash will meet mineral filler specification requirements for gradation, organic impurities and plasticity. Because it is hydrophobic (i.e., non-water wettable) and often contains lime, fly ashes can reduce the potential for asphalt stripping.



Jack Trice Stadium, Iowa State University, Ames, IA (ACAA)

Fly ash can also be used in reclaimed asphalt pavement ("RAP") projects. The parking lot at Iowa State University's Jack Trice Stadium is a RAP success story. In 2006, the parking lot was notably deteriorating. The University considered two design options.[16] The first included 8 inches of gravel stabilized with an asphalt emulsion. The second included 12 inches of reclaimed asphalt pavement stabilized with Class C fly ash. The latter was chosen. In reconstructing the parking lot, the existing pavement was reclaimed and reprocessed before the fly ash was spread and mixed with the reclaimed asphalt at the rate of 10 percent. Water was added



Deteriorating asphalt pavement at Jack Trice Stadium.

to the mixture to activate the calcium oxide in the C-ash to properly stabilize the subgrade. The final step was to add the new hot mix asphalt pavement. Quality control testing was performed in both the laboratory and the field. In particular, analysis of the fly ash was performed to determine, among other things, optimal gradations and the proper fly ash and moisture content.

Photo of parking lot eight years after repairs using Class C fly ash and reclaimed asphalt (ACAA).

A primary consideration in selecting the fly ash design was cost. The fly ash approach was almost half as expensive as the alternate design, at $4.10 per cubic yard versus $9.40 per cubic yard.[17] After eight years, the parking lot has only required routine maintenance like stripping and occasional sealcoating.

Coal ash – bottom ash in particular – can also be beneficially used in cold-in place asphalt applications. Bottom ash is usually sufficiently well-graded to meet gradation requirements for asphalt concrete, especially if it is produced in dry bottom boilers. It has been observed, however, that bottom ash is less durable than conventional aggregates. Consequently, bottom ash is better suited for use in base course and shoulder mixtures or in cold mix applications, as opposed to wearing surface mixtures (i.e., hot mix asphalt). Most bottom ash paving applications have been cold mix projects on low-volume secondary roadways.

Despite the observed benefits, the use of fly ash in asphalt has been relatively limited. The ACAA last reported the use of fly ash as mineral filler in asphalt in 2008. That year, 7,781 tons of fly ash and 257,806 tons of bottom ash were used in asphalt applications in the United States.[18] Since then, the ACAA has not specifically documented this beneficial use in its annual CCP Production and Use Report. Although North Carolina has reported using fly ash as mineral filler in the past,[19] its use in asphalt has not been documented by the state. When ash is used, the rate of application is often low, in the range of 1 to 5 percent of the total asphaltic concrete by weight.

Over the years, a few states have reported that fly ash performed poorly as a filler material and discontinued or eliminated the use of ash in asphalt applications.[20] It has also been observed, in isolated instances, that asphalt paving mixes with fly ash mineral filler have been tender and difficult to compact during hot weather. It seems that if the market for coal ash in asphalt paving applications is to grow, methods for assessing the suitability of coal ash in asphalt projects need to be developed and/or improved, and field performance testing, which is currently being done around the country, needs to continue; and results need to be assessed.

Permitting and Approval Considerations

The use of coal ash in asphalt products is deemed permitted under 15A NCAC 02T; no permit is required under 15A NCAC 13B. However, NCDOT and the State Construction Office should be consulted, and industry guidelines should be followed.

For more detail, see Appendix A.

PERMITTING AND APPROVAL FOR ASPHALT APPLICATIONS					
DWM	DWR	DEMLR SEDIMENT PROGRAM	DEMLR STORMWATER PROGRAM	DEMLR DAM SAFETY PROGRAM	DEMLR MINING PROGRAM
PROJECT DEPENDENT	**DEEMED PERMITTED**	**PROJECT DEPENDENT (e.g., size)**	**PROJECT DEPENDENT (e.g., facility permitting)**	**-------- (unless Jurisdictional Dam built for project)**	**-------**

STABILIZED ROAD BASE

High Carbon Fly Ash can be a viable stabilizing material (www.dot.state.mn.us)

Coal ash has also been used in highway construction projects as an aggregate for subgrades and road base. In road construction, the base layer must be able to support vehicular load bearing, withstand the deteriorating effects of climate and water, and maintain its strength and stability. Since most road erosion and sedimentation problems originate from unstable base, building a stable base is a vital step in highway construction. As is often the case in a variety of fill projects, local soils may not be inherently stable (i.e., incompressible and impermeable) and are therefore not well suited to provide an adequate base layer without stabilization. A stabilized base serves as a transitional load-bearing stratum between the pavement layer and the underlying subgrade soil. Conventional methods for obtaining the necessary stabilization include removing the soft soil and replacing it with a stiffer material such as gravel, and artificially stabilizing the soil through physical and chemical techniques. Both methods are often costly and time consuming.

The use of fly ash in road base stabilization ("ash bases") has a number of benefits. Fly ash lowers the soil water content, reduces shrink-swell potential, increases workability, and improves soil strength and stiffness. These superior properties result in roadways that last longer and need less maintenance, thereby reducing costs. Both C-ash and F-ash can be used; the process for achieving the optimum mix differs based on which type is obtained. C-ash is mixed with aggregates and water; it does not generally require a chemical reagent or additive. In some instances, this ash may actually be used by itself. Because it is typically self-cementing, the amount of C-ash used should be in the 5 to 15 percent range to prevent flash hardening.

Unlike C-ash, F-ash is usually combined with another binder material, such as lime, Portland cement or kiln dust, to aid in aggregating the particles together. When used with a chemical reagent, F-ash normally comprises between 10 and 20 percent by weight of a stabilized base or sub-base mix. When used with lighter weight aggregates (such as bottom ash or sandy aggregates), the percentage of fly ash may be as high as 30 percent.

As compared to other beneficial uses, bottom ash is used more often than fly ash as stabilized base material. In 2013, 136,318 tons of fly ash and 228,517 tons of bottom ash were used in this application in the United States.[21] Although used in much the same way as fly ash (i.e., typically mixed with a binder material), bottom ash has been used at rates as high as 46 percent. For example, the first known large-scale use of cement-stabilized bottom ash base was the relocation of West Virginia Route 2 in 1971. The aggregate used was a blend of bottom ash and boiler slag, which was mixed with approximately 5 percent of Portland cement. The roadway provided excellent service for over 10 years at a substantial reduction in cost compared with the use of conventional aggregates.

Route 2, West Virginia

Whether fly ash or bottom ash is used, once the stabilized base material has been mixed and amended with appropriate additives the material must be moisture conditioned and compacted in much the same way as structural fill material. The mixture should be conditioned and compacted at or near its optimum moisture content to maximize compaction and minimize the risk of flash hardening. After compaction, the stabilized base material must be properly cured to protect against drying and to assist in strength development. If the road base or sub-base will be covered by an asphalt layer, it is common for the contractor or engineer to require curing for 7 days before pavement is placed.

Newark Metropolitan Airport Administration Building was the first commercial airport terminal in the US and was relocated during expansion of what is now Newark Liberty International Airport.

