Fly Ash Use in Pressurized Grout Remote Backfilling of Abandoned Underground Mines in North Dakota[1]

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ABSTRACT

The Abandoned Mine Lands (AML) Division of the North Dakota Public Service Commission (PSC) has been charged with the reclamation of hazardous abandoned coal mines since 1981. More than 85 primary reclamation projects, at a cost of over $23 million, have been completed in North Dakota. Pressurized grout remote backfilling is a technique for stabilizing hazardous collapsing underground mines. In this technique, a cementitious grout is pumped through cased drill holes directly into mine cavities to fill them and thereby stabilize the surface from collapse. In 1995 the North Dakota State Health Department approved the use of grout formulations containing fly ash. This approval was based on results of a comprehensive grout testing research project funded by the PSC. Fly ash replaced some of the cement in the grout formulation. Fly ash is cheaper than cement and it also improves flowability of the grout. The AML Division estimates an approximate $500,000, or 18%, reduction in the cost of pressurized grout remote backfilling projects since 1995 resultant from the use of fly ash as a grout component.

Additional Key Words: Underground Mine Reclamation, Coal Combustion Byproducts

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Introduction

There are more than 600 abandoned coal mines in North Dakota. Most of these are abandoned underground mines. As these abandoned underground mines have deteriorated with time, deep collapse features, or sinkholes, have surfaced in many areas. These features are very dangerous, especially when they occur at or near residential and commercial areas and public roads. The Abandoned Mine Lands (AML) Division of the North Dakota Public Service Commission (PSC) has been using remote backfilling methods in an attempt to prevent mine subsidence in high-use areas since the early 1980's.

Gravity fill remote backfilling was utilized until 1990. In this method, slurry, usually consisting principally of sand and water, was poured down drilled holes directly into the underground mined workings. Results of gravity fill remote backfilling were often unsatisfactory because the slurry could not penetrate all void areas if the mine was already partially collapsed. In addition, the slurry was not cohesive and tended to flow, to be washed away, or to settle as the water dissipated.

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Since 1991 pressurized grout remote backfilling has been used in North Dakota for stabilizing hazardous collapsing underground mines. In this technique, a cementitious grout is pumped through cased drill holes directly into mine cavities. This method is effective for stabilizing the surface from underground mine subsidence, especially when mined workings have begun to collapse.

One of the drawbacks of pressurized grout remote backfilling was its high cost, mainly due to the high cost of Portland Cement. In the mid-1990's, the AML Division began looking for a more cost effective, yet environmentally safe grout formulation. In 1995, a comprehensive grout testing research project determined that flyash from specific sources readily available in North Dakota could be used to replace some of the cement in the grout mix. This research yielded a grout formulation that is cheaper and has better handling characteristics, yet is relatively safe.

Part 1 – Fly Ash

Fly ash is a solid fuel combustion residue collected by filtration of the smoke discharged by coal fired power plants. Power plants in the US produce around 100 million tons of fly ash annually.

Fly ash is about 80-90% composed of glass formed from molten clays, shales, limestone, and dolomite. These small spherical particles combine with calcium hydroxide to form calcium silicate hydrate, the principal binder of cement. Fly ash is classified by its cementitious properties by the American Society for Testing and Materials (ASTM).

Fly ash is a pozzolan. Pozzolans are materials that form cement-like compounds when mixed with lime and water. Fly ash is somewhat similar to volcanic ash used to produce the earliest cements about 2300 years ago near the Italian town of Pozzuoli. Although most of the fly ash produced in the US is disposed of as a waste product in landfills and impoundments, it has many potentially beneficial uses.

Fly ash is used in concrete for road construction, masonry, and in controlled density fills for residential sub-footings. It can also be used as filler in asphalt roofing products and in composites such as ceramics and plastics. Fly ash is sometimes used as a soil amendment and in production of potting soil. Finally, fly ash is used in mine reclamation projects to fill surface and underground mines and to treat acid mine drainage and soils.

