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Fabric Form With Cement Fly Ash Mixture for Erosion and Sediment Control

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December, 1987

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16. ABSTRACT

A study was conducted in Oklahoma in 1983 to determine the performance of fabric form mats filled with different proportions of fly ash cement grout mixtures. They were used to repair a 285 ft long severely eroded ditch. The mat was filled with three different mixtures. They were composed of 100 percent cement, a 50-50 mixture of fly ash and cement and an 80 percent fly ash 20 percent cement mixture.

The project was evaluated by the Oklahoma Department of Transportation Research Division for a period of four years following the installation of the fabric form mat. A cost analysis was made comparing the fabric form material to conventional concrete ditch liner. It was concluded that fabric form performs well and is cost effective, and that Class C fly ash be allowed in grout mixtures. It is recommended that, the fabric form installation be monitored with core samples taken periodically for the next 10 years.

A proposed specification is included in the appendix of this report. Also, a video tape showing the installation of the fabric form mat is available upon request.

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FABRIC FORM WITH CEMENT FLY ASH MIXTURE

FOR

EROSION AND SEDIMENT CONTROL

DECEMBER, 1987

By

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In Cooperation with the
Federal Highway Administration

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PREFACE

This report deals with the Oklahoma Department of Transportation Research Division field experimentation on the use of fly ash cement mixtures in a fabric form to control erosion. The report evaluates two types of fabrics and compares three different grout mixes. It also contains procedures for designing grout mixes using fly ash. Furthermore, it deals with site preparation, installation of the fabric mat, and a comparison of materials.

A section is included on the evaluation of the project performance and recommendations. Also, included is a proposed specification for the installation of the mat.

METRIC CONVERSION FACTORS

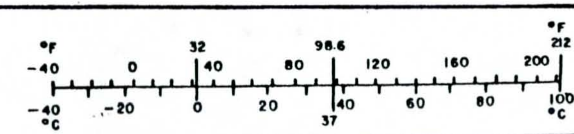
Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
	LENGTH			
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
	AREA			
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
	MASS (weight)			
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
	VOLUME			
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
	TEMPERATURE (exact)			
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.

Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
	LENGTH			
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
	AREA			
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
	MASS (weight)			
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
	VOLUME			
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
	TEMPERATURE (exact)			
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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EXECUTIVE SUMMARY

In 1983 a study was conducted to determine the performance of fabric form mat filled with different proportions of cement-fly ash grout mixtures.

The site for this project was an eroded ditch, about 285 feet long, 30 feet wide which was located along US 271, about two miles south of Antlers, Oklahoma.

Oklahoma Department of Transportation (ODOT) personnel did the installation work and conducted the study. The (ODOT) research team was interested in the engineering properties of the Portland cement (PC) fly ash (FA) mix designs as well as the durability of the two different woven fabrics used in the installation.

It was determined in the laboratory that mixtures of 0, 50, and 80 percent FA by weight of PC; would be most desirable for the comparison of performance.

In terms of costs, the initial cost analysis favored the use of fabric form. The fabric form ditch liner, in-place, cost \$15 per yd^2, while the conventional cement liner cost \$17 per yd^2, leaving a savings of \$2 per yd^2.

It was recommended that the project be continually monitored and core samples be taken periodically for the next 10 years. This will facilitate adequate comparison of laboratory design mix test results with actual in-place performance of the hardened fabric form grout.

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INTRODUCTION

Erosion is the wearing away of land by gravity, wind, ice and water to produce loose, suspended or dissolved particles called sediments. These agents of erosion pose several kinds of problems for highway construction. The primary concern of this report is the erosional problem caused by diverting streams and highway runoff. Erosion by water is a hydraulic and hydrological phenomenon governed by various complex physical processes. Water erosion problems are prevalent in ditches, channels and around headwalls of drainage structures. In many cases, this problem may result in extensive local damage along highways and their associated structures.

A product called fabric form, utilizing geotextiles, has been introduced, which may help solve the problems of erosion in ditches, flumes and channels of streams along highways.

The fabric form erosion control technique involves using two layers of woven fabrics, joined together at spaced intervals with drop stitches. A fine aggregate grout is injected between the fabric layers, which, when hardened, produces a durable erosion control mat. Fabric form was first used in Europe to control erosion in areas of high erosional stress e.g. canals, gullies, stream channels, beaches, lakes and river banks. According to Bruce Lamberton of Texacon, the concept of a geotextile fabric form was first suggested by an engineer named Henry Hillen of the Netherlands in 1968. (8) The technique was later introduced into the United States in the same year through the U.S. Corps of Engineers in the Allegheny reservoir project in southwestern New York State.(8)

Currently many state transportation and highway departments are using fabric form to control erosion. New York and Illinois are two States that have used fabric form extensively.(15) Fabric form exhibits two important qualities based on field results obtained from nationwide usage: its good physical and chemical resistance to degradation, and its effective structural integrity as an erosion control measure.

In 1983, the Oklahoma Department of Transportation (ODOT) decided to conduct a demonstration of the use of fabric form as an erosion control measure. It was prompted by the need for a new erosion control material that is more economical, durable, versatile, quick and easy to install. Furthermore, ODOT wanted to know the influence that Class C FA has on a grout mix when substituted, for PC in different proportions and injected into the fabric form mat. It became important to determine if the addition of FA with PC will provide pumpable grout that will flow more readily within the fabric layers, thus eliminating frequent cutting of fabric to inject the grout. Finally, the rising cost of PC concrete work constituted a major consideration in the ODOT decision to conduct the fabric form/FA project.

The use of fabric form for private and public purposes is gaining ground rapidly. Many states in the U.S., encouraged by the Federal Highway Administration (FHWA notice N5080.4 January 17, 1974), use FA with PC for various construction purposes. (15)

Background

The use of the Class C PC concrete, 1976 ODOT Specification, Section 701, pg. 334, as a conventional ditch liner has been one of the most common practices used in addressing the problem of erosion in ditches along highways.

With the advent of the use of FA in PC concrete mixes, many researchers, architects, engineers and state transportation agencies are slowly substituting portions of PC with FA in PCC mix designs. (14)

A review of published and unpublished literature has revealed that, concrete of equal or better strength can be obtained by using FA in PCC mixes. Class C FA is a pozzolanic material, and a silicious aluminous material. It is an inexpensive by-product of pulverized coal combustion that possesses a considerable amount of calcium silicates, enough to exhibit cementitious properties similar to PC when mixed with water. (5)

Objective

A review of literature revealed that fabric forms offered a workable, versatile and cost effective solution for some of the erosion problems encountered along highways.

The Oklahoma Department of Transportation undertook the fabric form installation because it needed answers to the following questions.

1. Can fabric form be installed under small amounts of flowing water?
2. Is it faster and easier to install, and does fabric form require less time and labor compared to conventional concrete liner?
3. Is fabric form as economical as conventional ditch liners?
4. Can fabric form be fabricated to conform to the contour of the land, over rough surfaces and especially around obstacles in the ditch area, without using conventional forms?
5. Is it feasible to use high percentages of Class C FA in the grout mixtures?

In an attempt to find answers to the above questions, the Research Division of ODOT set the following major objectives for the fabric form project:

1. Evaluate and analyze the physical and chemical properties of two cementing agents, FA and PC, to be used in filler grouts for fabric forms.
2. Ascertain the durability and economic feasibility of using a double layer of nylon and polypropylene woven fabrics as an envelope for fabric form grout.