Fly ash has been identified in numerous state DOT and Federal Highway Administration manuals as a cost-effective, time saving alternative to the traditional techniques, and has been successfully used to improve the strength characterizations of soils in a number of stabilization projects. Over the past two decades, at least 22 states have used fly ash in stabilized base or sub-base material. Many of these stabilization projects have been done in low traffic areas such as local streets or parking lots; although one of the largest single reported projects in the United States occurred in the 1970s during the construction of runways, taxiways and aprons at Newark International Airport in Newark, New Jersey. More recently, approximately 1000 feet of highway pavement base was stabilized with fly ash in Georgia. A two-year monitoring study of the impact of fly ash on the structural integrity and groundwater at the Georgia site revealed:

- Ash-stabilized sections performed better than the control section for the duration of the monitoring period;
- Generally, there was little pavement deterioration;
- Less cracking occurred; and
- Groundwater monitoring provided little to no evidence of leaching, and measured concentrations posed no threat to groundwater quality in the test-section area.

Conservative estimates indicate that since the 1970s, at least 25 to 30 million tons of ash base material has been placed in the United States. According to NCDOT, between 1989 and 2014 there have been no documented ash base projects in North Carolina.[22] Despite its documented durable, long-lasting performance, some highway engineers worry that ash bases may be susceptible to reflection cracks (i.e., the development of cracks within the base course that may reflect up to the payment surface). This concern is not particular to ash bases, as any improperly stabilized or unsuitable base can lead to cracking of the pavement surface; however, studies from other states indicate that ash bases may be more susceptible to both transverse and longitudinal cracking, especially when Portland cement was a part of the mixture. The risk of cracking has contributed to the fact that, to date, most ash base material has been applied in secondary roads, haul roads and parking lots, where the consequences and impact are less than a major highway. To mitigate these concerns concrete pavement can be used and/or the pavement can be sealed to prevent the intrusion of water and subsequent damage due to freezing and thawing.

The placing of fly ash mixtures on or near soils, such as stabilized road base, has raised concerns about trace element leaching. Siting considerations, such as the location of nearby aquifers, and ongoing monitoring (i.e., leach testing) are important to the immediate and long-term health of groundwater resources. As discussed, however, a number of studies have demonstrated that soils stabilized with fly ashes pose no greater risk for contamination of groundwater than leaching from natural or unstabilized soils. For example, in a study conducted by the University of Wisconsin-Madison's Geological Engineering Department, leachate water quality monitoring data from six field sites utilizing fly ash stabilized subgrade or base layers in Minnesota and Wisconsin was evaluated.[23] The University assessed 17 trace elements based on stated and federal water quality limits. Overall, the study found that in terms of potential trace element impact on the environment, there are no additional risks imposed by using unbound fly ash in roadways than roadways constructed with conventional construction materials. Although the specific field conditions of each stabilized road base project should be evaluated, the studies demonstrate that water quality concerns can be addressed.

Permitting and Approval Considerations

Use of coal ash as a base or sub-base under paved roads, parking lots, sidewalks or similar structures may require permits under 15 NCAC 02T or Session Law 2014-122 if it reaches a certain thickness or tonnage. NCDOT and the State Construction Office should also be consulted, and industry guidelines should be followed.

For more detail, see Appendix A.

PERMITTING AND APPROVAL FOR STABILIZED ROAD BASE APPLICATIONS

DWM	DWR	DEMLR SEDIMENT PROGRAM	DEMLR STORMWATER PROGRAM	DEMLR DAM SAFETY PROGRAM	DEMLR MINING PROGRAM
------	PROJECT DEPENDENT (e.g., depth)	PROJECT DEPENDENT (e.g., size)	PROJECT DEPENDENT (e.g., size)	------	------

FLOWABLE FILL

Flowable fill application (Headwaters Resources, Inc.)

Flowable fill is an engineered, strength-controlled "liquid" fill material that is used as a self-leveling, self-compacting backfill material in lieu of compacted earthen (e.g., soil) or granular fill. This fill material is delivered in a "liquid" form similar to workable concrete. Conventional flowable fill mixtures typically include fill material (e.g., coarse or fine aggregates such as sand, fly ash, blast furnace, slag and other pozzolan materials), cementitious material (e.g., Portland cement) and mineral admixtures (e.g., lime). Fly ash can be used as a replacement or partial replacement for all three constituents. Flowable fills are most commonly used in highway construction, with applications including trench backfill for storm drainage and utility lines, a wide variety of environmental remediation projects, and as fill material for retaining walls, bridge abutments, underground storage tanks, abandoned sewers or pipelines and building excavations.

The two basic types of flowable fill mixes that contain fly ash are high fly ash content and low fly ash content. The high fly ash content mixes typically contain 95 percent fly ash and 5 percent Portland cement, and enough water to make the mix flowable. F-ash is well-suited for use in high fly ash content mixes. Low fly ash mixes typically contain a high percentage of fine aggregate or filler material (usually sand), a low percentage of fly ash and Portland cement, and enough water to also make the mix flowable. Due to its self-cementing character, C-ash is typically used only in low fly ash content mixes and is added in a dry condition to avoid presetting. Similar to structural fill projects, there are no specific requirements for the types of fly ash that may be used in flowable fill mixtures (i.e., high LOI ashes may be used). Aside from F-ash versus C-ash considerations (i.e., differing composition and characteristics), ashes can practically be used as is. No special processing is required. Likewise, in addition to dry or conditioned fly ash, reclaimed ash from ponds may also be suitable for use in flowable fill.

Depending on the type and location of void to be filled, flowable fill can be placed by chute, conveyor, pump, or bucket. Because flowable fill is self-leveling, it needs little or no spreading or compacting. This speeds construction and reduces labor requirements.

The inherent characteristics of fly ash make it particularly well-suited for use in flowable fill. Its fine particle size and spherical particle shape enhances mix flowability, and its pozzolanic or cementitious properties allow for lower cement content than would normally be required to achieve equivalent strengths.

LABOR COST OF FLOWABLE FILL VS. GRANULAR FILL		
Project	**Flowable Fill**	**Granular Fill**
Placement	$36.99	$73.98
Compaction	--	$73.98
Heavy Equipment Operator	--	$40.33
Hand Compactor	--	$15.00
Backhoe	--	$25.00
TOTAL LABOR COSTS	**$36.99**	**$228.30**

Figure 9 - Flowable Fill vs. Granular Fill (National Ready Mixed Concrete Association)

As compared to granular fill, flowable fill is a cost-effective and less time consuming application. It can be utilized without the use of compaction equipment (it is essentially self-compacting) and related labor, and no onsite storage is needed, thus decreasing construction and overhead costs. As Figure 9 indicates, granular fill projects can cost over *6 times more* than flowable fill.

Flowable fill also reduces the days needed to complete a project. This is especially true when the hole or trench to be backfilled is wet or the trench to be filled is not wide enough to accommodate compaction equipment. If earthen material or granular fill is to be used, and the hole is wet, the project will be delayed until the contractor believes it is dry enough to not impact compaction. Drying takes time and/or additional equipment (e.g., dewatering pumps). Flowable fill, however, will displace any water and can therefore be used under wet or dry conditions (e.g., during or after rain or snow).

When earthen or granular fill is used, narrow trenches may need to be widened to allow for equipment to compact the fill mix. The added time and equipment is not necessary if flowable fill is used, thereby reducing leachate concerns. Additionally, worker safety is enhanced, as there is no need for laborers to work in the trench. There are also long-term cost savings. Because flowable fill does not form voids during placement, it is less likely to settle after paving than more traditional backfill materials, thus minimizing future maintenance needs and costs. In addition to the economic, performance, and safety benefits, flowable fill decreases the need to excavate and use virgin materials such as soil, sand and gravel. It may also replace the use of Portland cement, which, as discussed, reduces carbon emissions. Cold weather impact can be a concern for flowable fill. To minimize freeze-thaw damage, a protective layer can be placed above the top surface of the fill material.

