1 of 1

**Fly Ash Utilization in
McLean County, North Dakota**

**Task 7.25
Topical Report**

Charles J. Moretti

March 1993

Work Performed Under Contract No.: DE-FC21-86MC10637

For
U.S. Department of Energy
Office of Fossil Energy
Morgantown Energy Technology Center
Morgantown, West Virginia

By
University of North Dakota
Energy and Environmental Research Center
Grand Forks, North Dakota

MASTER

REPRODUCTION OF THIS DOCUMENT IS UNLIMITED

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

This report has been reproduced directly from the best available copy.

Available to DOE and DOE contractors from the Office of Scientific and Technical Information, P.O. Box 62, Oak Ridge, TN 37831; prices available at (615) 576-8401.

Available to the public from the National Technical Information Service, U.S. Department of Commerce, 5285 Port Royal Rd., Springfield, VA 22161; phone orders accepted at (703) 487-4650.

**Fly Ash Utilization in
McLean County, North Dakota**

**Task 7.25
Topical Report**

Charles J. Moretti

Work Performed Under Contract No.: DE-FC21-86MC10637

**For
U.S. Department of Energy
Office of Fossil Energy
Morgantown Energy Technology Center
P.O. Box 880
Morgantown, West Virginia 26507-0880**

**By
University of North Dakota
Energy and Environmental Research Center
P.O. Box 9018
Grand Forks, North Dakota 58202-9018**

March 1993

TABLE OF CONTENTS

	<u>Page</u>
LIST OF FIGURES	ii
LIST OF TABLES	iii
1.0 INTRODUCTION	1
2.0 OBJECTIVES AND COMMERCIAL BENEFITS	1
3.0 MATERIALS AND METHODS	2
4.0 RESULTS AND DISCUSSION	4
4.1 Development of Stabilized Soil Mix Designs for the Road Site	4
4.2 Development of Stabilized Soil Mix Designs for the Boat Ramp Site	6
4.3 Road Construction Activities	7
4.4 Boat Ramp Construction Activities	9
4.5 Inspection of the Completed Road and Boat Ramp	12
4.6 Cost Savings Resulting from Fly Ash Utilization	12
5.0 CONCLUSIONS	14
6.0 REFERENCES	17

LIST OF FIGURES

<u>Figure</u>		<u>Page</u>
1	A grader removed the old road surface, and the soil was piled on the side of the road	9
2	Fly ash was deposited at the road site using a belly dump truck	10
3	The fly ash and soil were mixed with a tractor-drawn disk	10
4	Moisture was added to the fly ash-soil mixture with a water truck	11
5	Lime was pneumatically spread on the road site with a truck	11
6	A section of the road after the lime had been spread	12
7	A section of the completed lime- and fly ash-stabilized road in McLean County	13
8	A view of the completed boat ramp in McLean County	13

LIST OF TABLES

<u>Table</u>		<u>Page</u>
1	Chemical and Physical Analyses of Coal Creek Station Fly Ash	3
2	Soil Classifications for the Road and Boat Ramp Samples	3
3	ASTM Test Methods Used to Formulate the Stabilized Soil Mixtures	5
4	Suggested Formulas for Lime and Fly Ash Stabilization of the Road Soil Samples	6
5	Physical Properties of Lime- and Fly Ash-Stabilized Soil Samples for the Road	7
6	Suggested Formulas for Cement and Fly Ash Stabilization of the Boat Ramp Soil Samples	8
7	Physical Properties of Cement- and Fly Ash-Stabilized Soil Samples for the Boat Ramp	8
8	Summary of the Cost Analysis Performed for the Road Construction Activities	15
9	Summary of the Cost Analysis Performed for the Boat Ramp Construction Activities	16

FLY ASH UTILIZATION IN McLEAN COUNTY, NORTH DAKOTA

1.0 INTRODUCTION

In 1989, the McLean County Commissioners requested assistance from personnel at the University of North Dakota Energy and Environmental Research Center (EERC) with the construction of a section of road and a boat ramp in their county. Assistance was sought from the EERC because the county's construction plans called for partial replacement of the lime and portland cement normally used for soil stabilization with fly ash. Since the EERC had recently conducted several research projects dealing with the use of coal combustion by-products for road construction, the commissioners requested that EERC personnel help to determine appropriate formulas for the stabilized soil mixtures to be used for both the road and boat ramp applications.