3. Observe and document the effect of ultraviolet radiation on the two different in-situ fabrics.
4. Determine the erosion control capabilities and durability of the different mixes, including resistance to abrasion.
5. Determine the feasibility of using fabric form as a procedure for construction as well as for maintenance operations.

DESCRIPTION AND LOCATION OF SITE

The area selected for the fabric form installation was influenced by the presence of a serious erosion condition. The site is located approximately two miles south of the city of Antlers on the east side of US 271 near ODOT Division II headquarters.

This area was a severely eroded ditch channel, approximately 285 ft long by 30 ft wide with a gradient of about 1.06 percent or 56 ft per mile and was covered with thick brush, trees, rocks and waste materials. There are utility lines running across the area. The channel itself carries a constantly flowing small stream of water. The stream typically is about 4 in deep and 12 in wide with an estimated maximum flooding capacity of 2370 cfs.

Figure 1 shows the location of the fabric form project in Pushmataha County, two miles south of Antlers, Oklahoma.

Figure 2 shows the deteriorating condition at the site before clearing and grading.

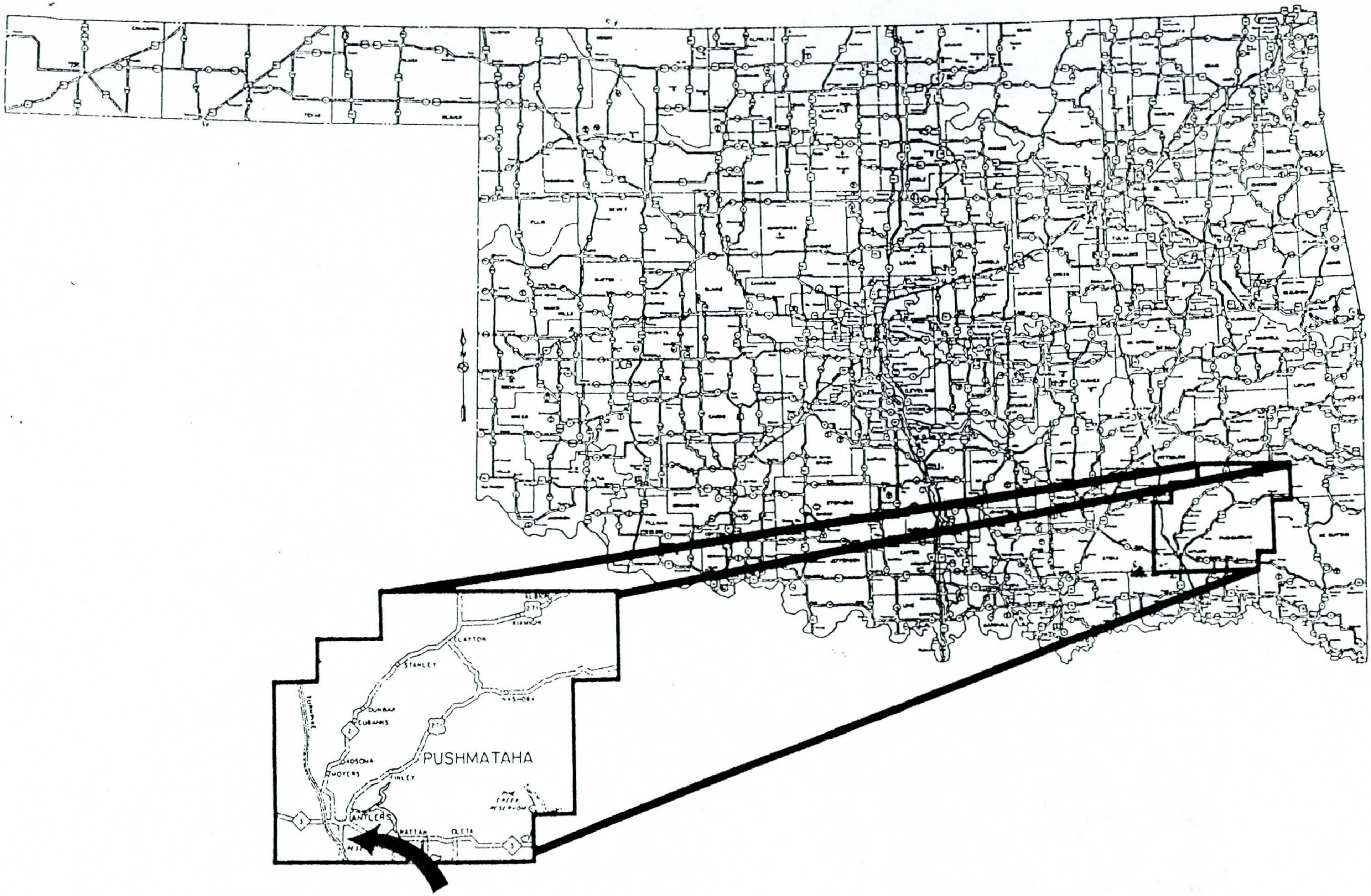

Figure 1. Project Location.

Figure 2. Preconstruction Condition of the Site.

MATERIALS AND METHODS

There are three aspects to the installation of the fabric form mat. These include all materials and testing methods used in the installation and they are:

1. The designing of the FA-PC grout mixes.
2. The selection of appropriate fabrics.
3. The installation of the fabric form mat at the site.

Grout Mix-Design

The first aspect of the fabric form installation required a laboratory determination of the amount of ingredients required to prepare specific mixes needed for the study. The mix proportions were tested according to ASTM procedures to enable the research team to determine the desired mix proportions needed for the field trial.

Trial batches were prepared using Type 1 Portland cement, sand, water, air entrainment agent, super plasticizer and Class C FA.

Three different mixes were selected and tested based on the amount of FA substituted for cement. They are as follows:

0 percent FA with 100 percent PC (control mix)

50 percent FA with 50 percent PC

80 percent FA with 20 percent PC

Figure 3 shows the composition of the three batches of grout mixtures used in the fabric form installation.

In designing the laboratory mixes, special consideration was given to the following items:

1. Substitution of a portion of PC with FA. This provided easy comparison of the maximum and minimum recommendable amounts of FA that could be substituted for cement in the mixes.
2. Preparation of low viscosity grout mixtures. This enabled a rapid and more efficient distribution of the grout in the mat. Low viscosity grout flowed farther in the mat and required fewer cuts into the fabric for grout pumping, thus reducing the amount of labor required.
3. Determining the ability of the grout mixtures to resist freeze-thaw deterioration. This was essential, since the freeze-thaw resistance of the grout mix influenced the durability of the mat; especially when the climate of the project location was known to have a history of freezing and thawing.
4. Evaluating the effect of superplasticizers on the selected mixes. Three rates of superplasticizer, namely 0, 15 and 30 oz/100 lb of cement, were used to determine if plasticizer is necessary for good flow characteristics.
5. Developing abrasion resistance and compressive strengths of the hardened grout. The results obtained can be used to determine the potential durability of the mat.