As discussed, the placing of fly ash mixtures on or near soils, such as stabilized road base, structural fill projects and embankments, has raised concerns about trace element leaching. Due to the low hydraulic conductivity of flowable fill, the rate at which water permeates the fill is reduced. Although flowable fill applications tend to utilize fly ash at high rates (up to 95 percent fly ash), creating a larger concentration of trace elements, the testing of leachate samples from flowable fill yield similar results to the other beneficial uses discussed in this Report. The Recycled Materials Resource Center (RMRC) at the University of Wisconsin-Madison notes that extraction procedure toxicity test results on leachate samples from flowable fill indicate the leachate did not appear to be hazardous.[24] For example, in a study conducted on high fly ash content mixes, researchers found leachate from fly ash flowable fill to be below the ground-water quality enforcement standards and drinking water standards of the Wisconsin Department of Natural Resources.[25] Again, while each flowable fill site should be assessed, and subsequent monitoring should be considered, these studies indicate that this beneficial use application can be done in a manner that preserves water quality. To ensure durability in some applications, additives, in addition to cement or lime, may be required to reduce porosity and permeability and to increase the strength of the flowable fill material.

In 2013, 44,142 tons of coal ash was used in flowable fill projects in the United States.[26] According to NCDOT, since 1989, North Carolina has used an average of 56 cubic yards of fly ash in flowable fill; however, use was much higher during the period of July 1, 2013 to June 30, 2014, with the Department reporting that 588 cubic yards were utilized in flowable fill.[27] Although most states have limited experience with fly ash flowable fill, nearly all states that have used the material thus far have indicated satisfactory performance with little to no problems.[28] Many in the industry believe that flowable fill is being underutilized, not because of performance concerns but because of a lack of knowledge about the product and/or a hesitation to move away from the status quo. Those that have utilized this beneficial use application firmly believe it to be the preferred aggregate material, as it is versatile, less-costly, less time-consuming, safer, easier and more efficient than its granular fill counterpart.

Permitting and Approval Considerations

Certain flowable fill applications, such as for backfill of water mains may require approval of the NCDHHS. Proposed mix design and the material's intended use must be submitted to NCDOT at least 35 days before use, and mix proportions should be based on laboratory tests approved by the Department. Industry guidelines should be followed.

For more detail, see Appendix A.

PERMITTING AND APPROVAL FOR FLOWABLE FILL APPLICATIONS

DWM	DWR	DEMLR SEDIMENT PROGRAM	DEMLR STORMWATER PROGRAM	DEMLR DAM SAFETY PROGRAM	DEMLR MINING PROGRAM
-------	DEEMED PERMITTED	PROJECT DEPENDENT (e.g., size)	PROJECT DEPENDENT (e.g., size)	--------	PROJECT DEPENDENT (e.g., mine fill)

BRICKS

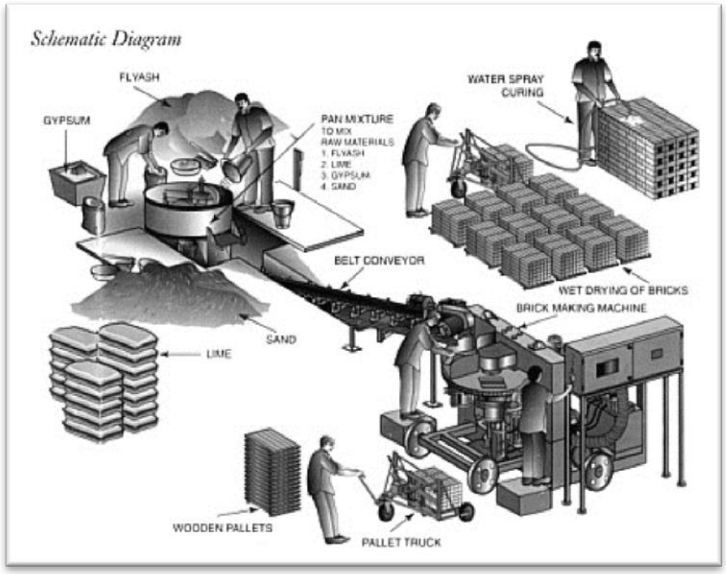


Figure 10 – Fly ash brick plant (Products.tradeindia.com)

Fly ash is increasingly being utilized around the world as an alternative to clay in the production of bricks. Utilized at rates between 35 to 80 percent, fly ash bricks are lighter in weight and more aesthetically versatile than their traditional counterparts. Unlike clay and concrete bricks, the manufacture of fly ash bricks is quicker, cheaper and more environmentally responsible. Although the specific recipe may vary, fly ash is generally mixed with some combination of lime, gypsum and sand. Water is added before the mixture is processed and compacted by either a hydraulic or vibratory process. Finally, the bricks are air-dried and cured (which may take 21 to 28 days and requires no energy), or steam cured (which may take only 12 hours to 2 days and require a relatively small amount of energy). Clay bricks, on the other hand, must be mixed, molded, dried in a 80 to 120 degree Celsius oven for 1-2 days, kiln fired at temperatures ranging from 200 to 1300 degrees Celsius for 2-5 days, and then cooled. Even for those fly ash brick curing processes that require energy, the molds are placed under 82 degree Celsius temperatures for only 12 hours.

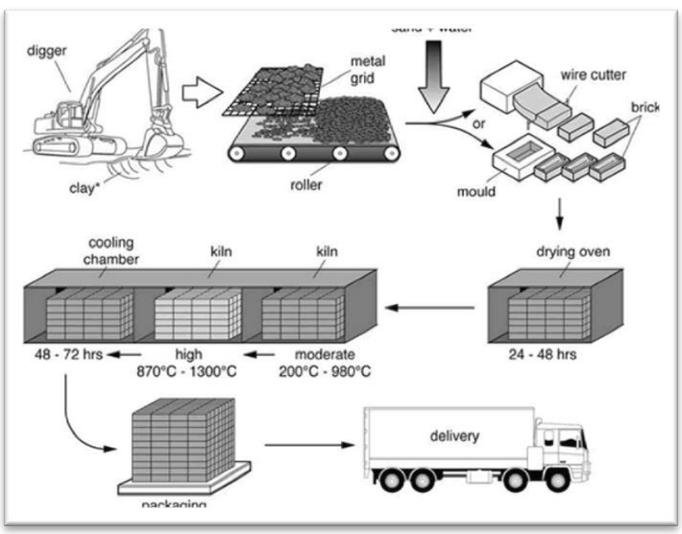


Figure 11 – Conventional brick manufacturing process

While fly ash bricks are structurally comparable to traditional bricks in terms of durability, long-term performance and, generally, freeze/thaw performance, they do surpass concrete and clay bricks in aesthetics. Advantages include: dimensional accuracy and uniformity of shape, and, in regions such as North America, color.