McLean County is located in west-central North Dakota. The section of road that the county wanted to build was to connect the Fort Mandan historical site with state Route 83. The Fort Mandan site is located about 5 miles west of Washburn, North Dakota. The boat ramp was to be located on the north shore of Lake Sakakawea close to Garrison, North Dakota.

The commissioners wanted to use fly ash for the construction projects because they believed that a significant cost savings could be achieved and, therefore, more construction could be done with the available tax dollars. An additional incentive was provided when the management of the Coal Creek Power Plant offered to donate the necessary fly ash at no cost.

The fly ash produced at the Coal Creek Power Plant is known to have excellent pozzolanic and hydraulic properties, and, in fact, large amounts of this ash are sold as a concrete admixture. Since the soil at the road construction site was expected to have a fairly high clay content, it was expected that a mixture of lime and fly ash could be used to stabilize the road base and create a durable wear surface for the road. The soil at the boat ramp site was known to have a high gravel content, and, therefore, it was expected that a mixture of portland cement and fly ash could be used to make a soil cement for constructing the boat ramp.

This project was performed as a joint venture between McLean County and the EERC. The EERC was primarily responsible for conducting a laboratory testing program to develop soil stabilization mixtures for the two construction activities. These mixtures were to contain a relatively high percentage of fly ash and to exhibit sufficient strength and durability so that the road and boat ramp would both have a service life of 20 years or more. McLean County would be primarily responsible for the road and boat ramp construction activities. The funding for the EERC portion of the project was provided by the U.S. Department of Energy through a joint venture support program.

2.0 OBJECTIVES AND COMMERCIAL BENEFITS

The objective of this project, from the EERC's perspective, was to demonstrate the economic benefit of using locally produced fly ash for the construction of roads and boat

ramps in a rural setting such as McLean County, North Dakota. The project activities included 1) the construction of 2.7 miles of hard-surfaced road using a lime- and fly ash-stabilized soil and 2) the construction of a 200-foot by 30-foot boat ramp using a soil-cement made from a mixture of portland cement and fly ash. In each case, a laboratory study was conducted at the EERC to determine the necessary amounts of lime, portland cement, and fly ash required to produce a durable structure.

The chief benefit of using fly ash to build the road and the boat ramp was to reduce the overall construction costs by reducing the amounts of lime and cement needed for the structures. Some additional anticipated benefits of this project were to promote a wider acceptance of fly ash as a construction material in North Dakota and to reduce the amount of fly ash being disposed of in landfills.

3.0 MATERIALS AND METHODS

The fly ash used for this research project was generated at the Coal Creek Power Plant located in Center, North Dakota. The fly ash was a "Class C" material as specified by ASTM C618. The fly ash was produced from a pulverized coal combustor burning a North Dakota lignite. The results of selected chemical and physical analyses performed on this fly ash are listed in Table 1. The lime used for the road construction was a Type M hydrated lime, and the cement used for the boat ramp construction was a Type 1 portland cement.

To determine the amounts of lime, cement, and fly ash needed to stabilize the soils, ten soil samples were collected from various locations at the road site, and two soil samples were collected from different locations at the boat ramp site. These samples were subjected to sieve and hydrometer analyses and classified according to ASTM D2487. The classifications determined for the road and boat ramp soil samples are shown in Table 2.

It had been expected that the soil samples from the road site would contain significant amounts of clay. For this reason, lime and fly ash were initially selected as the stabilizing additives. When the soil samples from the road sites were tested, however, it was found that, in addition to clay, they contained significant amounts of sand and gravel because there was a preexisting gravel road at the site. Even though there was substantially more sand and gravel in the samples than expected, it was decided that lime-fly ash addition was still the preferred method of stabilizing these soils.

As had been expected, the soil samples from the boat ramp site were composed predominantly of sand, gravel, and small stones. For this type of soil, it was decided that portland cement and fly ash would be the preferred stabilizing additives.