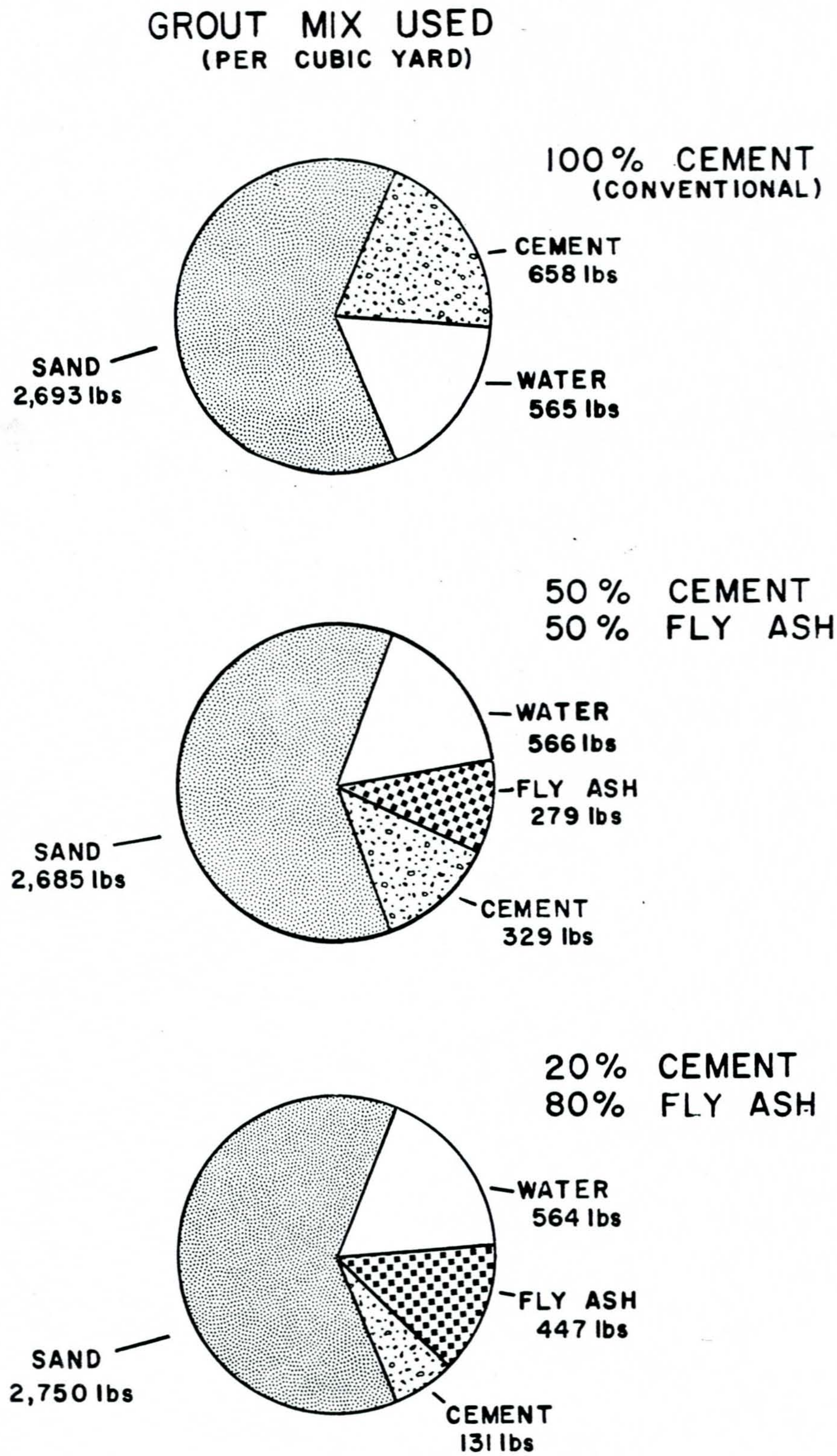

Figure 3. Composition of the Three Batches of Grout Mixes Used.

6. Using appropriate ASTM procedures to test and evaluate the potential durability of the fabric form mat.

The following tests were used in the determination of the mix design results.

The slump test was performed on specimens from each batch in accordance to the ASTM C 143. Compressive strength tests were performed by using cast cylinders of grout mix from each of the three batches. Compression tests at 28 and 180 days were done in accordance to ASTM C 39. The flexural strength of the mixes was tested in accordance to ASTM C 293. Twenty-eight and 180 day abrasion resistance of the mixes were tested according to ASTM C 418, using the sand blasting method. Samples obtained from the mix batches were tested for resistance to freeze-thaw in accordance to the ASTM C 666.

Table 6 shows the test results of the laboratory mix design.

Geotextiles Fabric Design

The second aspect of the project involved the comparison of geotextile fabrics.

Two different fabric types were selected for use, and they were a combination of nylon-polyester and a polypropylene.

Type I Fabric: This fabric is made of nylon-polyester fiber and it is woven, with the two layers joined together by 4 in drop stitches. This particular fabric type exhibits a characteristic shiny appearance. Figure 4 shows the Type I fabric with the drop stitches between the two fabric layers.

Type II Fabric: This fabric is made of woven polypropylene fibers that have been treated with ultraviolet inhibitor by the manufacturer. This fabric also has a uniform 4 in thickness with the characteristic two layers connected with drop stitches.

The main differences between Type I and Type II fabrics are the fiber chemical composition and visual appearance, one is shiny the other is dull. Figure 5 shows the Type II fabric.

There are several different kinds of fabric mats available in the market today. Three commonly used ones for fabric form, depending on the type and magnitude of the erosion problems, are as follows: (6)

1. Filter Point Mat
2. Articulated Block Mat
3. Uniform Section Mat

In this installation the Research Division of ODOT used the Uniform Section Mat. Tables 1 and 2 show the characteristics and properties of the three commonly used fabric form mats.