Fly ash bricks offer several economic and environmental advantages over conventional bricks. Bricks made out of fly ash are the most cost-effective, require less energy, consume less virgin material, generate less waste during production, and contribute *significantly* less CO2 emissions (see Figure 12). It is estimated that *for a 100,000 brick project, the use of fly ash bricks can save 500 million BTUs of energy, avoid 210 tons of new raw material mining, divert more than 85 tons of landfill waste and reduce CO2 emissions by more than 40 tons.*[29] Estimates further indicate that if clay bricks were no longer produced, at least 20 billion cubic feet of top soil would be saved each year, which would make available nearly 80,000 acres of fertile land for agricultural use.[30]

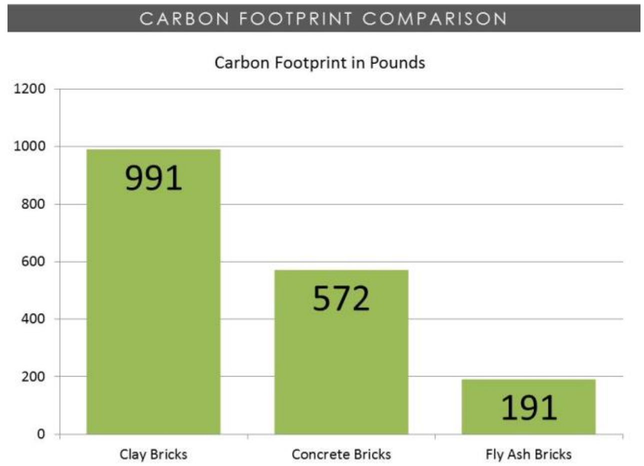


Figure 12 – National Institute of Standards and Technology

The manufacture of fly ash bricks is increasing across the globe; most notably in India. Annual production of traditional clay bricks in India is approximately 200 billion, which throw off 76 million tons of CO_2 from kilns and consume significant amounts of virgin materials such as red clay.

Since 1999, India's Ministry of Environment and Forests has issued a number of directives encouraging and instructing the proper use and disposal of fly ash. In 2000, India had 100 fly ash brick plants in operation. Today, with support from the World Bank and its national government, India now has more than 16,000 fly ash brick plants in operation, consuming approximately 20 million tons of fly ash each year.

In 2009, the New Delhi government issued a notification requiring that all brick units within a 100km radius of a coal power plant be made with fly ash and that every agency engaged in construction within a 100km range use fly ash based products. In April 2015, the government announced it was going to extend the area from 100km to 500km. The new notification will also make utilization of fly ash bricks mandatory by putting it as a condition in local municipal laws.

By making the utilization of fly ash mandatory, India's environment ministry special secretary says a huge market for fly ash bricks will be created, and power plants won't be able to complain that there is no market for fly ash. (www.livemint.com; photo: Sattish Bate/HT)

In India, within a radius of 100km from coal based thermal power plants, no person shall manufacture clay bricks, tiles or blocks (for use in construction activities) without mixing at least 25 percent of ash with soil on weight basis. (Ecobrick.in)

In the United States, a few companies are producing fly ash bricks at a commercial level. Processes utilized domestically require 81 percent less energy to manufacture and emit 84 percent less CO_2 during production. In 2014, by using bricks produced by just one producer, CO_2 emissions were reduced by 2410 tons (equivalent to taking about 430 cars off the road for a year); energy consumption in the masonry industry was reduced by 20,600 MBTUs (equivalent to the energy needed to power about 166 homes.); and nearly 7000 tons of fly ash was diverted from landfills.

Lower energy costs and inexpensive raw materials allow producers to offer competitive pricing while still maintaining high margins. C-ash is primarily used, and is mixed with local aggregates. No Portland cement is used. The fly ash acts as a cementitious pozzolan to harden the brick, which passes industry standard tests for facing brick at both the severe weathering and highest dimensional tolerance levels.

Invest Collegiate, Charlotte, NC (CalStar Products)

Fly ash bricks have been used in the construction of commercial buildings throughout North Carolina. For instance, in 2014, Invest Collegiate, a public charter school, was constructed in Charlotte, North Carolina using fly ash bricks. For that LEED certified project, the environmental impact of utilizing fly ash brick over the incumbent product resulted in energy savings of 490,128,396 BTUs (enough to power a home in North Carolina for about 2 years) and avoided 136,200 lbs. of CO_2 (equivalent to removing 14 cars from the road for a year).

Critics of fly ash bricks have concerns about the structural integrity and long-term performance of the product. Research conducted at Freight Pipeline Company sponsored by the National Science Foundation found that fly ash bricks made by compacting C-ash have excellent structural properties including freeze-thaw resistance, compressive strength, flexure strength, shear strength, and bonding strength, matching those of traditional clay or concrete bricks.[31]

Critics also cite concerns about the potential leachability of toxins. Questions have been raised as to the: (1) potential for mercury vapor emission from the products, (2) potential for radon emission from products, (3) potential for leaching pollutants (heavy metals) from such products into the ground caused by rain, and (4) potential for polluting landfills when a building is demolished and the broken fly ash products enter landfills. The research conducted at the Freight Pipeline Company sponsored by the National Science Foundation tested each of these four concerns. The test results showed that: (1) fly ash bricks made from C-ash do not emit mercury into air. On the contrary, they absorb mercury from the air, making the ambient air cleaner. (2) Fly ash bricks do emit radon gas, but only at about 50 percent the rate of that emitted from concrete; thus, if it is considered safe to use concrete and concrete products in buildings it should be even safer to use fly ash bricks. (3) Leaching of pollutants from fly ash bricks caused by rain is negligible. (4) Fly ash bricks pass the EPA-mandated toxicity characteristics leaching procedure (TCLP) test and are therefore considered “non-hazardous” for landfilling or handling.[32] Interestingly, a number of studies also suggest that fly ash bricks may have the ability to absorb carbon dioxide from the atmosphere thereby reducing the CO_2 in the atmosphere and further mitigating global warming.

Although the fly ash brick industry is established, and producers are successfully operating in countries across the world, including the United States, it is not yet certain how viable this beneficial use is in North Carolina. As mentioned, fly ash bricks are primarily (and for some producers in the United States almost exclusively) made with C-ash; more specifically, C-ash that is taken directly from the utility (i.e., production ash). The ash supply in North Carolina is primarily F-ash, and much of the supply is unseparated ponded ash – including a mix of both fly ash and bottom ash. Unless and until a new formula is developed for the manufacture of fly ash bricks using F-ash, this beneficial use is more suited for states with a supply of C-ash.

Permitting and Approval Considerations

The use of coal ash in brick products is deemed permitted under 15A NCAC 02T and no permit is required under 15A NCAC 13B. However, the State Construction Office should be consulted, and industry guidelines should be followed.

For more detail, see Appendix A.