The lime- and fly ash-stabilized soil mixtures tested in the laboratory for the road construction task were prepared following ASTM D3551. The optimum moisture content and maximum compacted density of each mixture were determined using ASTM D1557. Specimens for unconfined compressive strength tests were prepared by compacting the mixtures into 4-inch-diameter by 4.5-inch-long cylindrical molds at their optimum moisture contents and using a modified Proctor compactive effort. The specimens were

TABLE 1

Chemical and Physical Analyses of Coal Creek Station Fly Ash

<u>Chemical Composition (wt%)</u>	
Silicon Dioxide (SiO ₂)	45.83
Aluminum Oxide (Al ₂ O ₃)	15.23
Iron Oxide (Fe ₂ O ₃)	7.24
Sulfur Trioxide (SO ₃)	1.38
Calcium Oxide (CaO)	18.26
Moisture Content	<.01
Loss on Ignition	<.01
Available Alkalies as Na ₂ O	0.78
<u>Physical Test Results</u>	
Material Retained on a #325 Sieve	18.93 wt%
Strength Activity Index with Portland Cement	
Percent of Control at 7 days	67%
Percent of Control at 28 days	83%
Strength Activity Index with Lime at 7 days	1470 psi
Water Requirement, percent of control	92%
Autoclave Expansion, percent of specimen length	0.08%
Specific Gravity	2.39

TABLE 2

Soil Classifications for the Road and Boat Ramp Samples

Road Samples	Unified Soil Classification
A	Silty clay with gravel (CL-ML)
B	Silty clay with gravel (SP-SC)
C	Lean clay with gravel (SC)
D	Poorly graded sands and gravelly sands (SP)
E	Silty lean clay with gravel (SP-SC)
F	Poorly graded sands and gravelly sands (SP)
G	Poorly graded sands and gravelly sands (SP)
H	Silty sand (SM)
I	Silty sand (SM)
J	Poorly graded sand (SP)
Boat Ramp Samples	
L	Poorly graded sands and clayey sands (SP-SC)
U	Poorly graded sands and gravelly sands (SP)

cured for either 7 or 14 days at 100°F. Initially a 7-day curing period was used, but this was changed to a 14-day period after the first set of samples was tested. The curing time was increased to allow the specimens more time to gain strength. After curing, the cylinders were treated with a vacuum saturation procedure to simulate weathering stresses and then tested for residual unconfined compressive strength following ASTM D593. The general design criteria for acceptance of a specific stabilized soil mixture was that it display a minimum unconfined compressive strength of 400 psi after vacuum saturation treatment.

For the soil samples from the boat ramp site, optimum moisture contents and maximum compacted densities were determined for the cement- and fly ash-stabilized soil mixtures using ASTM D558. The mixtures were molded into 3-inch-diameter by 6-inch-long cylindrical test specimens following ASTM D1632. The specimens were cured for 7 days at 70°F, and then tested for unconfined compressive strength following ASTM D1633. The general design criteria for acceptance of a stabilized soil mixture was that it display a minimum unconfined compressive strength of about 450 psi.

Once a mix formula had been determined for each of the boat ramp samples that demonstrated the proper unconfined compressive strength, it was further tested for freeze-thaw durability and wet-dry durability following ASTM D560 and D559, respectively.

The various ASTM methods used to characterize the soil samples from both the road and boat ramp construction sites and to evaluate the stabilized soil mixtures are listed in Table 3.

4.0 RESULTS AND DISCUSSION

4.1 Development of Stabilized Soil Mix Designs for the Road Site

The ten soil samples collected from the road construction site were labeled A through J. After receipt at the laboratory, each of the soils was tested and classified. Based on similarities among the physical properties of several of the soils, Samples B and E were combined and Samples H and I were combined for the follow-on soil stabilization study.

For the stabilization tests, the +4 sieve fraction for each soil sample was increased to 25% of its dry weight by mixing in an appropriate amount of gravel. The gravel was added to the samples because it had been learned that much of the surface gravel present at the road site had been removed before the samples were taken. Thus the gravel was added to make the samples more representative of the soils actually present at the site.

Stabilization tests for Samples D, B and E, and H and I were performed first. Initially 1.5 wt% lime and 8 wt% fly ash were mixed with the soils, which were then compacted into cylinders at their optimum moisture contents. After curing and vacuum saturation treatment, the unconfined compressive strengths of the cylinders were measured and found to be well below the minimum acceptable value of 400 psi.