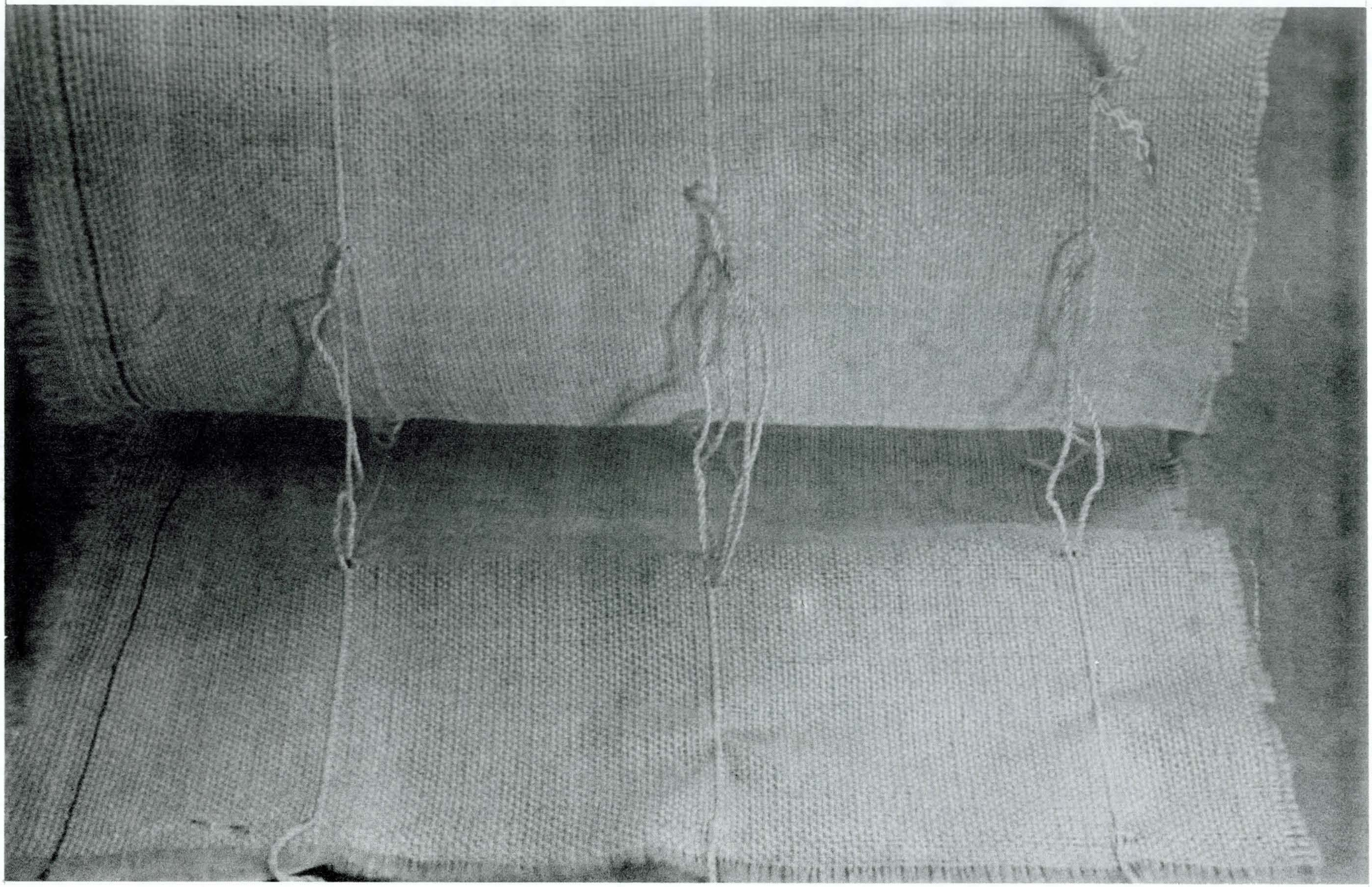

Figure 4. Nylon-polyester Fabric Type I.

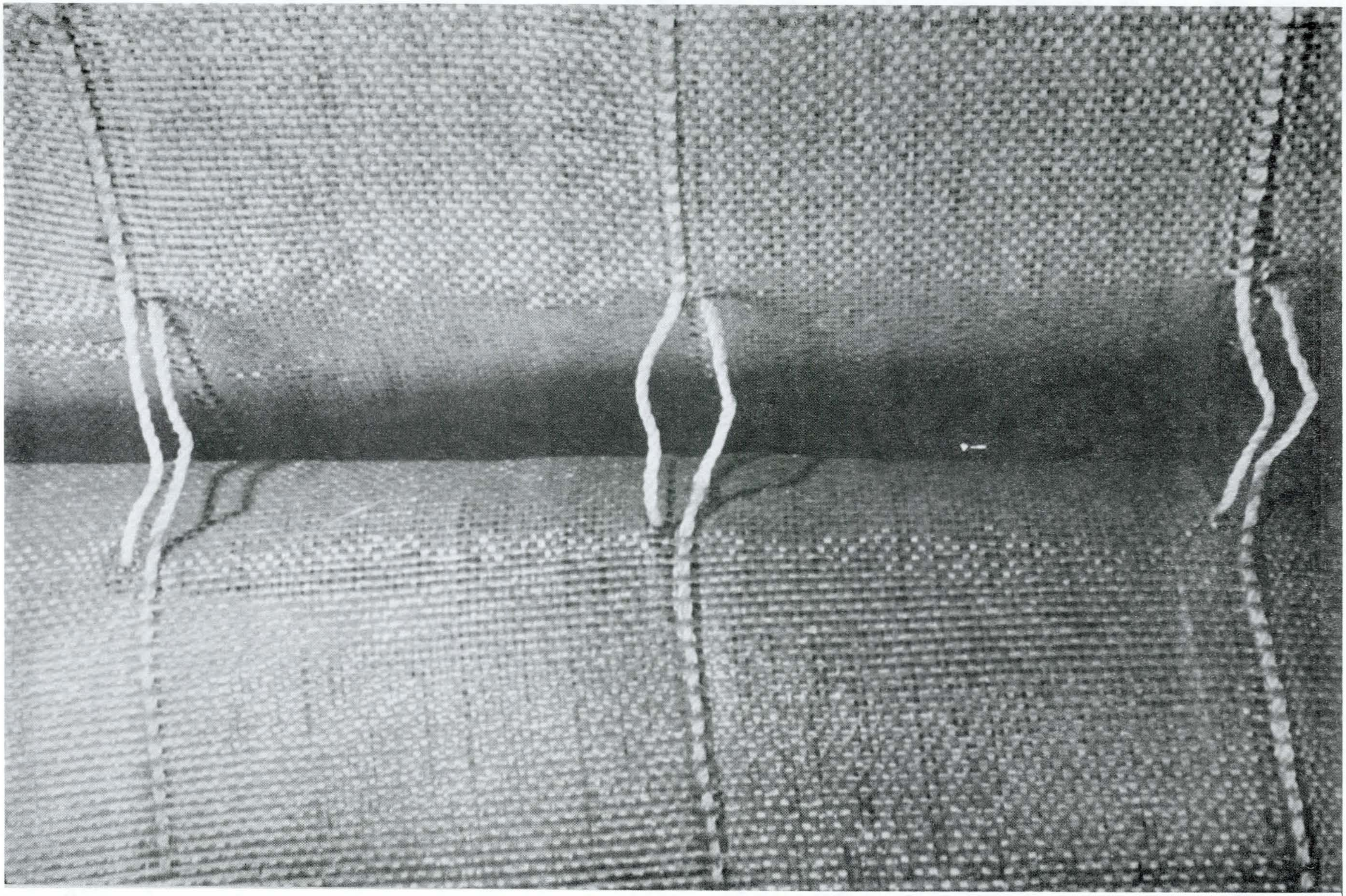

Figure 5. Polypropylene Fabric Type II.

TABLE 1. DIMENSIONS AND CHARACTERISTICS OF FABRIC FORMS

FILTER POINT FABRIC STYLES	SPACING OF FILTER POINTS (in)	AVERAGE THICKNESS (in)	MAXIMUM THICKNESS (in)
5 in Filter Point	5	2.2	3.3
8 in Filter Point	8	3.5	5.0
10 in Filter Point	10	6.0	8.0

UNIFORM CROSS SECTION STYLES	NOMINAL THICKNESS (in)	DROP THREAD SPACING (in)
3 in UNIMAT	3	3 (1½ available)
4 in UNIMAT	4	3 (1½ available)
6 in UNIMAT	6	3 (1½ available)
8 in UNIMAT	8	3
4 in UNIFORM CROSS SECTION	4	1

DESCRIPTION OF STYLES

YARN WARP - 1000 denier, 140 filament heat set nylon

YARN FILLING - 1000 denier, 140 filament heat set nylon

DROP THREADS Unimat 3 and 4 has number 9 nylon seine cord (5820 denier, 84 pound test). Unimat 6 and 8 has number 15 nylon seine cord (15,290 denier, 153 pound test). 4 in Uniform Cross Section has 1880 denier, 280 filament nylon.

