

Use of Coal Ash Generated at Minn-Dak for Soil Stabilization at a Sugarbeet Piling Site

CARLSON, JEFFREY L¹, PETE W. JENSEN¹, JOHN GRONEMAN¹, PARKER J. THILMONY¹, MELANIE G. NIDAY², JON SCHARF², ¹ Minn-Dak Farmers Cooperative, 7525 Red River Road, Wahpeton, ND 58075-9698; and ²Earth Tech, Inc., 3033 Campus Drive North, Suite 175, Minneapolis, MN 55441.

Introduction

Like all other process industries beet-sugar companies spend significant resources on protecting the environment from unintended affects of sugar manufacture. Since beet-sugar manufacturing is and energy intensive process, beet-sugar companies constantly look to improve their energy efficiencies and find lower cost energy. In the USA coal is a very attractive low-cost energy source. Minn-Dak Farmers Cooperative burns coal from the Powder River Basin in Wyoming for steam generation and pulp drying. Although coal is a relatively inexpensive energy source, it has the associated problem of ash disposal. In the 1999-2000 campaign, Minn-Dak burned 129,525 tons of sub bituminous coal that averaged 9,300 BTU per pound and 4.5% ash. In recent years, concerns about heavy metals in ash have prompted the United States Environmental Protection Agency (USEPA) to develop national standards to address wastes from coal burning plants that are either presently land disposed or used it as fill in mining. The USEPA is particularly concerned about the arsenic, cadmium, chromium, lead and mercury found in coal ash.

On April 25, 2000 the USEPA stated that they were not going regulate boiler ash as a hazardous waste. However, they felt that states and industry should adopt safer approaches to the disposal of coal combustion wastes that are disposed of in landfills, surface impoundments and when used in fill in mining. They left the door open to future regulation. Anyone considering a landfill option for coal ash must also consider the liability of the landfill. By putting ash into a landfill, a beet-sugar company becomes liable for future problems associated with that landfill. Hazardous waste landfill operators design their landfills to stringent standards, which could reduce the potential future liability. However, the cost of using such a landfill will be greater and in the unlikely event of a hazardous waste landfill leaking, liability could be great.

One option for fly as is safe reuse in construction. The USEPA has stated that safe reuse in construction did not warrant regulatory action by that agency. Since Minn-Dak was going to be rebuilding a piling ground that had always been soft, the cooperative's managers decided to use the ash as a soil stabilizer. This option was attractive for several reasons. First, Minn-Dak would not have all the liabilities associated with putting it in a landfill. Second, it would replace costly soil stabilizers that would have to otherwise be used. Finally, Minn-Dak could avoid the cost of trucking the ash thirty miles to a landfill and avoid the tipping fee.

Before the North Dakota Department of Health would allow Minn-Dak to use its coal-combustion ash as a soil stabilizer, they needed to be satisfied that the ash did indeed stabilize the soil and that once in place it would not pose a threat to the environment. Working with NDDH and Earth Tech, Inc. employees Minn-Dak developed a plan to test these issues.

The Gorder piling site is located near the town of Galchutt in northeastern Richland County, North Dakota. This area of North Dakota has unique physical characteristics because it lies within the lake plain that was occupied by the former glacial Lake Agassiz.

During operations at the piling sites, access has been difficult due to on-site soil conditions and poor surface water drainage. In 1997, conditions at the Lyngass piling site in Wilkin County, Minnesota, prompted Minn-Dak to request the Minnesota Pollution Control Agency (MPCA) to use coal ash generated at the Wahpeton facility to stabilize the on-site soils. The MPCA approved the request in a letter dated June 10, 1997. Since the soil stabilization project was completed at the Lyngass piling site, site operations have shown considerable improvement. Other coal ash utilization projects within Minnesota are still pending approval by the MPCA.