TABLE 3

ASTM Test Methods Used to Formulate the Stabilized Soil Mixtures

Analysis of Chemical and Physical Properties of Fly Ash:

ASTM C311: "Method for Sampling and Testing Fly Ash or Natural Pozzolans for Use as a Mineral Admixture in Portland Cement Concrete"

Classification of Soil Samples:

ASTM D2487: "Classification of Soils for Engineering Purposes"

Preparation and Testing of Lime-Fly Ash Stabilized Soils:

ASTM D3551: "Laboratory Preparation of Soil-Lime Mixtures Using a Mechanical Mixer"

ASTM D1557: "Test Methods for Moisture-Density Relations of Soils and Soil-Aggregate Mixtures, Using a 10-lb Rammer and an 18-in Drop"

ASTM D593: "Specification for Fly Ash and Other Pozzolans for Use with Lime"

Preparation and Testing of Cement-Fly Ash Stabilized Soils:

ASTM D558: "Moisture-Density Relations of Soil-Cement Mixtures"

ASTM D1632: "Methods of Making and Curing Soil-Cement Compression and Flexure Test Specimens in the Laboratory"

ASTM D1633: "Test Method for Compressive Strength of Molded Soil-Cement Cylinders"

ASTM D560: "Methods for Freezing-and-Thawing Tests of Compacted Soil-Cement Mixtures"

ASTM D559: "Methods for Wetting-and-Drying Tests of Compacted Soil-Cement Mixtures"

To increase the strengths of these samples, the lime and fly ash contents were gradually raised. By repeated testing, it was eventually determined that in order to achieve a compressive strength exceeding 400 psi, the lime and fly ash contents had to be raised to 4% and 16%, respectively.

Samples A, C, F, G, and J were tested next using the addition of 4% lime and 16% fly ash. The compressive strengths measured for these soil mixtures all greatly exceeded 400 psi. Based on these results, the amount of lime added to the mixtures was reduced to 2%, while the amount of fly ash was kept at 16%. When this was done, the strengths of the stabilized soil mixtures were much closer to the 400-psi target.

Based on the results of the stabilization tests described above, appropriate lime and fly ash addition levels were selected for the ten different soil samples collected at the road construction site. The soil stabilization formulas are listed in Table 4, and some selected physical properties of the stabilized soils are listed in Table 5.

4.2 Development of Stabilized Soil Mix Designs for the Boat Ramp Site

The two soil samples collected at the boat ramp construction site were labeled U and L. These samples were examined and classified in the same manner as the road samples. The amounts of cement (without fly ash) required to stabilize these two soils were estimated based on their soil properties and by using a procedure contained in the "Soil-Cement Laboratory Handbook" (Portland Cement Association, 1971). Once the initial cement addition levels were determined for the samples, 70% by weight of the cement was replaced with fly ash to obtain initial stabilization formulas for the boat ramp samples.

TABLE 4

Suggested Formulas for Lime and Fly Ash Stabilization of the Road Soil Samples

Sample Designation*	Lime Content (% dry wt)	Fly Ash Content (% dry wt)
A	2	16
B and E	4	16
C	2	16
D	4	16
F	2	16
G	2	16
H and I	4	16
J	2	16

*All soil samples contained 25% +4 aggregate before addition of lime or fly ash.

TABLE 5

Physical Properties of Lime- and Fly Ash-Stabilized Soil Samples for the Road

Sample Designation	14-day Compressive Strength (psi)	Dry Unit Weight (lb/ft ³)	Mod. Proctor Density (lb/ft ³)	Optimum Moisture (% dry wt)
A	640	125.5	129.9	8.4
B and E	405	118.0	123.0	10.2
C	865	118.7	122.7	11.4
D	525*	115.9	119.9	11.7
F	810	125.1	127.6	10.0
G	743	116.6	121.8	10.2
H and I	405	122.0	127.0	9.2
J	770	124.4	125.9	9.7

*Sample D was the first soil tested, and a 7-day cure was used for this sample.