Part 2 - Coal Mining and Abandoned Mine Reclamation in North Dakota

North Dakota has the largest reserves of lignite coal in the US. Lignite is a low-grade, relatively soft coal. The lignite bearing area in ND covers about 28,000 square miles (Burr 1954). Lignite has been mined commercially in North Dakota since the 1870's. Underground mining was predominant in North Dakota until the 1930's. The number of commercial lignite mines in North Dakota peaked at about 320 in 1940 (Dahlberg et al 1984).

Lignite markets changed primarily to electric generation in the late 1940's as household demand began switching to fuel oil and natural gas. In the 1960's, huge "mine-mouth" electrical generating plants were constructed in North Dakota. A large coal gasification plant (the only one in North America) was constructed near Beulah, North Dakota in the 1970's.

In 1980, North Dakota compiled an inventory of surface and underground coal mine sites in the state abandoned prior to 1977. This inventory categorized 616 abandoned mine land (AML) sites in ND. These sites were prioritized with regard to their danger to public health, safety, general welfare, and property. Many sites have been added to this inventory and Wald and Beechie, 1996, estimated that there may be more than 2000 AML sites in the state. Often new sites are added as landowners call to report new sinkholes resulting from collapse of mined workings.

North Dakota's AML Reclamation Program was authorized in 1981. Program funding comes from a ten cent per ton production tax on lignite coal mined within the State. Currently State lignite production is about thirty million tons per year. Thus, approximately three million dollars is paid annually into the AML Fund, administered by the Office of Surface Mining Reclamation and Enforcement (OSMRE), Department of Interior. About half of this money, $1.5 million, is returned to the State of North Dakota to eliminate existing and potential public hazards resulting from abandoned surface and underground coal mines.

Since 1981, more than 85 primary reclamation projects have been completed in North Dakota at a cost of over $23 million. In addition, several smaller maintenance and emergency projects have been conducted. These projects have included backfilling dangerous surface mine pits, extinguishing mine fires, filling dangerous sinkholes resulting from collapse of underground mines, and remote backfilling to prevent collapse of underground mines beneath homes, buildings and roads. Reclamation projects are designed in-house by AML Division project managers and are conducted by contractors who are selected by competitive bidding.

Remote backfilling of North Dakota underground mined workings in the 1980's was usually accomplished by gravity feed methods in which sand/water slurry was poured down drilled holes into the mine. This method was somewhat successful if the underground mined workings were intact. If they were in a state of collapse, the gravity fed slurry would not penetrate the collapsed soil materials and significant void areas could be left to collapse in the future. Also, the sand/water slurry was not cohesive and could be washed away if there was water movement in the mine.

Most of the abandoned underground mines in North Dakota are at least partially collapsed. In the late 1980's the North Dakota AML Division made a transition from gravity fill to pressurized grout remote backfilling. In this technique, a cementitious grout is pumped through cased drill holes directly into mine cavities to fill them and thereby stabilize the surface from collapse. Grout pumped under pressures from 0-400 psi can usually penetrate rubblized soil materials adequately. In addition, after the cementitious grout hardens it will not flow or wash away.

Pressurized grout remote backfilling is effective but is also costly, often tens or even hundreds of thousands of dollars per acre. However, it is relatively cheap compared to "daylighting," or excavating down to the mined workings and backfilling with dirt. Pressurized grout remote backfilling is used in North Dakota to stabilize high-use properties such as residential and commercial areas and public roads.

Part 3 - Fly Ash-Grout Use in North Dakota

The grout mix presently in use for North Dakota reclamation projects was developed as the result of a comprehensive grout testing research project funded by the North Dakota Public Service Commission. This research project is described in a paper entitled, Flyash Grout Testing In a Simulated Wet Mine Environment by Wald and Beechie, 1996. Prior to this research, the North Dakota State Department of Health had not allowed the use of fly ash-grout for reclamation of underground mines containing water.

