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Fly Ash Concrete: Future Foundations?

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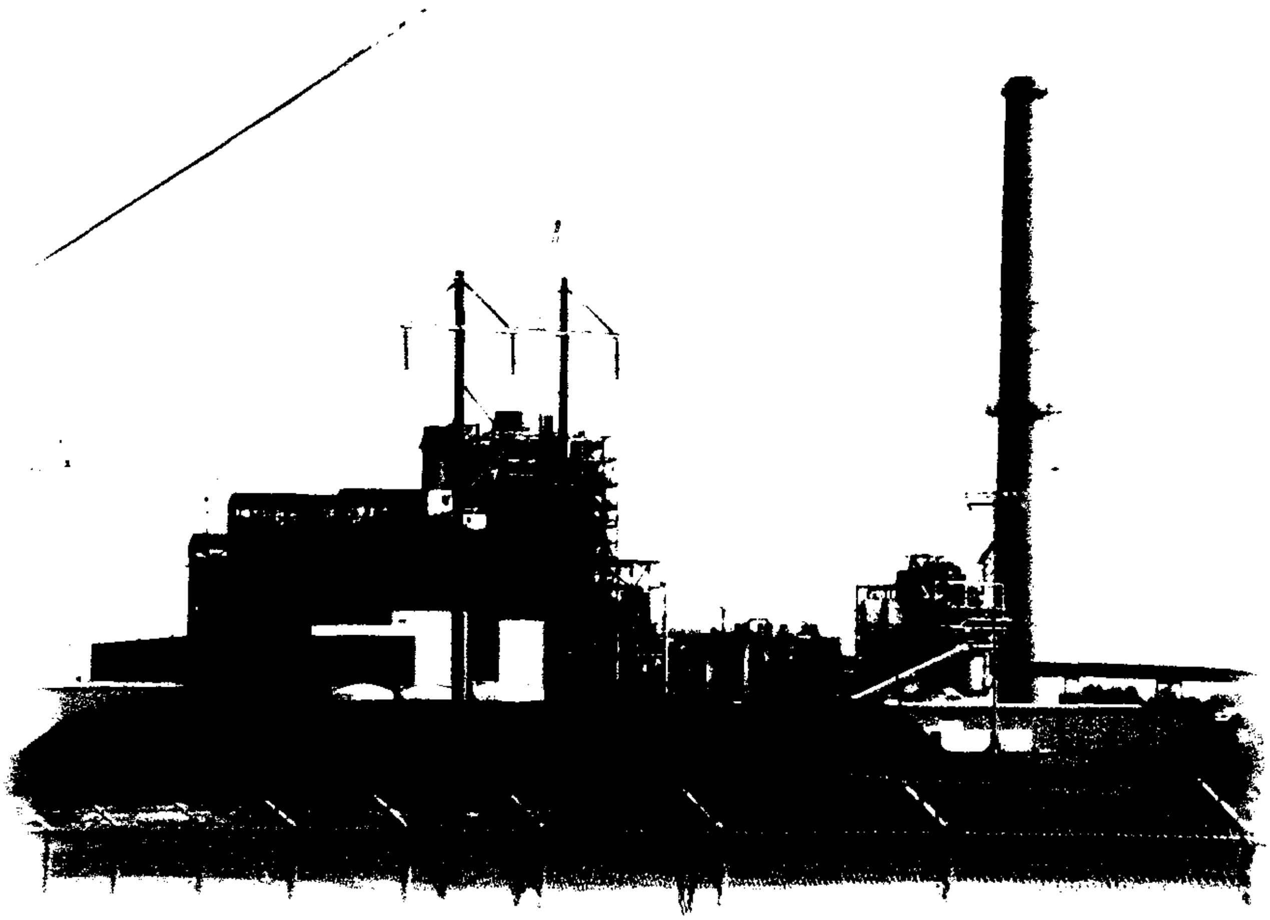

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by

Rebekah Pairsh

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Southern Illinois University at Carbondale

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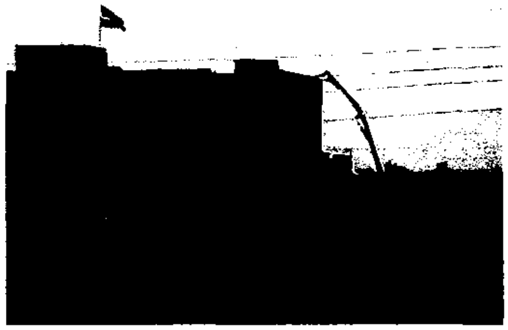



Marion Memorial Hospital's New Complex

Fly Ash Concrete: Future Foundations?