The initial formulas determined for the boat ramp samples did not meet the target compressive strength of 450 psi. The formulas were adjusted by preparing additional test cylinders containing various amounts of cement and fly ash. Eventually, appropriate formulas that met the target strength were determined for the boat ramp soils. These formulas were further evaluated for freeze-thaw durability and wet-dry durability to ensure that they provided adequate stabilization for the soils. The formulas determined for the boat ramp soils are listed in Table 6, and some selected physical properties of the stabilized soils are listed in Table 7.

4.3 Road Construction Activities

The road and boat ramp construction projects in McLean County were performed in August of 1991. A county work crew performed the construction activities.

Construction of the road was performed in the following steps:

1. A road grader was used to scrape the top 9 inches off of the existing gravel road surface. The soil was stockpiled along the side of the road.
2. Fly ash was transported from the Coal Creek Power Plant to the construction site in a belly dump truck and was spread evenly down the center of the excavated road bed.

TABLE 6

Suggested Formulas for Cement and Fly Ash Stabilization of the Boat Ramp Soil Samples

Sample Designation	Cement Content (% dry wt)	Fly Ash Content (% dry wt)
L	4.5	9.5
U	3.0	6.0

TABLE 7

Physical Properties of Cement- and Fly Ash-Stabilized Soil Samples for the Boat Ramp

Sample Designation	7-day Compressive Strength (psi)	Dry Unit Weight (lb/ft ³)	Mod. Proctor Density (lb/ft ³)	Optimum Moisture (% dry wt)
L	485	127.9	130.5	7.7
U	525	135.1	137.9	7.1

3. The stockpiled soil was then spread evenly over the fly ash, water was sprayed on the soil, and the fly ash and soil were mixed using a set of disks pulled by a tractor.
4. When the fly ash and water were thoroughly disked into the soil, the mixture was scrapped to the side of the road, and lime was spread on the exposed road bed.
5. The lime was covered with the soil-fly ash mix, water was added, and the pile was disked to incorporate the lime. The moisture addition and diskings were repeated until the lime was thoroughly incorporated and the proper moisture content was obtained. The target moisture was the optimum moisture determined in the laboratory tests. The moisture content of the soil mixture was judged by visual inspection.
6. When the lime and water were thoroughly mixed with the soil, it was compacted with a sheepsfoot roller.

7. After compaction, a grader was used to shape the crown with a slope of 0.02%, a pneumatic tire roller was used to smooth the surface, and a sealer was sprayed on the road to prevent evaporation of moisture.
8. After the road had been allowed to cure for several weeks, the surface was sprayed with tar, and a thin layer of fine gravel was spread over the tar to create a wear-resistant surface for the road.

The 2.7-mile stretch of road was constructed in 1000-foot sections. Figures 1 through 6 illustrate the various operations involved in constructing the road.

4.4 Boat Ramp Construction Activities

The boat ramp was constructed in a manner similar to the road, except that cement and fly ash were used as stabilizing additives and the surface was not coated with tar and gravel after the ramp was completed. The only significant problem reported with construction of the ramp was that it was difficult to apply the water to the soil evenly. This was because the ramp was built on a slope, and the water tended to run downhill before it soaked into the soil. The problem was corrected by applying the water more carefully.

Figure 1. A grader removed the old road surface, and the soil was piled on the side of the road.

Figure 2. Fly ash was deposited at the road site using a belly dump truck.

Figure 3. The fly ash and soil were mixed with a tractor-drawn disk.

Figure 4. Moisture was added to the fly ash-soil mixture with a water truck.

Figure 5. Lime was pneumatically spread on the road site with a truck.

Figure 6. A section of the road after the lime had been spread.

4.5 Inspection of the Completed Road and Boat Ramp

Visual inspections of the road and the boat ramp were made in October of 1992, which was approximately 14 months after they had been built. Both of the structures appeared to be in excellent condition. The boat ramp had some cracks in its surface, but that is normal for a cemented soil. There were no visible cracks in the road surface, but they may have been hidden by the tar and gravel coating. There were no ruts, potholes, or surface wear of any type observed on either the road or the boat ramp. Based on this inspection, it was concluded that both structures were holding up extremely well and should have long service lives.