The fly ash-grout testing project compared 23 different grout formulations with varying amounts and sources of fly ash, cement, sand, water and superplasticizer. This fly ash grout-testing project was developed to determine the most cost effective, environmentally safe grout material available for use in reclamation of dry and wet underground mines. Grout formulations were evaluated for flowablility, pumpability, cohesiveness (non-segregation during pumping), compressive strength, and leaching potential in water. Leaching potential was determined by comparing leachate from each formulation to North Dakota's drinking water standards.

Results of this project indicated that two sources of fly ash were superior and a grout formulation was developed using these sources: Great River Energy's Coal Creek Station, Underwood, ND, and Basin Electric's Antelope Valley Station (AVS), Beulah, ND. The selected grout formulation contains 100 pounds cement, 600 pounds of fly ash, 70 ounces superplasticizer, approximately 2200 pounds of sand, and 65 gallons of water, per cubic yard. The North Dakota State Health Department approved the use of this formulation in 1995 with the stipulation that only Coal Creek or AVS Fly Ash could be used. The Health Department preferred Coal Creek Fly Ash because of its superior leachate characteristics, but AVS Fly Ash was also approved as an acceptable alternative.

Part 4 – Benefits of Fly Ash-Grout

Fly ash replaced some of the more expensive cement in the grout mixture, thereby reducing the cost per cubic yard. The AML Division estimates a nearly $500,000, or 18%, reduction in the cost of pressurized grout remote backfilling projects since 1995 as a result of the use of fly ash (Table 1).

When used with cement, fly ash improves flowability and increases compressive strength. It improves flowability because the spherical particles act like ball bearings. This allows the grout to move more freely and the small particle size promotes better filling of voids. The cementitious properties of fly ash increase compressive strength. Contract specifications for grouting projects in North Dakota presently require that the unconfined compressive strength of grout be at least 150 psi at 28 days. Use of fly ash also reduces shrinkage and slows set-up time, an important factor if grout pumping must be interrupted for a few hours. Another important reason for using fly ash is recycling: every ton of fly ash used beneficially is one not disposed in a landfill.

Fly ash can potentially pose environmental and health risks. It contains trace amounts of several toxic elements including boron, molybdenum, selenium, and arsenic. These elements could contaminate soil and water. Portland cement also contains these elements and they can occur naturally in soil and water. If used responsibly, fly ash is a safe product and can be used safely with very limited chances of polluting soils or water.

After grout containing fly ash hardens it is fairly inert. Research conducted by North Dakota Public Service Commission (Wald and Beechie 1996) found that grout mixes using fly ash often leached lower concentrations of trace minerals than cement-only grout. This research also indicated that, depending on the source of fly ash, leachate from hardened grout could meet safe drinking water standards for heavy metal concentrations.

Summary and Conclusions

Fly ash will continue to be produced as long as coal-fired electricity is generated. Coal is an abundant and relatively cheap resource. Although concerns about fly ash use and disposal are valid, some environmental groups have sensationalized these concerns. These groups are lobbying the US Environmental Protection Agency (EPA) to classify fly ash as a hazardous waste. This could severely limit fly ash recycling and its beneficial uses and result in higher energy costs.

The use of fly ash as a grout component has resulted in improved performance and significant cost savings in pressurized grout remote backfilling projects in North Dakota. Research conducted in North Dakota indicates that sources differ markedly in chemistry and performance of their fly ash. These differences result from properties of the coal itself and the method of coal processing and combustion. A responsible user should thoroughly test fly ash from each potential source to ensure that it is appropriate for its intended use.

The North Dakota Public Service Commission, Abandoned Mine Lands Division intends to continue using fly ash grout in its pressurized grout remote backfilling projects. It remains in close consultation with the North Dakota Department of Health and we will jointly continue to monitor the performance and environmental aspects of the use of fly ash grout in the future.

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