PROLOGUE

It was Summer 2001. Marion Memorial Hospital of Marion, Illinois, a small regional hospital, announced its intention to build a new hospital complex that would triple its current size. The Hospital spokesman, Tom Keim, announced that the Hospital's contractor intended to use fly ash (also known as coal ash) concrete in the buildings. Some scientists, engineers, and environmentalists believe that fly ash material is environmentally safe and structurally sound. Others, however, do not. Suddenly, the celebration of the new Hospital turned into controversy.

Throughout the past thirty years, many studies of the feasibility of using fly ash concrete have been conducted. Some of the scientific results were negative, including one where the structures built collapsed 95 percent of the time. However, the majority of the scientific results have been positive. In one study, the strength of the concrete was found to be better in fly ash concrete than in regular aggregate concrete. In addition to questions about strength, there are also questions about environmental safety. The debate between environmentalists is one of safety for humans and the environment. Although fly ash is considered by most to be environmentally safe, no one can be 100 percent sure whether daily exposure to fly ash is safe for humans to be exposed to, or if fly ash concrete releases dangerous chemicals into the groundwater.

Complicating the issue even further is the lack of communication that often accompanies the use of fly ash concrete. Marion Memorial Hospital, its engineers, and the City Council never clarified their reasons for using fly ash concrete. As a matter of fact, fly ash is not really being used in the Marion Memorial Hospital concrete. They are using bottom ash, a denser byproduct of burning coal that is considered safe by all experts. There are no buildings currently being built or that have been built with fly ash in this area. According to Ray Serati, reporting for The Southern Illinoisan newspaper on the Hospital, "The project incorporates the use of coal bottom ash, a coal combustion by-product, in concrete support piles for the hospital's new Medical Office Building and Power House" (1). The project calls for the use of 200 tons of bottom ash from Springfield's City Water Light and Power's (CWLP) plant complex to supplant the aggregate that is normally used in concrete.

Still, to this date, many Marion citizens do not realize that the new complex is not being built with fly ash. Not only this, they also do not understand the difference between fly ash and bottom ash. Marion Memorial Hospital and the engineers of the project do not seem to be concerned enough with the misconceptions of the public to come forward and explain the issue to the community and this lack of communication with the public could become a serious public relations problem. The lack of information given to Marion citizens is astounding. The problem Marion citizens are faced with is that no scientist, engineer, public relations official, or anyone else for that matter has informed the public about the safety of a building composed of bottom ash or fly ash. In doing research on this matter, it becomes evident that the scientific community is at a loss in how to communicate the benefits of using coal ash, specifically fly ash, to the public. This thesis, then, will attempt to define and explain fly ash in layman's terms and hopefully, will answer some common questions and amend some misconceptions about fly ash concrete.

FLY ASH DEFINED

When coal is burned to create energy, specifically electric power, fine coal particles become airborne. These airborne particles are called fly ash because they literally float through the air. Because of the Clean Air Act, which will be discussed in more detail later, the fly ash particles must be collected. According to the Dictionary of Coal Science and Technology, these airborne particles would normally be expelled with the gas out of the smoke stacks if it were not gathered by electrostatic precipitators (Merritt 149-150).

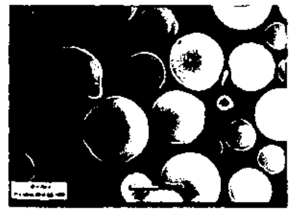
Fly ash is collected in four different ways, but it generally uses the aid of an electrostatic precipitator. The electrostatic precipitator is an apparatus that is attached to the smoke stacks of coal-fired power plants. The fly ash particles have a natural static-cling, and this device is used "to remove the fly ash from the stack gas and to collect it" (Merritt 133), presumably with the opposite electric charge. According to Coal Processing and Pollution Control, particulate (fly ash) emissions are also controlled by cyclones, wet scrubbers, and fabric filters - also known as a 'baghouse' (Edgar 302) - the form of collection Southern Illinois University at Carbondale uses.