Figure 7 shows a stretch of the completed road, and Figure 8 shows the completed boat ramp. These pictures were taken during the inspection.

4.6 Cost Savings Resulting from Fly Ash Utilization

Construction data and cost information supplied by McLean County were used to estimate the cost savings resulting from using fly ash to stabilize the road and boat ramp soils. Savings were estimated by comparing the actual construction costs to calculated costs for stabilization done using cement alone. The calculations were based on the actual purchase costs of lime and cement, the trucking costs for the fly ash, the purchase cost of the fly ash (if it had not been donated at no cost), and an estimate of the amount of cement that was replaced by the use of fly ash.

Figure 7. A section of the completed lime- and fly ash-stabilized road in McLean County.

Figure 8. A view of the completed boat ramp in McLean County.

It was assumed for the cost analysis that if fly ash had not been used for stabilizing the road and the boat ramp, then portland cement would have been the single preferred additive for both projects. The amounts of cement that would have been required to stabilize the soils at the two sites, assuming that no fly ash was used, were estimated using a method contained in the "Soil-Cement Laboratory Handbook" (Portland Cement Association, 1971). Thus, for the road, it was estimated that about 10% cement by weight would have had to have been added to the soil to achieve the necessary strength and durability and, for the boat ramp, about 8% cement would have had to have been added to the soil.

Other information used for the cost analysis included the price of the cement delivered to the sites, which was \$105/ton (Davis, 1992), and the price of the fly ash used for the road and the boat ramp (if it had not been donated), which would have been \$11/ton picked up at the power plant (Hvinden, 1991).

The results of the cost analysis for construction of the road indicate that if cement alone had been used to stabilize the soil instead of lime and fly ash, the cost of the project would have increased from \$94,724 (the actual construction cost) to \$153,181, which is an overall increase of 61.7%. Determination of this increase was based mainly on the difference in cost between the amounts of lime and fly ash actually used and the amount of cement that would have been required to produce an equivalent road. Since, in most cases, the fly ash will not be donated, a comparison was also done between the cost of building the road with purchased fly ash and the cost of using cement alone to build the road. For this case, the construction costs would have increased from \$118,176 (the construction cost if the fly ash had been purchased) to \$153,181, which is an overall increase of 29.6%.

The results of the cost analysis for construction of the boat ramp indicate that if fly ash had not been used, the cost of the project would have been increased from \$6617 (the actual construction cost) to \$7995, which is an overall increase of 20.8%. Determination of this increase was based mainly on the difference in cost between the amounts of cement and fly ash actually used and the amount of cement that would have been required to produce an equivalent road. Since, in most cases, the fly ash would not be donated, a comparison was also done between the cost of building the road with purchased fly ash and the cost of using cement alone to build the road. For this case, the construction costs would have increased from \$7015 (the construction cost if the fly ash had been purchased) to \$7995, resulting in an overall increase of 14%.

The calculations used to develop the costs for this analysis are summarized in Tables 8 and 9.

5.0 CONCLUSIONS

In 1989, the McLean County Board of Commissioners was interested in constructing a hard-surfaced road accessing the Fort Mandan historical site and a boat ramp on Lake Sakakawea. The county commissioners requested technical assistance from personnel at the EERC because they wanted to use fly ash to stabilize the soils for both projects. In response to the commissioners' request, the EERC conducted a laboratory testing program to develop soil stabilization formulas for the two construction activities. These mixtures

TABLE 8

Summary of the Cost Analysis Performed for the Road Construction Activities

Actual amount spent by McLean County to build 2.7 miles of road using 382 tons of lime and 2,132 tons of donated fly ash to stabilize 10,718 tons of soil: **\$94,724**

Estimated cost of road construction if the fly ash had been purchased for \$11/ton:

Actual cost	=	\$ 94,724
Cost of fly ash	= (+)	<u>\$ 23,452</u>
Total adjusted cost	=	\$118,176

Estimated cost of road construction if lime-fly ash had not been used, assuming that 1191 tons of cement (an average of 10% cement by weight) would have been required to stabilize the soil in a similar manner:

Actual cost	=	\$94,724
Avoided cost of hauling fly ash	= (-)	\$ 4,522
Cost of additional cement		
\$124,994 - \$62,015	= (+)	\$62,979
(Cost of 10% cement minus cost of 3% lime-16% fly ash, assuming fly was purchased for \$11/ton*)		
Total adjusted cost	=	<u>\$153,181</u>

* Cost of lime delivered to the construction site was \$100.5/ton, and the cost of cement delivered to the site was \$105/ton.

contained a relatively high percentage of fly ash and exhibited sufficient strength and durability so that both the road and boat ramp should have a relatively long service life. The funding for the EERC portion of the project was provided by the U.S. Department of Energy through a joint venture support program.