TENACITY - 7.8 grams per denier

ELONGATION AT BREAK - 21.5 percent

TEAR RESISTANCE - greater than 200 lbs

POROSITY - minimum 100 ft^3/min ASTM D-737-75

Source: Elish Construction Inc. of Naperville, Illinois.

TABLE 2. FABRIC PROPERTIES

PROPERTY	TEST METHOD	UNIT	VALUES** FPM/ABM	USM
Physical:				
Composition			Poly*	PP*
Weight	ASTM D-3776-79	oz/yd	15	10
Thickness	ASTM D-1777-75	mils	23	15
Yarn Specific Gravity	ASTM D-885-79		1.3	0.92
Mill Width		in	80/165	84
Mechanical:				
Grab Tensile Strength	ASTM D-1682-75	lbs		
Warp			310	200
Fill			300	200
Grab Tensile Elongation	ASTM D-1682-75	%		
Warp			18	20
Fill			22	20
Diaphragm Burst Strength	ASTM D-3786-80a	psi	625	500
Trapezoid Tear Strength	ASTM D-1117-80	lbs		
Warp			130	50
Fill			130	50
Puncture Strength	ASTM D-3787-80	lbs	80	60
Hydraulic:				
Water Flow Rate	ASTM D-4491	gal/min/sf	105	90
Coefficient of Permeability(k)	ASTM D-4491	cm/sec	0.09	0.05
Permeativity(k/l)	ASTM D-4491	l/sec	1.5	1.2
Porosity	ASTM D-737-75	cf/min/sf	300	125

* Poly-Polyester, PP-Polypropylene
** FPM - Filter Point Mat (polyester)
ABM - Articulated Block Mat (polyester)
USM - Uniform Section Mat (polypropylene)

Source: Erosion and Soil Technologies Inc. of Kingwood Texas.

Fly Ash Properties

One of the major components of the grout mixtures is fly ash (FA). Fly ash is a silicious aluminous pozzolanic material, obtained from burning finely powdered coal. It is removed from the flue gasses by electrostatic precipitation or other methods. In the presence of water, Class C FA reacts to form a cementitious compound. Oklahoma Class C FA is tan in color due to its high content of lime. It is a crystalline material with a spherical shape. It's composed primarily of silt sized particles ranging from 1 to 100 um.

The physical and chemical properties of FA vary depending on coal source, processing methods, degree of pulverization, age of plant, condition of plant operation and ash collection methods. The quality of FA may be determined by its fineness, chemical composition and loss on ignition which is a measurement of the unburned carbon in the ash. (7) Physical and chemical properties and classification of FA is presented in ASTM C 618 "Standard Specification for FA and Raw Calcined Natural Pozzolan for Use as a Mineral Admixture in Portland Cement Concrete".

ASTM C 311 and C 618 further detail the characteristics as well as methods of sampling and testing FA.

The properties of FA will vary with sources and combustion characteristics as it relates to the generating plant. Tables 3 and 4 show an elemental analysis of two different fly ashes.

Table 3 shows an elemental analysis of a specific FA from a typical coal, mined in Wyoming but burned by Oklahoma Gas and Electric at Muskogee, Oklahoma. Table 4 on the other hand shows a FA analysis done by Monier Resources Inc. of San Antonio, Texas. This was the FA used in the installation in Antlers, Oklahoma. The FA was produced by Western Farmers Electric of Hugo, Oklahoma and supplied by Monier Resources of San Antonio, Texas.

Cement Properties

The cement used in the fabric form placement is a Type I Portland cement (ASTM C 150).

Installation Procedure

The third aspect of the fabric form installation involved mat placement. First, the ditch area was prepared. This consisted of clearing the brush, and the addition of soil fill material for proper grade. Second, an anchor trench, 18 in deep was dug on both sides of the ditch slopes parallel to the stream channel. Figure 6 shows the site preparation.

The fabrics used on the job were furnished by Construction Techniques Inc. of Cleveland Ohio. Fabrics were delivered to the job site in rolls consisting of several separated panels per

TABLE 3. ELEMENTAL ANALYSIS OF FLY ASH FROM COAL MINED IN WYOMING

Elemental Analysis of Ash	Assay (%)
SiO_2	31.50
Al_2O_3	18.50
TiO_2	0.84
Fe_2O_3	7.00
CaO	28.00
MgO	4.82
Na_2O	1.47
K_2O	0.34
P_2O_5	0.41
SO_3	5.47
Ash Viscosity Calculations	
Base Content (PCT)	45.03%
Acid Content (PCT)	54.98
Dolomite Content (PCT)	78.84
Base to Acid Ratio	0.82
Silica to Alumina Ratio	1.70
T250 (Temp in $^{\circ}F$ for 250 Poise)	$2199^{\circ}F$

This is an analysis of a sample of fly ash from a modern electric power generating station burning Wyoming coal.

Source: Oklahoma Gas & Electric Company of Muskogee, OK, 1977

TABLE 4. ANALYSIS OF FLY ASH FROM HUGO PLANT

Chemical Analysis %	Results	Spec* Class F/C
Silicon Dioxide(SiO_2)	38.8	
Aluminum Oxide(Al_2O_3	20.4	
Iron Oxide (Fe_2O_3)	5.9	
Sum of SiO_2,Al_2O_3 Fe_2O_3	65.1	70.0/50.0 min
Sulfur Trioxide(SO_3)	2.0	5.0 max
Moisture Content	0.04	3.0 max
Loss on Ignition	0.29	12.0/6.0 max

Physical Analysis	Results	Spec*
Amount Retained on 325 Sieve,%	19.9	34 max.
Pozzolanic Activity Index with portland cement at 28 days, % of control	96	75 min.
With lime at 7 days, psi	1017	800 min.
Water Required, % of Control	92	105 max.
Autoclave Expansion, %	0.03	0.8 max.
Specific Gravity	2.72	

* ANSI/ASTM C618-80

Source: Moiner Resources Inc. and Raba-Kistner Consultants Inc. of San Antonio, Texas, 1983.

Figure 6. Site Preparation for the Fabric Form Installation.

Figure 7. Sewing of the Fabric Panels.

roll. These were prefabricated to size to conform to the dimensions of the ditch. The rolls of fabric were joined together in the field where some cutting and seaming was required, especially around a gas pipe line. A Fischbein Model E portable sewing machine that sews at a rate of 30 ft/min was used. A portable generator supplied the 115 volt electricity needed by the sewing machine. To sew the rolls together a nylon thread, #138 BST, was used. Figure 7 shows the sewing operation.

The fabrics were laid out along the ditch, with the upper ends tucked into the anchor trenches at the top of the ditch slope. The tucked part of the fabric was filled with grout first, to hold the remaining fabric in place and to prevent undercutting during flooding. A small slit is cut into the fabric at a suitable location usually high on the slope. The nozzle of the pump hose is inserted between the fabric layers through the slit and grout is injected. After the anchor trenches were filled and properly covered with grout, the remaining part of the fabric was filled one section at a time. Figure 8 shows the anchor trenches being filled.