PERMITTING AND APPROVAL FOR BRICK APPLICATIONS					
DWM	DWR	DEMLR SEDIMENT PROGRAM	DEMLR STORMWATER PROGRAM	DEMLR DAM SAFETY PROGRAM	DEMLR MINING PROGRAM
PROJECT DEPENDENT	DEEMED PERMITTED	PROJECT DEPENDENT (e.g., size)	PROJECT DEPENDENT (e.g., facility permitting)	-------- (unless Jurisdictional Dam built for project)	PROJECT DEPENDENT (e.g., other materials processed at facility)

ELEMENT EXTRACTION

Rare earth elements ("REEs") and other strategic elements are becoming increasingly vital components of advanced technologies used in the national defense and aerospace sectors, as well as renewable energy industries. Global demand continues to grow, outpacing current production volumes at unsustainable rates. In 2010, demand exceeded supply by approximately 3000 tons. The limited supply and resulting price increase has prompted nations, companies and academics alike to consider alternate sources of securing these elements. The need to identify additional sources of REEs and strategic metals is particularly warranted given that over 85 percent of REE production takes place in China and nearly 50 percent of global REE supply is controlled by the country. Extracting metals from coal ash – both ponded and production ash – has been identified as a possible untapped source for REEs and other strategic metals. As compared to mining elements from unprocessed coal ore, a process that is costly, labor-intensive, complex (complicated regulatory oversight) and potentially hazardous to the environment and human health, the extraction of metals from stored coal ash presents a more economical and safer alternative. In addition, the coal combustion process has been shown to enrich the metal concentrations in coal ash at some utility plants, yielding concentrations of REEs and other strategic elements that exceed those found in raw coal deposits.

EXAMPLES OF STRATEGIC ELEMENTS AND THEIR APPLICATIONS

Element	Atomic Number	Example Technology Application
Selected Rare Earth Elements		
Yttrium (Y)	39	Phosphors, metal catalysts
Lanthanum (La)	57	Electric vehicles, phosphors
Cerium (Ce)	58	Electric vehicles, phosphors
Praseodymium (Pr)	59	Permanent magnets, electric vehicles
Neodymium (Nd)	60	Permanent magnets, electric vehicles
Europium (Eu)	63	Phosphors, light-emitting diodes
Terbium (Tb)	65	Phosphors, electric vehicles
Dysprosium (Dy)	66	Permanent magnets, vehicle batteries
Other Strategic Elements		
Gallium (Ga)	31	Photovoltaics, semiconductors
Germanium (Ge)	32	Fiber-optics, semiconductors
Indium (In)	49	Photovoltaics, liquid crystal displays
Tellurium (Te)	52	Photovoltaics, thermoelectronic devices

Figure 13 – U.S. Department of Energy, Critical Materials Strategy (2011); National Research Council (2008)

Ongoing research over the last 30 years has led to the development of several extraction technologies. Generally, these processes include initial acid leaching of ash material, followed by removal of undesired minerals, and purification using solvent extraction. The leaching stage employs the use of low-pH acids (e.g., hydrochloric, sulfuric or nitric) and varying temperatures and leaching times, depending on the composition of the fly ash. After leaching, removal of non-target minerals (e.g., silicates, iron, and calcium) can be conducted using chelating resins or other precipitates (e.g., calcium sulfate). Finally, the individual metal is purified from solution using chemical extraction solvents. Extraction efficiencies can vary depending on the specific process used (e.g., type of acids and extractants used) and the concentrations of other elements in the fly ash, but initial studies demonstrate extraction rates of between 50 to 99 percent of available elements.

Such studies have been and currently are being done primarily on a limited or laboratory scale, or at pilot plants around the world. In one process, nearly 60 percent of the 14 rare earth and strategic metals available in ash samples obtained from a Colorado Springs Utilities power plant were extracted.[33] At a pilot plant in Canada, on average nearly 90 percent of the available metals in coal ashes are extracted. The processes utilized at this Canada plant are now being scaled to a commercial level, and a commercial plant is expected to be operational in 2015. And although not considered a rare earth or strategic element, China is currently pursuing the extraction of lithium (which is widely used in batteries) from ashes. Laboratory tests have demonstrated recovery rates of 55 to 60 percent.[34]

Until recently, commercializing this beneficial use was not considered economical, but the risk of supply shortages, the steady increase in global demand, and the initial assessments of the value of REEs and strategic elements – which range from hundreds to thousands of dollars per ton of fly ash – has encouraged companies, both new and existing, to explore commercial extraction. Getting to a commercial scale requires substantial capital investment. A pilot plant can cost between $10 and $20 million, while the construction of a commercial extraction plant can run upwards of hundreds of millions of dollars, depending up size, processing capability and other factors. Because the commercial extraction of REEs and other strategic elements is still being developed, and the business and economics have not yet been adequately proven or explored, projected costs are at early stage estimates. As commercial plants become operational and the market is tested, the economics of element extraction will be better understood. Today, a barrier to further development of extraction technologies is the amount of capital required.

Orbite element extraction pilot plant (Canada)

For some pilot plants and extraction companies around the world, financial support has been provided by government grants and/or an investment by the local utility. Given the huge capital cost of constructing an extraction facility, the availability of such financial assistance will have a significant impact on the ability to commercially scale separation technologies.

Pursuit of commercially viable extraction technologies should be balanced with potential environmental and health concerns. Metal extraction techniques are chemical and resource intensive. Extraction is facilitated by the use of leaching acids, caustic precipitates and organic solvents. Without adequate precautions and safety measures, these chemicals could result in unintended exposure, which may have both human health and environmental consequences. The chemical processes utilized in extraction technologies generate secondary waste streams (which may include residual naturally occurring radioactive or organic wastes) at various stages of metal extraction, requiring proper recovery and disposal.

In addition to being chemically intensive, the extraction process is also very water intensive. Large volumes of water are required during the acid leaching stages, a portion of which may not be recoverable as a result of contaminate concentrations. And as with most beneficial use applications, the coal ash may need to be transported to and stored at the separation facility, which raises considerations about cost, dust and potential leaching. With element extraction arguably still in its infancy, these considerations have not yet been fully vetted. Further, because the United States has not previously produced or extracted REEs in scale, occupational and environmental health standards specific to this industry have generally not been developed.

Ongoing research and monitoring will be especially important as pilot plants and commercial facilities become operational in other countries.

For countries such as the United States that: (i) remain largely dependent on foreign suppliers such as China (the primary global supplier of strategic rare earth metals), (ii) currently lack domestic access to resources containing sufficient concentrations of heavy rare earth elements, and (iii) produce millions of tons of coal ash each year, extraction may have potential. What is certain is that the future of numerous commercial and defense technologies is dependent upon the availability of strategic elements. As the technologies and processes develop at a commercial level, the economics become more certain, and the environmental and health impacts are better understood, this beneficial use of fly ash should be revisited and reevaluated.

Permitting and Approval Considerations

The extraction of REEs and other strategic metals is not specifically regulated in North Carolina. However, the construction of an extraction facility would require a number of permits and approvals, as is standard for manufacturing and processing plants.

For more detail, see Appendix A.

PERMITTING AND APPROVAL FOR ELEMENT EXTRACTION APPLICATION

DWM	DWR	DEMLR SEDIMENT PROGRAM	DEMLR STORMWATER PROGRAM	DEMLR DAM SAFETY PROGRAM	DEMLR MINING PROGRAM
PROJECT DEPENDENT	PROJECT DEPENDENT (e.g., facility permitting)	PROJECT DEPENDENT (e.g., size)	PROJECT DEPENDENT (e.g., facility permitting)	------- (unless Jurisdictional Dam built for project)	PROJECT DEPENDENT (e.g., other materials processed at facility)

MINE RECLAMATION

At excavated and abandoned mine sites, fly ash can be used as: (1) an agricultural supplement to create artificial soil, improve existing soil properties and/or enhance vegetation growth; (2) alkaline fill material to act as a liming agent to neutralize or treat acid-forming materials; and (3) flowable fill material that seals and stabilizes abandoned underground mines to prevent infiltration of surface water and protect water quality. Of these applications, fly ash is commonly used as a bulk-blending liming agent in acid forming refuse piles and as a soil amendment for textured and acidic mine soils.