In recent years, the physical and chemical properties of coal ash have initiated more research into its beneficial use. The American Standards for Testing Materials (ASTM) has developed the Standard Practice for Characterizing Fly Ash for Use in Soil Stabilization (ASTM D 5239-98). The American Coal Ash Association, Inc. (ACAA) has been involved in a number of publications including Soil and Pavement Base Stabilization with Self-Cementing Coal Fly Ash (ACAA, May 199) and Fly Ash Facts for Highway Engineers (ACAA, August 1995). Federal Highway Administration sponsored the latter of the two publications.

Soil Stabilization

The coal from which Minn-Dak generated the ash was from the Spring Creek Coal Company's Kennecott mine in Montana. The type of coals mined in this region is considered low sodium (Dr. G. J. McCarthy, NDSU, personal communication). Chemical analysis conducted on the ash produced by Minn-Dak indicates that the levels of calcium oxide are nearly 10 times greater by weight than sodium oxide (Appendix A). The presence of calcium oxide is a primary basis for the beneficial use properties of the coal ash.

The clays present within the soils in the Red River Valley are predominantly smectites including beidellite and montmorillonite. The sodium present within the soils significantly increases the swelling potential of the clay minerals (Drever, 1988). The addition of calcium from a low sodium coal ash allows the calcium to replace the sodium within the interlayered mineral structure, which stabilizes the soils by reducing the shrink-swell potential (Dr. G.J. McCarthy, NDSU, personal communication). In addition, coal ash can exhibit pozzolanic properties. ASTM C618-94a (Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use as a Mineral Admixture in Portland Cement Concrete) defines a pozzolan as "siliceous or siliceous and aluminous materials which in themselves pose little or no cementitious value but will . . . chemically react with calcium hydroxide at ordinary temperatures to form compounds possessing cementitious properties." When the coal ash is combined with soil and hydrated, the calcium oxide plus water form calcium hydroxide, which contributes to its cementitious properties (Dr. G.J. McCarthy, NDSU, personal communication). Therefore, the use of coal ash for soil stabilization projects serves two significant functions: 1) it stabilizes expansive soils by adding calcium and 2) it reacts with water and soils to provide cementitious properties. Once compacted, these physical properties minimize contact with air and water.

Investigations

On March 28, 2000, a field investigation was conducted by Earth Tech, Inc. to characterize and evaluate the geologic, hydrogeologic, and geotechnical conditions at the Gorder piling site. Soil samples were logged, classified, and geologically interpreted in the field. Soil descriptions included consistency or density, matrix color (using a Munsell Color Chart), unified soil classification (using procedures described in ASTM D 2488), field moisture, plasticity, cohesiveness, primary sedimentary structure (and secondary soil structure if applicable), weathering zone abbreviation, observed secondary features, soil horizon if applicable, and depositional interpretation.

A representative soil sample from each split spoon was placed in a glass jar and submitted to Midwest Testing for further laboratory testing. In addition, a duplicate soil sample was collected from the first split spoon from each boring and submitted to MVTL Laboratories for analytical testing. Soil cuttings from the upper 2 feet was placed into 5-gallon buckets and submitted to Midwest Testing for geotechnical testing.

A number of the samples collected in the field were selected for further laboratory testing including moisture content, particle size distribution with hydrometer, and Atterberg limits. As requested by the NDDH, the ash was characterized for chemical and beneficial use properties. For purposes of this study, both fly ash and a mixture of fly and bottom ash were tested. The following sections discuss the results of testing.

Ash Leach Testing

Samples of the site soil, fly ash, and fly/bottom ash were collected and sent for analysis to Minnesota Valley Testing Laboratories, Inc. of Bismarck, North Dakota. The soil sample represented a composite of six samples, one from the upper two feet from each of the soil borings completed as part of the field investigation. The fly ash came from the coal ash generated during the 1999-2000 campaign and the combined fly and bottom ash came from coal ash generated during the 1998-1999 campaign. As requested, the samples were analyzed for parameters included ammonia, antimony, arsenic, barium, beryllium, bicarbonate, boron, cadmium, calcium, carbonate, cation/anion balance, chloride, chromium, copper, fluoride, iron, lead, magnesium, manganese, mercury, molybdenum, nickel, nitrate, nitrite, phosphorous, potassium, selenium, silver, sodium, sodium absorption ratio, sulfate, thallium, total alkalinity, total dissolved solids, total suspended solids, vanadium, and zinc.