The Electric Power Research Institute's (EPRI's) Fly Ash Structural Fill Handbook defines fly ash as:

> a by-product of the combustion process necessary for the production of electrical energy at modern power stations which burn fossil fuels. It is the very fine, light dust which is carried off in the stack gases from the boiler units and collected by the air pollution control equipment. Fly ash is composed of the noncombustible mineral matter present in coal and any carbon which remains unburned due to incomplete combustion....
> (Section 2, Page 1)

As one may discern from the definitions above, fly ash is a powder-like substance. However, the particles may be shaped in various sizes and compositions, depending on the type of coal that is being burned. No matter what type of coal is being burned, according to the federal government, fly ash only has two different classifications.

Class F Fly Ash



Class C Fly Ash

Class F fly ash is more pozzolanic (glassy) in nature, making it ineffectual for use in concrete. Class C fly ash, on the other hand, contains more calcium making it more suitable for use in concrete. Over the last three decades, many attempts have been made to develop a useful concrete containing 15-20% fly ash. This new concrete is now being tested.

FLY ASH UTILIZATION

Miscellaneous

Fly ash is utilized in many different ways. The Electric Power Research Institute's Final Report in March 1992 noted that in addition to its use in concrete, fly ash "has been used in highway construction work as an embankment material, in agriculture as soil amendments, [and] in metals and plastics as filler..." (High-Volume 1-2). Fly ash is also used in the creation of artificial reef for endangered fish and modified shingles for roofing.

Concrete

The use of fly ash in concrete is relatively new, considering how long the United States has used traditional aggregate concrete and is a result of studies that have been conducted by scientists, engineers, professors, and environmentalists from as early as the 1940's. The fly ash that is used in concrete must be converted from its original state - a solid powder-like waste - into concrete blocks. Usually, the fly ash is mixed into the concrete from its powder form.

CONCERNS ABOUT USING FLY ASH CONCRETE: THE DEBATE

The use of fly ash for buildings and landfill is very controversial. Coal ash in its natural pre-cleaned state was classified as a hazardous solid waste for many years. It is currently not considered a hazardous material by the government; it has now been classified as merely a solid waste. Nonetheless, action must be taken to clean up the coal ash before it can used as a substitute for the aggregate in concrete, as well as in other coal ash projects.

Advocates of Fly Ash Concrete

On one side of the debate are the scientists and engineers who believe that fly ash concrete is safe. They argue that after mixing aggregate, lime, fly ash, and gypsum, the concrete produced is safer than a concrete product that just uses fly ash to replace the aggregate. The authors of "Evaluation of the Properties of Fly Ash from Coal," presented at the 1991 Shanghai Ash Utilization Conference, suggest that lime may increase the strength of fly ash concrete. "The combined lime content with fly ash is still low after 28 days and increases substantially for up to a year [because it settles].... When cement is replaced by fly ash, the volume of very fine material in the mortar and concrete is increased" (Proceedings 12-1). What this means is that fly ash being used as a replacement for the aggregate in concrete should have lime mixed in with it in order for it to withstand natural aging for more than one year.

In 1992, a research program at the Center for By-Products Utilization at the University of Wisconsin - Milwaukee, sought to develop low-cost construction materials by using coal combustion by-products like fly ash. Many different products were made such as bricks, blocks, and paving stones with the materials being tested. The study found that "fly ash can be utilized as a replacement of *clay* in commercial manufacturing of structural products such as bricks, blocks, paving stones, etc." (Low-Cost Ash-Derived Construction Materials 2-1).