Mining companies use fly ash to repair and revitalize mining areas once extraction activities have ceased. Benefits of fly ash use include improving the quality of nearby lakes and streams, rapid re-establishment of wildlife populations, aquatic habitats and grasslands, and increasing land value. (FlyAshDirect)

Alkaline fly ash has the potential to contain acid forming materials and prevent the formation of acid mine drainage. The fly ash, which may be supplemented with other liming materials based on its inherent alkalinity, can be bulk-blended with the coal refuse ("ash-blended refuse") to lower the acidity and inhibit pyrite oxidation. It may also decrease the rate of water movement through the fill, thereby reducing the risk of acid runoff. Some estimates indicate that fly ash can be mixed with coal refuse at rates of 30 to 50 percent by volume. Mixing and adjustment of pH is, however, a rather exact science, and is often verified by treatability testing in the field at the time the fly ash materials are installed. The alkalinity of fly ashes must be determined prior to use, as the alkaline concentration must be consistent and sufficient to actually offset acidity (i.e., the ash-blended refuse must be net alkaline).

There are numerous costs and environmental trade-offs to the applications of fly ash for mine reclamation. Although utilizing fly ash in mining activities can reduce reclamation costs, as fly ash is cheaper than other liming materials, the transportation of fly ash to these sites can be considerable. And while fly ash has the potential to accelerate restoration of mine lands and facilitate re-vegetation of previously rocky, acidic soils, improperly mixed fly ash-coal refuse piles may pose environmental risks. A primary concern with the beneficial use of coal ash in mining applications is the risk of groundwater contamination. This risk is mitigated when fly ash is applied above the water table in accordance with state, federal and industry standards, and if one of the structural fill methods (lime/cement additives or liner and leachate collection system) is employed.

In 2013, 1,843,292 tons of fly ash and 250,113 tons of bottom ash were used in mining applications throughout the United States, largely in Pennsylvania where there are more than 5,000 abandoned, un-reclaimed mine areas covering over 189,000 acres.[35] Of the approximately 15 million tons of coal ash produced in Pennsylvania each year, an average of 8 million tons is beneficially used at mine sites. The evaluation of more than 15 years of groundwater monitoring data for permitted sites throughout the coal regions of Pennsylvania has not resulted in any significant findings of environmental damage or groundwater pollution.[36]

Reclamation of a mine in Pennsylvania (PA Department of Environmental Protection).

The placement or use of coal ash on mine sites is regulated under both federal and state regulatory programs, including requirements for leachate testing and groundwater monitoring.

Permitting and Approval Considerations

The application of coal ash into active or abandoned coal mines, whether surface or underground, is not, however, currently covered by the Final EPA Rule. The EPA has stated that it (and the Department of the Interior) will address this usage in future regulatory action.

Mine reclamation projects other than coal mines (e.g., other open pits), would generally be treated as either a structural fill or landfill, and would be subject to those rules.

For more detail, see Appendix A.

PERMITTING AND APPROVAL FOR MINE RECLAMATION APPLICATIONS

DWM	DWR	DEMLR SEDIMENT PROGRAM	DEMLR STORMWATER PROGRAM	DEMLR DAM SAFETY PROGRAM	DEMLR MINING PROGRAM	FEDERAL
PROJECT DEPENDENT	-----	PROJECT DEPENDENT	PERMIT REQUIRED	-----	PROJECT DEPENDENT	FEDERAL LANDFILL RULES MAY APPLY

AGRICULTURE

Fly ash has been used to improve soil health and increase certain crop yields.

Due to its alkaline character and high concentrations of elements such as iron, calcium, magnesium and phosphorus, fly ash has been used as an agricultural application to improve soil health and increase certain crop yields. When applied, fly ash can modify the physical properties of soil and, as a result, alter soil texture, improve water-holding capacity, regulate soil pH and enhance crop performance. This is particularly useful in areas where the soil is inherently poor or has been degraded. When applied to sandy soils, fly ash can permanently alter soil texture, increase micro porosity, and improve water retention. When applied to acidic soils, fly ash acts as a liming material that neutralizes soil acidity and improves the nutrient status (i.e., provides plant-available nutrients). Generally, studies have shown that the addition of fly ash increases plant growth and nutrient uptake. Field experiments show that the use of fly ash can increase the yield of cereals, oil seeds, cotton and sugarcane by 10 to 15 percent and vegetables by 20 to 40 percent.[37] Yields of groundnut, sunflower, safflower and maize have also been shown to increase.

In addition to its chemical and biological benefits, the beneficial use of fly ash in agriculture also offers a number of economic and environmental advantages. Fly ash can act as a replacement for chemical fertilizers and organic materials. According to one study, integrated use of fly-ash in organic and inorganic fertilizers reduced nitrogen, phosphorus and potassium up to 45.8, 33.5 and 69.6 percent, respectively.[38] The use of fly ash also has the potential to decrease greenhouse gas emissions by reducing or replacing agricultural lime, which is said to release carbon dioxide into the atmosphere.

Despite the benefits, the beneficial use of fly ash in agriculture is especially limited. In 2013, only 15,861 tons of coal ash (just 217 tons of bottom ash) was applied in the United States in an agricultural setting.[39] The North Carolina Department of Agriculture and Consumer Services has no data on the extent to which fly ash or bottom ash has been used on agricultural lands in North Carolina.

The relatively minimal amount of reuse can be largely attributed to environmental and health concerns. The application of fly ash on agricultural fields is not regulated at a federal level, nor is it regulated in most states (including North Carolina, which does not currently require permitting of sites on which coal ash is applied as a lime or fertilizer source), raising questions about the potential effect on human health and food safety. Although some studies indicate that when moderately applied, yields of certain crops increased without impacting groundwater or soil fertility, other studies have shown that crops grown in quantities of fly ash ranging from 5 to 20 percent of soil weight absorbed toxic metals such as arsenic and titanium.[40] In some cases, the application of certain fly ashes may accumulate elements such as boron, molybdenum, selenium and aluminum, which at high concentrations result in damage and reduction in crop yields.[41] For example, scientists have found that concentrations of greater than 2 ppm can have severe effects on vegetables, damaging the plants and decreasing the production.[42] This may be of particular concern in North Carolina where crop sensitivity has been noted in local soils.[43] While fairly intensive research into trace element accumulation in plants has been conducted globally, there appears to be little consensus. What the studies have shown is that fly ash application in agriculture requires rather precise calculations, taking into account the crop, fly ash type, soil, climate, and fly ash to soil weight ratio.

Unless and until environmental and health questions are answered, or concerns are alleviated based on proven research, and an accepted consensus exists as to the healthy parameters of use in agriculture, the market for this fly ash application is likely to remain minimal. In North Carolina, the general response from the agricultural community in the state is that the negatives appear to outweigh the positives.

Permitting and Approval Considerations

The use of coal ash in agriculture is deemed permitted under 15A NCAC 02T. Although North Carolina does not specifically regulate this beneficial use application, if coal ash is sold and distributed to farmers as a liming material or fertilizer with labeling and a guarantee of analysis, then NCDA&CS requires registration of the product. NCDA&CS does provide a voluntary advisory service to those farmers that want to consider using coal ash as a soil amendment.

For more detail, see Appendix A.