The purpose of the leach testing is to evaluate the constituents in the soil/ash mixture which may leach through the underlying soils, be transported through the groundwater or eventually discharge into a surface water body. A screening level assessment was conducted to determine if the constituents in the ash/soil mixture would be present in concentrations that would degrade ground water or surface water quality. In this assessment, the Synthetic Precipitation Leaching Procedure (SPLP) was performed on samples of pure fly ash, fly ash/bottom ash mixture, and soil. The SPLP results for each sample were compared to Federal and North Dakota drinking water standards and North Dakota surface water quality. To be conservative, the surface water criteria in the table for those of Class II streams were used. The nearest surface water body is Pitcaim Creek, which is three miles north of the site where the ash will be utilized. Pitcaim Creek

has no state water classification, but it drains into the Wild Rice River, which is Class II surface water.

Beneficial Use Testing

To simulate mixing of soils resulting from site grading, all of the samples were blended to form one composite sample. Tests were run on this composite sample to determine the baseline characteristics of the surface soils. These same tests were run on the composite sample amended with varying percentages of pure fly ash as well as combined fly ash and bottom ash. The results of all of the tests are summarized in Table I and discussed in the following sections.

Soil Classification: Each of the prepared samples was classified using the Unified Classification System. The classifications are based on grain size analysis and Atterberg limits results. The composite soil sample was classified as clayey sand (SC). With the addition of ash (both pure fly ash and the bottom ash mixture), the plasticity of the samples was reduced which resulted in some samples being classified as a silty sand (SM).

Table I: Soil Stabilization Test Results

	Classification	Optimum Moisture Standard Proctor (%)	Maximum Dry Density Standard Proctor (%)	Liquid Limit	Plasticity Index	California Bearing Ratio (CBR)
Composite Soil Sample	SC	14.6	111.7	44	25	9
Soil and 10% Fly Ash	SC	19.2	102.7	46	21	15.4
Soil and 20% Fly Ash	SM	24.4	93.8	48	16	18.4
Soil and 30% Fly Ash	SM	25.6	90.2	48	9	27.5
Soil and 10% F Ash Mix	SC	18.2	104.4	45	23	7.3
Soil and 20% Ash Mix	SC	20.4	98.8	45	21	11.6
Soil and 30% Ash Mix	SM	22.9	95.5	45	18	21.5

Moisture Density Relationship: The moisture density relationship of each prepared sample was determined using the standard Proctor method. The results indicated that the optimum density decreases and the optimum moisture increases as the percentage of ash is increased in the sample. The range in values was most pronounced with the soil amended with pure fly ash and less pronounced with the bottom ash mixture. The decrease in optimum density is to be expected in that the ash has a lower unit weight than the soil.

Atterberg Limits: The most common use of the Atterberg limits test results is for soil classification and qualitative measure of engineering properties. The Atterberg limits vary with the amount of clay present in the soil, the type of clay mineral, and the nature of the ions absorbed on the clay surface. Generally, soils with high liquid limits are clays with poor engineering properties. A low plasticity index indicates a soil with little cohesion and plasticity, such as a granular type soil.

The test results of the prepared samples indicate that, with the addition of either the fly ash or bottom ash mixture, the liquid limit did not appreciably change. The plasticity index however, was significantly reduced with the addition of pure fly ash. Some benefit was also observed, but to a lesser extent, with addition of the bottom ash mixture.