The grout used for the fabric form was mixed based on the laboratory test designs. It was prepared at Rustin Concrete's Hugo plant and delivered to the site in a ready mix truck, one batch at a time. The pre-mixed grout was transferred into a Mayco Model C-30 portable grout pump rated at 12 yd^3/hr. A 150 ft long hose, 2 in in diameter was used to deliver the grout to the fabric panels. A screen was placed on the hopper leading to the pump to prevent oversize material from entering the pump.

Figure 8. Filling Anchor Trenches.

There were 13 test sections in the fabric form mat, and each section was filled with a predetermined mix which was specified in the plan. The type of mix that went into a specific test section was randomly selected from the three batches of the original design mixes. Figure 9 shows the plan for the randomly selected test sections of the fabric form mat.

The first batch of grout mix containing 0 percent FA and 100 percent PC was used to fill the preselected sections 1, 2, 5, 8, 11 and 13. The second batch of grout mix containing 50 percent FA and 50 percent PC was used to fill sections 4, 6, 9 and 12. Finally, the third batch that contained 80 percent FA and 20 percent PC was used to fill the remaining sections 3, 7 and 10. No plasticizer was required in the mixes used in the installation because, the laboratory test results indicated that FA was able to adequately enhance the flow characteristics of the mixes.

Poke sticks were used to assist in the filling of the fabric mat so that the grout was evenly distributed. As work progressed downstream, the fabric was continually spread and each test section filled with grout. This procedure allowed the fabric form to conform to the contours of the ditch.

In completing the fabric form installation, a total of 95 yd^3 of grout and 8,600 ft^2 of fabric were used. The fabric form mat, as placed, produced a mat with a nominal thickness of 4 inches, weighing 44 lbs/ft^2.

The entire installation lasted two days, requiring a crew of four to six people. Figure 10 shows the appearance of the fabric

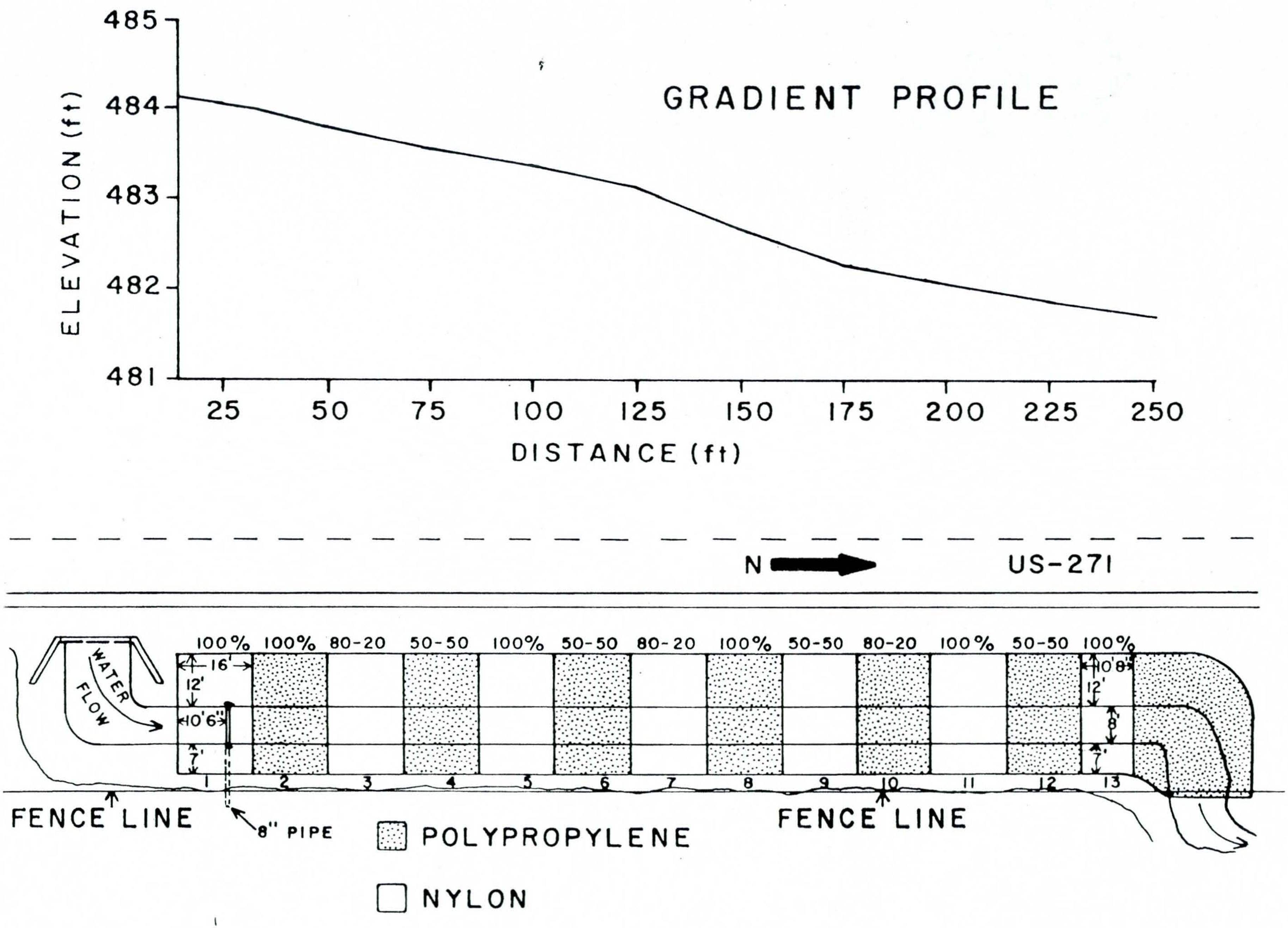

Figure 9. Arrangement of Test Sections and the Ditch Gradient.

form mat after installation, Figure 11 shows a typical cross section of the mat and details of the anchor trench.

Figure 10. Fabric Form Site After Installation.