The objective of this project, from the EERC's perspective, was to demonstrate the economic benefit of using locally produced fly ash for construction of roads, boat ramps, and similar structures and to reduce the amount of fly ash being disposed of in landfills. McLean County's objective was to get the most value for its tax dollars by reducing the overall cost of constructing the road and boat ramp.

TABLE 9

Summary of the Cost Analysis Performed for the Boat Ramp Construction Activities

Actual amount spent by McLean County to build a 200-foot by 30-foot boat ramp using 17.5 tons of portland cement and 36.2 tons of donated fly ash to stabilize 413 tons of soil: **\$6,617**

Estimated cost of boat ramp construction assuming that the fly ash had been purchased for \$11/ton:

Actual cost	=	\$6,617
Cost of fly ash	= (+)	<u>\$ 398</u>
Total adjusted cost	=	\$7,015

Estimated cost of road construction if cement-fly ash had not been used, assuming that 36 tons of cement (an average of 8% cement by weight) would have been required to stabilize the soil in a similar manner:

Actual cost	=	\$6,617
Avoided cost of hauling fly ash	= (-)	\$ 157
Cost of additional cement \$3,771 - \$2,236	= (+)	\$1,535
(Cost of 8% cement minus cost of 3.75% cement-7.75% fly ash, assuming fly was purchased for \$11/ton*)		
Total adjusted cost	=	<u>\$7,995</u>

* Cost of lime delivered to the construction site was \$100.5/ton, and the cost of cement delivered to the site was \$105/ton.

The project activities included the construction of 2.7 miles of hard-surfaced road using a lime- and fly ash-stabilized soil and the construction of a 200-foot by 30-foot boat ramp using a soil-cement made from a mixture of portland cement and fly ash. In each case, a laboratory study was conducted at the EERC to determine the necessary amounts of lime, portland cement, and fly ash required to produce a durable structure.

Soil stabilization formulas for the road and the boat ramp were developed by taking soil samples from each site, mixing the soil with various amounts of fly ash and lime or fly ash and portland cement, and then testing the strength and durability of the mixtures. For the road, lime and fly ash were used as stabilizing additives with the required

amount of lime being either 2% or 4% (by weight) and the required amount of fly ash being 16%. For the boat ramp, cement and fly ash were used for stabilizing additives with the required amount of cement being either 3% or 4.5% and the required amount of fly ash being either 6% or 9%.

The road and boat ramp were constructed by a McLean County construction crew in the summer of 1991. The lime, cement, and fly ash were added to the soil with in-place mixing methods using a grader and a tractor-drawn disk. No significant problems were encountered with either project. A visual inspection of the road and the boat ramp was made in October of 1992, approximately 14 months after they had been constructed. Both of the structures appeared to be in excellent condition.

A cost analysis was done to evaluate the economic benefit of using fly ash in the soil stabilization mixtures. The results of the cost analysis for construction of the boat ramp indicate that if fly ash had not been used, the cost of the project would have been increased from \$6,617 (the actual construction cost) to \$7,995, which is an overall increase of 20.8%. The results of the cost analysis for construction of the road indicate that if cement alone had been used to stabilize the soil instead of lime and fly ash, the cost of the project would have increased from \$94,724 (the actual construction cost) to \$153,181, which is an overall increase of 61.7%.

6.0 REFERENCES

Davis, R., Contech Admixtures Inc., 1992, Personal communication.

Hvinden, M., County Auditor for McLean County, 1991, Personal communication.

Portland Cement Association, 1971, Soil-cement laboratory handbook: 5420 Old Orchard Road, Skokie, Illinois.

**DATE
FILMED**

10 / 18 / 93

END