California Bearing Ratio: The California Bearing Ratio (CBR) test was developed to evaluate the strength, or resistance to deformation, of subgrade soils for use in pavement design. Subgrade soil is compacted into a mold at a specific density and moisture, immersed in water for a number of days, then subjected to penetration by a piston. The loading on the piston and resulting penetration is an expression of soil strength.

The CBR test was used to evaluate the potential benefits of the ash amendment. For this, the prepared samples were molded at approximately 95 percent of standard Proctor density to simulate the conditions during construction. The samples were then set aside for seven days to allow any chemical or cementitious benefits to occur. The samples were then soaked and tested. No improvement was observed in the samples amended with the bottom ash mixture. However, the results indicated significant improvement of samples amended with pure fly ash. For comparison, engineering literature indicates a CBR value of 9 (result of the un-amended soil sample) is a typical value for clays. A CBR value of 27.5 (result of the sample amended with 30 percent fly ash) is a typical value for sand or gravel.

Results of the analytical testing confirmed that little or no environmental impacts were anticipated by incorporating ash into existing soils to improve soil stabilization. The results of the geotechnical testing indicated that the strength of the subgrade soils could be significantly improved by amending them with pure fly ash. The tests showed that the engineering properties of the soil continue to improve as the percentage of fly ash was increased. The bottom ash mixture did not provide near as much benefit to the soils as the pure ash.

Based on the test results, Minn-Dak and the North Dakota Department of Health decided to go ahead with the project. Ash was blended into the top 24 inches of the soils and the amended material was graded and compacted to form a newly constructed pad. Approximately 4-inches of clayey soil was placed above the amended soil to minimize the potential exposure of the

Finished Piling Site Leachate Testing

Four samples were submitted to Minnesota Valley Testing Laboratories (MVTL) for analysis. The samples were prepared for analysis according to ASTM 3987 (Test Method for Shake Extraction of Solid Waste with Water) and a modified solution ratio of 4:1. The extract was analyzed for the parameters above.

The analysis of the extract from the amended soil samples reported concentrations of boron, nitrate+nitrite, sulfate, and arsenic above water quality criteria.

Boron was detected at concentrations above the Maximum Limit for Class II streams. This limit was set to restrict the use of water for irrigation when boron content was above 0.75 mg/l because of the effects to some plants. The use of site water for irrigation is not being considered. It should be noted that boron was also detected above this standard in the non-amended native soil collected from the site prior to the construction.

Nitrate+nitrite was detected at concentrations above the Maximum Limit in three of the four extract samples. The concentrations are less than that detected from the non-amended soil sample from the site analyzed previously. This evidence suggests that the ash is not increasing, and in fact may be reducing, the leachable concentration of nitrate+nitrite in the soils.

Sulfate was detected in all four samples at concentrations in exceedance of both the groundwater standards and the Maximum Limit for Class II streams. The elevated concentrations in these samples were unexpected in that previous analysis of separate ash and site soil samples reported concentrations an order of magnitude lower. Although the cause for this is not clear, it appears that sulfate concentrations in leachate are influenced by the chemical interaction between the soil and the ash-amending agent. The reported concentration may be further influenced by the use of the modified 4:1 leaching procedure as opposed to the standard method in the sample preparation. It should be noted that even higher concentrations of sulfate have been documented as naturally occurring in nearby aquifers (Baker et.al., 1967, Geology and Ground Water Resources, Richland County).

Arsenic was detected in the four samples at concentrations above the Human Health Value for Class II streams and below the other listed standards. Although slightly higher in concentration, the results are similar to the result obtained for the non-amended soil sample analyzed previously. Considering that arsenic was not detected in two of three previous ash analyses, it is possible that the presence of arsenic in these samples is more representative of the source soils than the amending agent.

Conclusions

Based on the results of the in-place CBR tests, it is apparent that amending the soils with either the pure fly ash or the fly/bottom ash mixture provides significant benefit by providing additional strength to an otherwise weak subgrade. The sampling of the amended soils and subsequent chemical analysis suggests that potential environmental impacts that may result from the soil amendment are minimal.

material at the surface. The ash was incorporated at 30% by weight. The construction took place in June and July of 2000.