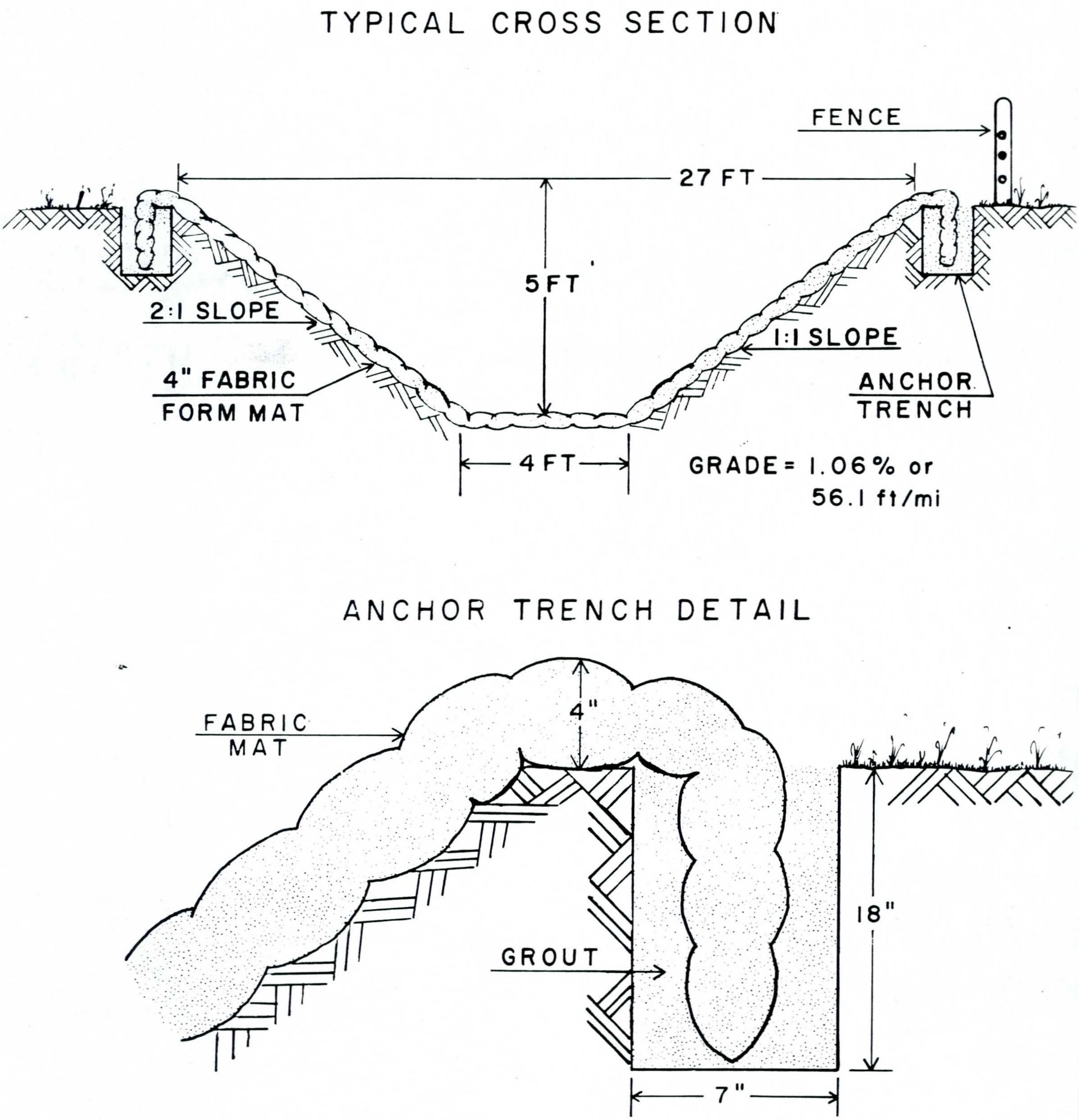

Figure 11. Typical cross Section of Mat & Anchor Trench.

PROBLEMS

While much of the sewing may be done by the fabricator, some work will be required in the field. A portable generator is required. Also, the fabric to be sewn must be kept clean. Dirt is very abrasive and can clog or cause excessive wear in the sewing machine feeding mechanism. Most of the time three people are required to facilitate the sewing of a seam.

As with any project utilizing fabrics, wind could be a problem. Provisions should be made to weigh down the fabric to keep it in place.

Weep hole assemblies must be used when ground water tables are expected. Figure 12 shows a typical cross section of weep holes installed in the mat.

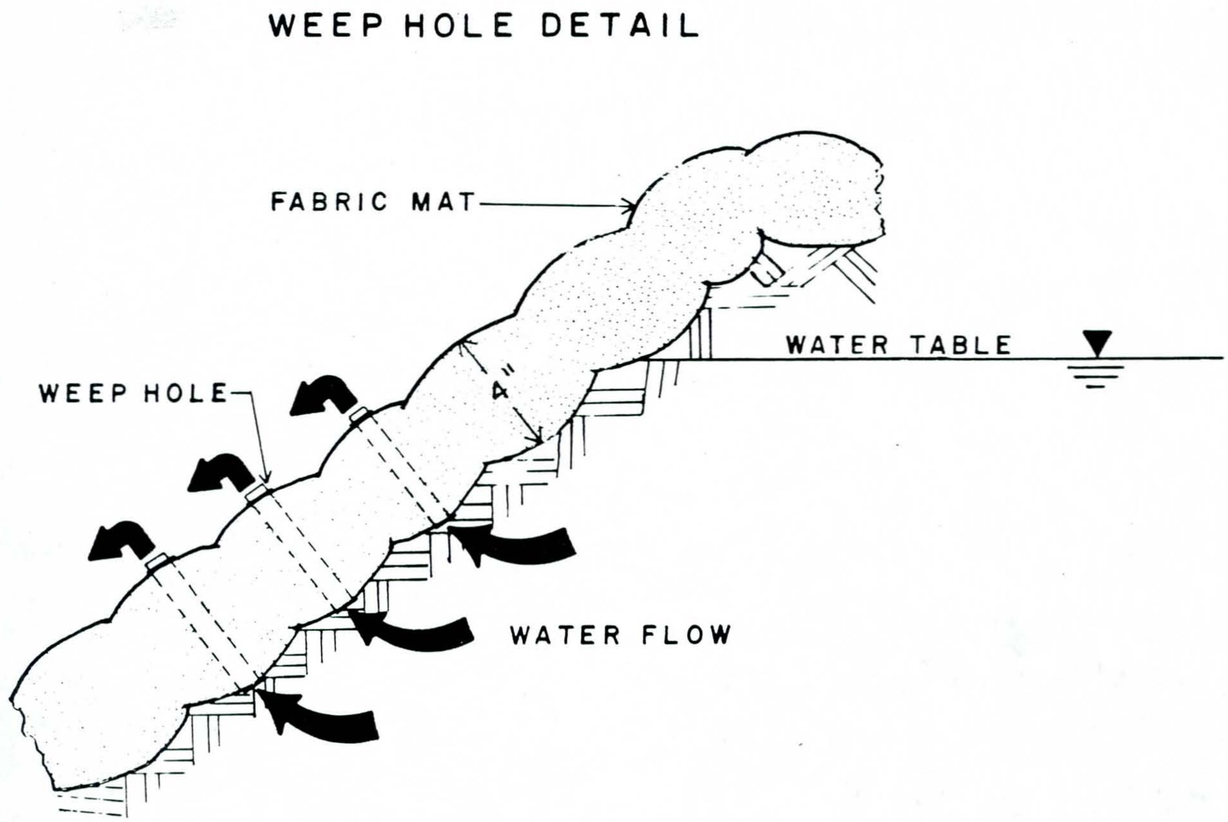

Figure 12. Cross Section of Weep Holes.

EVALUATION AND ANALYSIS OF DATA

There are two aspects to the evaluation and analysis of data collected from the fabric form installation.

The first aspect was the analysis of data obtained from laboratory tests of the mix designs. Three batches of grout were tested based on recommendations indicated in the mix design section of this report, and in accordance to the ASTM standard practices. Data collected included calculated values of several different variables e.g. slump, percent of air, percent of FA or PC, water-cement ratio, rate of plasticizer, flexural strength, 28 and 180 day compressive strength, and 28 and 180 day abrasion.

The flexural strength at 28 and 180 days, and the compressive strength at 28 and 180 days, including abrasion resistance, were used as dependent variables. Table 5 shows the 18 mix designs tested in the laboratory, while Table 6 shows the mix design results for each value of the dependent variables in the 18 mixes.