PERMITTING AND APPROVAL FOR AGRICULTURAL APPLICATIONS					
DWM	DWR	DEMLR SEDIMENT PROGRAM	DEMLR STORMWATER PROGRAM	DEMLR DAM SAFETY PROGRAM	DEMLR MINING PROGRAM
MAY REQUIRE DA&CS APPROVAL	DEEMED PERMITTED	-------- (Agricultural Exemption)	--------- (Agricultural Exemption)	-------	-------

WASTE STABILIZATION

When coal ash is combined with industrial waste containing toxic heavy metals, the mixture can stabilize the waste in such a way that it can be disposed of in an ordinary landfill. Fly ash can be used as a binding agent alone or in conjunction with other binders such as lime or Portland cement for stabilization of such wastes. The reactions of fly ash in the mix, both cementitious and pozzolanic, entrap or microencapsulate the waste.

There are a number of potential waste stabilization applications. Fly ash can be added to drill cuttings (e.g., the soil, mud, rocks and other debris removed from a borehole after drilling) to help solidify and stabilize them for transport and disposal. In light of its alkalinity and water absorption capacity, fly ash may be used in combination with other alkaline materials to transform sewage sludge into organic fertilizer or biofuel. Fly ash can also be utilized for water pollution control measures such as neutralization of acidic wastewaters, removal of phosphorus from wastewater, physical conditioning for sludge dewatering, and sealing of contaminated sediments. These processes work because coal ash is generally adsorbent, meaning that it can adhere to atoms, ions, or molecules from a dissolved solid, gas, or liquid. As a result, it can aid in the stabilization of heavy metals and solidification of wet materials. To mitigate concerns about trace element leaching, the waste-fly ash mixture should be appropriately proportioned to meet environmental and stability requirements.

New and improved methods continue to be investigated. For example, scientists in Greece and Romania are working on a method to transform power plant ash into materials that could be used for nuclear waste treatment or soil remediation, and the prospect of using fly-ash based geopolymers is still being explored.[44]

In 2013, 2,093,933 tons of fly ash was used in the United States in waste stabilization and solidification applications.[45] There has been no documented use of coal ash in stabilizing waste in North Carolina.

Permitting and Approval Considerations

The use of coal ash in waste stabilization (i.e., stabilization of residuals) is deemed permitted under 15A NCAC 02T and no permit is required under 15A NCAC 13B. However, NCDENR should be consulted, as other permits and approvals may be required.

For more detail, see Appendix A.

PERMITTING AND APPROVAL FOR WASTE STABILIZATION APPLICATIONS

DWM	DWR	DEMLR SEDIMENT PROGRAM	DEMLR STORMWATER PROGRAM	DEMLR DAM SAFETY PROGRAM	DEMLR MINING PROGRAM
PROJECT DEPENDENT (e.g., hazardous waste)	DEEMED PERMITTED FOR STABILIZING RESIDUALS	PROJECT DEPENDENT (e.g., size)	PROJECT DEPENDENT (e.g., facility permitting)	-------- (unless Jurisdictional Dam built for project)	--------

SNOW AND ICE CONTROL

Bottom ash has been used in snow and ice control applications. Much like salt, bottom ash aids in the melting of snow and ice. It has the ability to absorb sunlight, which speeds up melting and reduces glare on the roads.

In 2013, 421,087 tons of bottom ash was beneficially used in the United States for snow and ice control.[46] Iowa has been using ash (which it receives for free from a local utility) since the late 1970s on city streets to melt snow and ice. Iowa state law allows for the use of bottom ash as a "traction agent for surfaces used by vehicles."[47] In addition to conserving salt, state representatives say that the bottom ash is easier to clean up from surfaces than sand.

Coal ash is used to provide traction on icy roads in Muscatine, Iowa. (AP Photo/The Muscatine Journal, Beth Van Zandt)

Nebraska has also utilized bottom ash for snow and ice control. In 1979, 1994, 2001, 2010 and 2011, the state applied bottom ash to the Platte River in Omaha, Nebraska. The Nebraska Emergency Management Agency has a discharge permit allowing it to apply bottom ash when it is determined that the likelihood of ice jams and flooding along the Platte is high, and the Governor has declared it to be an emergency situation.[48] In Missouri, bottom ash used on roads is specifically exempted from the oversight provided by the solid-waste permit process, provided that a "health hazard is not created."[49] Among utilities in the Midwest, American Electric Power, for example, distributes about 3.5 percent of the bottom ash from its 25 coal-fired plants for use on roads.[50]

In addition to aesthetic complaints, the application of bottom ash to snow and ice raises environmental and health concerns. Unlike salt or sand, bottom ash contains trace elements of metals, and unlike most of the other beneficial uses, the ash is not mixed with a reagent or cementitious material, thus it remains unbound. To date, there is no consensus about the impact of this bottom ash application on the surrounding environment.

Permitting and Approval Considerations

The use of coal ash for traction control is deemed permitted under 15A NCAC O2T.
For more detail, see Appendix A.

PERMITTING AND APPROVAL FOR SNOW AND ICE CONTROL APPLICATIONS
DWR
DEEMED PERMITTED BUT DOT APPROVAL REQUIRED

OTHER APPLICATIONS

This section discusses beneficial uses of coal ash that we categorize as "other", which do not currently utilize a meaningful amount of coal ash, or have questionable market viability in sufficient quantities to serve as beneficial uses that can address large scale inventories of coal ash. One such application is the use of boiler slag, and occasionally bottom ash, in blasting grits and roofing granules. Boiler slag is a black granular material, uniform in size, hard, and durable relative to surface wear. Boiler slag is also in high demand for various beneficial use applications; however, the supply is decreasing. Blasting applications include general purpose repair and maintenance of bridges, structural steel, sea faring vessels, railroad equipment, and buildings, as well as paint and rust removal. This type of product retails for approximately $91 per ton, while a premium version of the material containing garnet and alumina sells for over $200 per ton. The use of coal ash for blasting grit and roofing granules is deemed permitted by NCDWR, but pollutant limits apply.

Fly Ash Metal Matrix Composites

Metal matrix composites ("MMCs") are engineered materials formed by the combination of two or more materials, at least one of which is a metal, to obtain enhanced properties. MMCs tend to have higher strength/density and stiffness density ratios, compared to monolithic metals. They also tend to perform better at higher temperatures, compared to polymer matrix composites. Such composites can be applied for use in automotive components, machine parts and related industries.

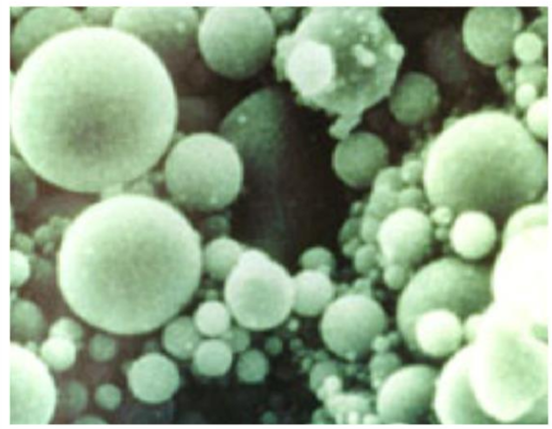
The utilization of waste by-products such as fly ash as a filler material in light metals and alloys, such as aluminum, has been explored at the University of Wisconsin – Milwaukee for potential applications in engineering components. This research has examined various aspects of making aluminum/fly ash composites utilizing an inexpensive stir mixing and casting technique, and has evaluated the properties of the resulting composites. Fly ash represents a unique, inexpensive resource of solid and partly hollow microspheres that are otherwise quite expensive to produce.