The authors of The Supplemental Proceedings: Fourth International Conference on Fly Ash, Silica Fume, Slag, and Natural Pozzolans in Concrete High-Volume Fly Ash Concrete Session agree with the Milwaukee findings. The Electric Power Research Institute, which funded both studies, concludes that the "[p]roper mix design can produce high-volume fly ash (HVFA) concretes of high strength, low temperature rise, superior durability, and exceptional mechanical properties" (Supplemental 1). This means that if done properly, fly ash concrete may actually be superior to normal (aggregate) concrete. Some fly ash concrete producing companies are betting their fortunes that these findings are true.

ISG Resources, Incorporated use fly ash for their concrete products because they believe

> [the] ball-bearing effect of fly ash particles creates a lubricating action when concrete is in its plastic state. This creates benefits in Workability (concrete is easier to place, with less effort, responding better to vibration)....Ease of pumping...Improved finishing...Reduced bleeding [which] decreases porosity and chemical attack...Reduced segregation that leads to rock pockets and blemishes and Reduced slump loss resulting in greater working time. (ISG 2)

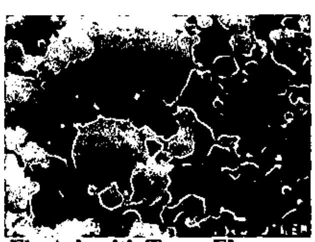
ISG Resources, Incorporated is one of the leading fly ash developers in the country, and they currently offer FlexCrete and Dynastone products, two fly ash concrete derived products.

The federal government uses fly ash concrete wherever they want. The Corps of Engineers (COE) allows the use of fly ash as a cement replacement in concrete in all military construction and civil works projects. An EPRI report also mentions that the Federal Highway Administration (FHWA), FAA, and the Environmental Protection Agency (EPA) will not disclose information about the safety of fly ash concrete, but they will promote it (EPRI, Institutional 3-7).

Opponents of Fly Ash Concrete

In 1995, Kurt F. Von Fay produced a report for the U. S. Department of the Interior entitled "Effects of Various Fly Ashes on Compressive Strength, Resistance to Freezing and Thawing, Resistance to Sulfate Attack, and Adiabatic Temperature Rise of Concrete." In this government publication, Von Fay reported on all of the experiments that he and his group of scientists performed. One such experiment involved the long-term strength of fly ash in concrete. Surprising and very scary results were discovered. All samples of the concrete with fly ash in them expanded, collapsed, or otherwise failed (29). Sometimes, the samples failed after only 300 days of exposure to normal natural elements (see Appendix B). This study suggests that fly ash would not be the best building material.

In addition to the structural problems, there is another factor in using fly ash for concrete that must be examined: the environmental aspect. According to the report Chemical Form and Leachability of Inorganic Trace Elements in Coal Ash, "Laboratory studies showed that combustion conditions strongly influence the chemical form of trace elements in ash produced by coal-fired power plants (i). The writers also believe that a potential problem of fly ash is the "contamination of surfacewater and groundwater by trace elements as a result of leaching of residues" (iii). However, trace element leachates as well as fly ash composition are variable. Leachates are unwanted, sometimes toxic chemicals such as arsenic that seep out of the concrete and into the groundwater. Trace elements are traces (small amounts) of the specific element such as arsenic that can leach into the ground. Trace elements, leachates, and fly ash composition vary from plant to plant and are site specific due to the various ways the coal is burned and fly ash is collected. "[I]f the chemical affiliation of trace elements in ash were mainly dependent upon the burning conditions, it would be possible to predict the leaching of trace elements from knowledge of the combustion conditions....Coal with a lower heat content yields more leachable trace elements, possibly because of lower combustion temperatures inside the furnace" (iii). It is easy to



Fly Ash with Trace Elements

see, then, that the temperature at which the fly ash is originally created at can have a huge impact on the environment.

In 1992, the authors of the Electrical Power Research Institute's report Institutional Constraints to Coal Fly Ash Use in Construction ascertained that because of controversy surrounding the safety of fly ash concrete, only 12 states allow fly ash to be used in concrete pavement. They also note that only 17 states use fly ash for structural fill, and three states allow fly ash to be used in soil. "Many states indicated that their current rules and regulations do not specifically address coal fly ash utilization. Although this is the case, some environmental agencies indicated that they do currently allow certain fly ash uses. In addition, the Illinois Environmental Protection Agency indicated that fly ash use is evaluated on a case-by-case basis" (3-7). Since the report, the number of states allowing fly ash to be used in concrete pavement has increased to 26, although some states still evaluate on a case-by-case basis.