During construction a heavy rain drained into the partially constructed stormwater runoff pond. Samples of this water were sampled and tested for the same heavy metals tested for in the leachate test of the ash. The testing showed no heavy metal concentrations at levels above the standards.

Testing to Verify Beneficial Use Objectives

Testing for soil strength parameters and sample collection for chemical analysis were conducted on September 25, 2000, approximately 60 days after the completion of construction. The purpose of this testing was to evaluate physical and chemical conditions of the amended soil after a reasonable curing time to allow the chemical reactions that are inherent in the ash/soil mixture to occur

Minn-Dak contracted Midwest Testing Laboratories, Inc. of Fargo, North Dakota to perform in-situ tests to verify that beneficial use objectives have been met. In-place field California Bearing Ratio (CBR) tests were used to determine the relative strengths of soils in the condition at which they exist at the time of testing. The CBR tests were conducted using a Dual-Mass Dynamic Cone Penetrometer. The results varied with depth at each location. The weighted average values for each test location are listed in Table II.

Table II: Results of the In-place CBR Tests

Soil Amending Agent	CBR *	Percent Increase **
Fly/Bottom Ash Mixture	16.2	80
	14.1	55
Fly Ash	17.5	90
Fly Ash	17.4	90
	17.0	85
	25.0	175

* Weighted average for 24-inch thickness

** Compared with a laboratory CBR of 9.0 for non-amended compacted soil

For comparison purposes, non-amended soil collected from the Gorder Site and compacted in the laboratory was determined to have a CBR value of 9.0. As indicated by the in-situ test results, the amended soils showed significant increase in the CBR value from that demonstrated in the non-amended laboratory sample. At all of the test locations, it appears that the soil amendment was beneficial. Although both the fly ash and fly/bottom ash mixture performed well, it appears that the soil stabilized with pure fly ash provided the best results.

Samples of the amended soil were collected on September 25, 2000. As with the CBR testing, the 4-inch cover soil was removed to obtain samples of the amended soil. Samples were collected using a 2-inch outer diameter split-barreled sampler in accordance with ASTM D1586.

A 4-inch layer of non-amended clay covers the amended soils. Therefore, the actual exposure of the amended soil to the environment will be nominal. Dust control practices and general maintenance of the pad should be performed as necessary for beet piling operations.

In addition to the benefit of a more-stable beet-piling site, Minn-Dak received two other benefits from this project. First since Minn-Dak's cost for using the ash beneficially was about \$66,000. This was considerably less than the \$250,000 it would have cost to truck it to a landfill. In addition, it prevents Minn-Dak from accepting liability for the operation of the landfill. Minn-Dak does still have any potential environmental liability from the site but use of ash as a soil stabilizer is well known and the site specific testing done significantly reduces the possibility that there will be any unknown future costs. Minn-Dak will have to pick up any decommissioning costs when it closes the piling ground.

Table II. Results of the in-place CBR tests

Soil Amending Agent	CBR*	Percent Increase
Hydramon Ash	14.2	40
Minnas	14.1	39
Fly Ash	17.0	45
Control	12.0	0
Fly Ash	17.0	42
Control	12.0	0

* Compared with a laboratory CBR of 9.0 for non-amended control soil. Weights used for the 24-inch thickness.

The laboratory tests were conducted on samples of the amended soil collected from the control site and compared in the laboratory. The laboratory tests were conducted on samples of the amended soil collected from the control site and compared in the laboratory. The laboratory tests were conducted on samples of the amended soil collected from the control site and compared in the laboratory.

Samples of the amended soil were collected on September 12, 2001. A total of 12 samples were collected. The 4-inch soil was removed to obtain samples of the amended soil. Samples were collected using a 2-inch outer diameter split-barrel sampler in accordance with ASTM D1586.