Fly ash can be used as a filler or part of a filler blend that when combined with asphalt produces asphalt composites such as roofing shingles with improved mechanical properties at a lower cost than asphalt shingles produced using conventional calcium carbonate fillers. The fly ash filler or filler blend can be used in amounts of greater than 45 percent by volume or greater than 70 percent by weight to increase the mechanical properties of the asphalt composites such as pliability, tensile strength and tear strength, while decreasing the cost to produce the asphalt composites. When fly ash is used to replace "calcium carbonate fillers" and ground-up limestone, quarrying and processing costs, as well as environmental disruption is reduced or completely avoided.

Fly ash can also be used as "filler" for certain types of plastic, both to improve the properties and to lessen the cost of articles made from that plastic. Such use of inert fillers in molded plastics is quite common. Anyone who has recently gone bowling has probably used a polyurethane bowling ball. The weight of the ball is dependent on the amount of ground limestone, or now more advanced filler such as fly ash, that is added to the resin from which the balls are molded.

Cenospheres

Hollow ash microspheres (cenospheres) are a byproduct of certain coal burning power plants. Cenospheres are the lighter particles that are contained within the fly ash in small proportion. The properties of cenospheres depend on the consistency of the coal used and the operating parameters of the power plant. Cenospheres have a particle size range of 10-600 microns, and are used in the following end products:



Fly ash from power plants contains tiny ceramic spheres, typically ranging in diameter from 5 to 75 micrometers, which are called cenospheres; they have many uses. Scanning electron photomicrograph from the American Coal Ash Association.

1. Ceramic products: light ceramic wall materials and coatings. Cenospheres are widely used in the construction of refractories. They are more heat resistant than metals and required for heating applications above 600C.
2. Paint and varnish materials: thin-layer, energy-saving, and fire-retardant paints. Such coatings are stronger and more durable. They have a more hardened surface and are resistant to most chemicals.
3. Plastics: manufacture of certain boats, buoys, life vests, buoyancy submarines and submersibles.
4. Applications in epoxy resins: concrete repair mortars, molds and modeling compounds, tooling blocks, syntactic buoyancy foams, marble floor tile adhesives, tile cement and grouts, honeycomb and void filler pastes, coatings and paints, and decorative building profiles.
5. Applications in polyurethanes: plywood patching compound, synthetic wood, foam carpet backing, electric potting and jointing compounds, de-burring chips, pipe-line insulation, rigid and flexible molds, and coatings (high solids, low slump, corrosion resistant).
6. Applications in PVC: cushion floor, homogenous safety flooring, car underbody coatings and seam sealants, steering wheels, roofing membranes, air filter seals, and shoe soles.
7. Applications in latex emulsions: latex carpet backing foams, gypsum board joint compounds, veneering plasters, crack fillers, anti-condensation paints, and textured paints.
8. Applications in unsaturated polyester resins: sandwich panel cores, molding compounds, cast sanitary ware, tenpin bowling ball cores, buttons, car body putties, and adhesives.
9. Chemical industry: catalysts for neutralization of waste water, sensitizers of emulsion explosives, tire production, abrasive tools of high performance, and furniture moldings.
10. Other: radar absorbing paints, plastics (stealth coatings), electromagnetic shielding, conductive composites, infra-red reflectors, and aerospace composites.

Various forms of coal ash filler can also be used in makeup. All of the above mentioned beneficial uses would require preprocessing to occur in order for impounded ash to be used in these applications. This would require costs that do not allow large scale consumption, which is the goal of our clean-up initiative in North Carolina.

CONCLUSION

Clearly there is no shortage of applications where coal ash can be beneficially used. However, since our objective is to identify and promote uses which are generally accepted to be environmentally safe, economically viable, and which can absorb a large enough amount of coal ash to not only absorb future production ash, but reduce the amount of ash currently stored in landfills and impoundments, we recommend focusing on the concrete and structural fill markets. These are complimentary applications, as coal ash with certain properties can be used in cement production, while much of the remainder can by beneficially used in structural fill projects. More work needs to be done to fully understand what dynamics will be required to markedly expand the consumption of coal ash in these applications, but it appears the limitations are not scientific in nature. Therefore, we encourage policy makers and power industry stakeholders to focus on the business aspects of beneficial use applications to forge strategies for expanding the current market consumption of coal ash.

CAMC
North Carolina Coal Ash Management Commission

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APPENDIX A: Permitting and Approval

	DWM	DWR	DEMLR Sediment Program**	DEMLR Stormwater Program***	DEMLR Dam Safety Program	DEMLR Mining Program	Federal	Other
Concrete & Cement	Project Dependent. Air Quality permit may be needed if there is reburning of the ash.	Deemed Permitted.	Project Dependent.	Project Dependent.	Not triggered, unless a Jurisdictional Dam is built as part of this process.			Consult with NCDOT and State Construction Office.
Structural Fill	Permit Required.		Project Dependent.	Project Dependent.		Project Dependent.	Landfill rules may apply under Final EPA Rule.	
Stabilized Road Base		Deemed permitted if ≤ 1' thick.	Project Dependent.	Project Dependent.				Consult with NCDOT and State Construction Office.
Asphalt and Bricks	Project Dependent. Air Quality permit may be needed if there is reburning of the ash.	Deemed permitted.	Project Dependent.	Project Dependent.	Not triggered, unless a Jurisdictional Dam is built as part of this process.	Project Dependent. Depends on what other materials (e.g., clay) are processed at the facility.		Consult with NCDOT and State Construction Office.
Flowable Fill		Backfill generally deemed permitted.	Project Dependent.	Project Dependent.		Project Dependent.		Some types of flowable fill projects require NCDHHS approval.
Element Extraction	Project Dependent. Air Quality permit may be needed if there is reburning of the ash.	Project Dependent.	Project Dependent.	Project Dependent.	Not triggered, unless a Jurisdictional Dam is built as part of the process.	Project Dependent. Depends on what other materials (e.g., clay) are processed at the facility.		
Mine Reclamation	Project Dependent. If not a coal mine site, it is regulated as a structural fill/landfill.		Project Dependent.	NPDES Stormwater permit required.		Project Dependent. Mining permit may apply if not already in existence.	Landfill rules may apply under Final EPA Rule.	
Agriculture	May require NCDA&CS approval.	Deemed permitted.	Not triggered. Agriculturally exempt.	Not triggered. Agriculturally exempt.				May require NCDA&CS approval.
Waste Stabilization	Project Dependent. Depends on whether hazardous waste is being treated.	Deemed permitted for stabilizing residuals.	Project Dependent.	Project Dependent.	Not triggered, unless a Jurisdictional Dam is built as part of this process.			
Snow & Ice Control		Deemed permitted.						Consult with NCDOT.

* Even if a use is deemed permitted, pollutant limits may apply under 15A NCAC 02T.
** "Project Dependent" – an E&SC plan may apply depending on the acreage disturbed, the location in an area with a delegated local program, or disturbance from temporary staging and storage.
*** "Project Dependent" – a NPDES construction stormwater/stormwater permit may be required depending on the acreage disturbed. Whether the manufacturing/processing plant has an active permit will also be considered.

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