Debate Summary

The main problem with using fly ash concrete for buildings is the fundamental disagreement among credible experts. One scientist or engineer believes it is safe, while another believes it is dangerous. Upon study of the debate, it seems that the best position to take is that of the authors of the report Utilization of Coal Combustion By-Products for Masonry Construction. "Future research is recommended in order to get better understanding of the engineering performance, durability, and manufacturing of ash-masonry products" (iii).

CONTROL OF FLY ASH

The Clean Air Act

Throughout time, changes have been made in the requirements for the collection of fly ash. The New Clean Air Act of 1990, signed by President Clinton, specified changes in emissions from coal power plants. The 1970 and 1977 Clean Air Acts were the first federally regulated programs to control air pollution from emissions including fly ash. Prior to the 1970 Act emissions were not controlled, causing pollution to the air, "fires caused by sparks from passing locomotives" and "claims that fluoride emissions from aluminum smelters damage gladiolus and other crops" (Lock 3). Beyond such nuisances, there were serious health concerns. The 1990 Amendments to the Clean Air Act will, according to the EPA, "remove 56 billion pounds per year of air pollution, reduce by 50 percent emissions causing acid rain, eliminate 75 percent of toxic air pollutants and assure that all areas of the country meet national ambient air quality standards" (Lock 6). Thanks to the 1990 Amendments, airborne particulates (including fly ash), sulfur dioxide, nitrogen oxides, and carbon dioxide emissions from coal are lowering.

Environmentalists

According to many environmentalists, the primary concerns about the safety of fly ash concrete have not been addressed. They want to know: Is it safe to use coal ash, the residue of burned coal, in a recycled manner, or will it cause more harm than good? Before we can safely address the problem of hazardous coal byproducts, these questions must be answered. Moreover, as a nation, we need to become more informed about coal byproducts. We need to know why and how coal byproducts are used in each of our regions so we can make an educated decision about whether or not we want to use recycled coal byproducts.

Until the 1970's, fly ash was just another inconvenient side-effect of burning coal that no one cared about. However, as the Nation started to use increasing amounts of energy, the fly ash residue also increased. Thanks to the scientists, engineers, and environmentalists who pushed for reform, we have taken an unwanted residue and made it recyclable. Now, instead of filling landfills with tons of fly ash, we can now use that same material to build with fly ash concrete. According to ISG, the use of fly ash instead of cement decreases the need for cement production, a source of "greenhouse gas" emissions. They also state:

> For every ton of cement manufactured, about 6.5 million BTUs of energy are consumed, and one ton of carbon dioxide is released. Experts estimate that cement production contributes to about 7 percent of carbon dioxide emissions from human sources. If all the fly ash generated each year were used in producing concrete, the reduction of carbon dioxide released from cement production would be *equivalent to eliminating 25 percent of the world's* vehicles. (ISG 4 Italics mine)

Obviously, if we would use the resources at our fingertips (fly ash) instead of filling up the landfills with it, we would have a lot less pollution not only in the United States, but in the world.

However, the concerns of the environmentalists about the safety of fly ash are not imaginary. According to Edgar's Coal Processing and Pollution Control, fly ash contains arsenic, lead, chlorine, mercury, fluorine, copper, nickel, zinc, tin, chromium, sulfur, boron, uranium, and many other elements, although they are in trace amounts (272-273). The buildup of such elements in landfills could do a lot of damage, as could the improper cleaning (removal) of the majority of these elements before the fly ash is used for concrete.

THE FUTURE

The Marion Memorial Hospital complex has aroused the interest of some citizens. Will the new Marion Memorial Hospital building ultimately harm as much as it heals? Given what we know based on the research, I do not believe so. Fly ash concrete appears to be a safe and economical choice. More importantly, Marion Memorial Hospital, its engineers, and the City Council should have come forward and clarified the issue with the public, teaching the general public about fly ash - and bottom ash, which is what they are really using.

In The Future of Energy Use, Hill, et. al., wisely note that the need for energy in our world is expanding rapidly. With the increasing need for energy comes the increase in need for fuel, including coal. With an increase of coal combustion, we have an increase of coal byproducts like fly ash.

What we do with this fly ash will determine our future society.

APPENDIX A

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APPENDIX B

CHART

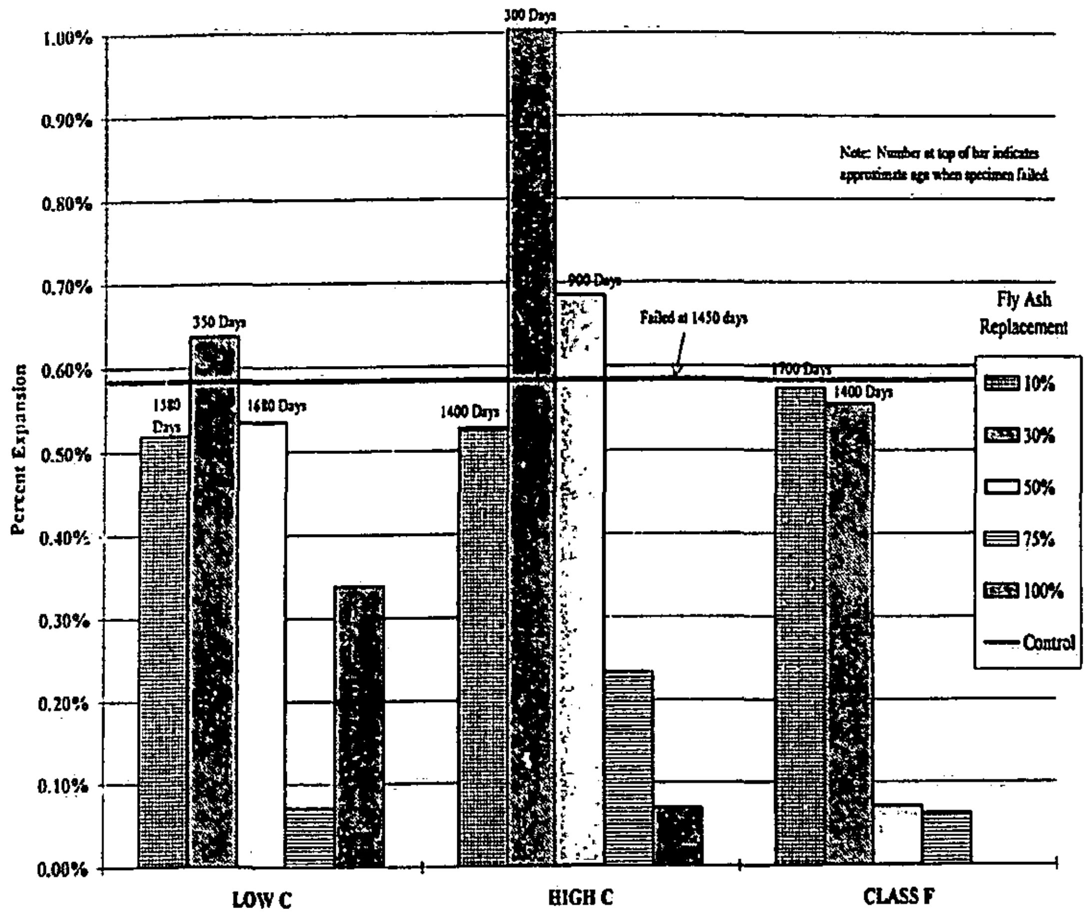

Figure 12. - Expansion of fly ash mixtures with 424 lbm/yd³ of cementitious materials at about 1650 to 1750 days (accelerated test).

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Von Fay, Kurt F. (U. S. Department of the Interior). "Effects of Various Fly Ashes on Compressive Strength, Resistance to Freezing and Thawing, Resistance to Sulfate Attack, and Adiabatic Temperature Rise of Concrete." Government Publication (Feb. 1995): 1-56.