TABLE 5. TRIAL MIX PARAMETERS

Sample No.	Fly ash/Cement Ratio (%)		Water Cement Ratio	Rate of Plasticizer (oz/100 lbs cement)	Air Content (%)	Slump (in)	Density (lbs/yd^3)
1	50	50	0.5	0	8	1.0	3384
2	50	50	0.5	15	8	4.0	3524
3	50	50	0.5	30	8	4.0	3431
4	80	20	0.6	0	8.5	2.0	3334
5	80	20	0.6	15	7.5	3.0	3348
6	80	20	0.6	30	7.5	4.0	3390
7	80	20	0.5	0	8.5	1.0	3675
8	80	20	0.5	15	8.0	1.5	3680
9	80	20	0.5	30	7.0	1.5	3692
10	50	50	0.6	0	7.5	2.0	3582
11	50	50	0.6	15	7.0	4.0	3652
12	50	50	0.6	30	7.5	4.0	3659
13	0	100	0.5	0	8	.75	3353
14	0	100	0.5	15	8	2.0	3595
15	0	100	0.5	30	8	2.0	3595
16	0	100	0.6	0	8	1.5	3548
17	0	100	0.6	15	8	2.0	3552
18	0	100	0.6	30	9	2.25	3413

Absolute volume was used for calculating the design mixes.

TABLE 6. MIX DESIGN RESULTS

Sample No.	Fly Ash/Cement Ratio (%)		Flexural Strength (psi)	28 Day Compressive Strength (psi)	180 Day Compressive Strength (psi)	28 Day Abrasion Resistance (cm^3/cm^2)	180 Abrasion Resistance (cm^3/cm^2)
1	50	50	275	2257	3205	3.83	3.20
2	50	50	256	1426	2077	3.79	4.63
3	50	50	258	1774	2706	3.32	2.74
4	80	20	113	521	1750	6.19	7.81
5	80	20	121	733	1243	4.32	5.66
6	80	20	124	640	1900	5.11	6.93
7	80	20	177	880	2013	6.78	4.74
8	80	20	166	866	1816	5.56	3.34
9	80	20	164	803	1973	5.99	3.00
10	50	50	232	1703	2085	5.32	5.32
11	50	50	249	1820	2003	2.71	1.78
12	50	50	288	2260	2763	1.95	2.44
13	0	100	423	2867	3200	2.50	2.08
14	0	100	421	3344	3728	1.21	2.02
15	0	100	461	3377	3456	2.75	2.21
16	0	100	478	3545	3810	2.40	2.40
17	0	100	451	2910	3262	1.20	1.43
18	0	100	436	3816	3939	1.93	1.90

Compressive strengths were found to increase with decreasing amounts of FA in the absence of plasticizer and with low water-cement ratios. It was further indicated from analyzed data that the specimens increase in strength with age.

In summary, the laboratory test results indicated the following:

1. Plasticizer has no effect on abrasion loss while an increase in FA produced increases in abrasion loss. This is shown in the graph in Figures 13 and 14.
2. Increases in plasticizer content predictably increase the slump as in standard PC mixes.
3. Air content has no effect on any of the variables considered.
4. The water-cement ratio of 0.5, in the absence of plasticizer, provided better compressive strength than the 0.6 water-cement ratio, also with no plasticizer.
5. An increase in the proportion of FA substituted for PC tends to decrease the compressive and flexural strengths and the abrasion resistance as shown in Figures 15, 16, and 17.
6. The maximum amount of FA that may be substituted for PC to obtain better flexural and compressive strength is somewhere near 20 percent.

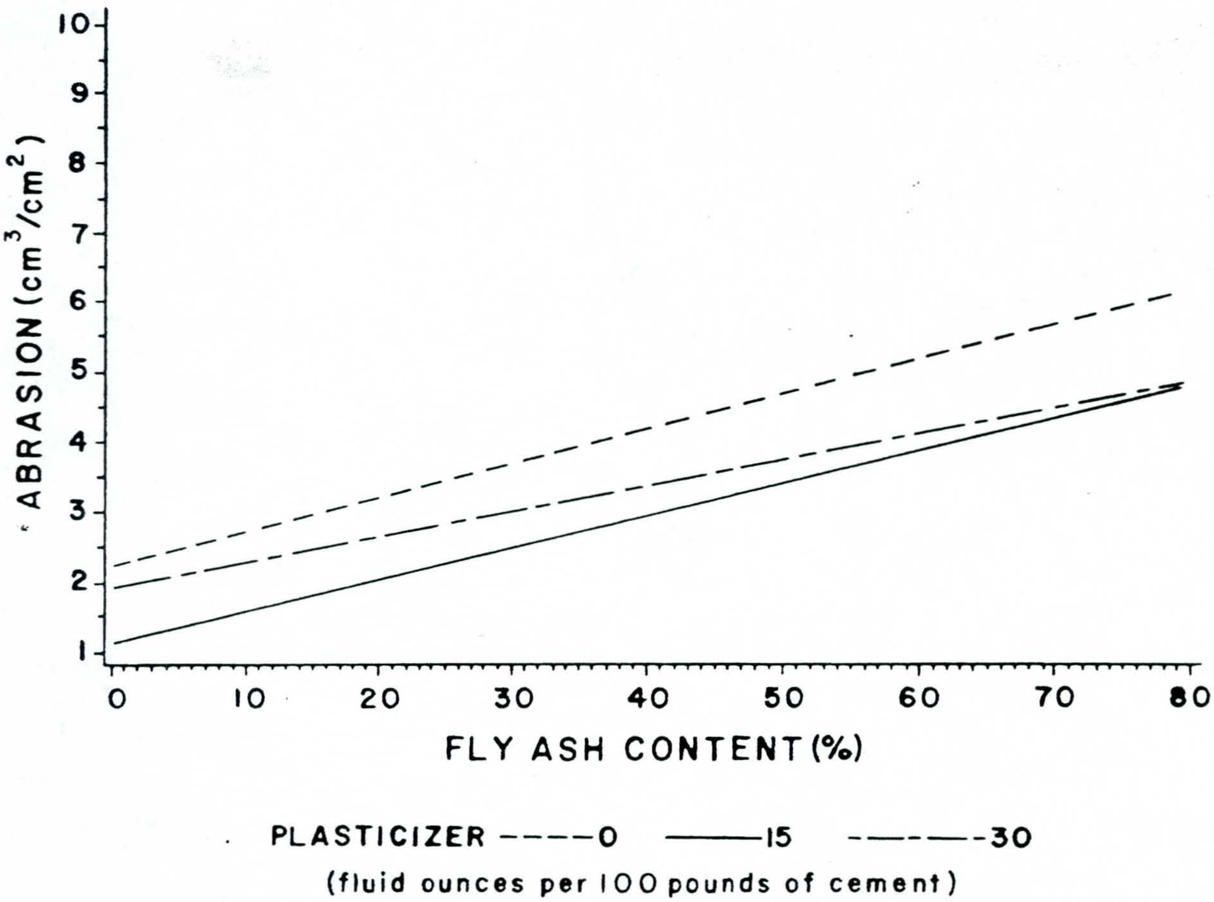

Figure 13. Abrasion Resistance at 28 days.

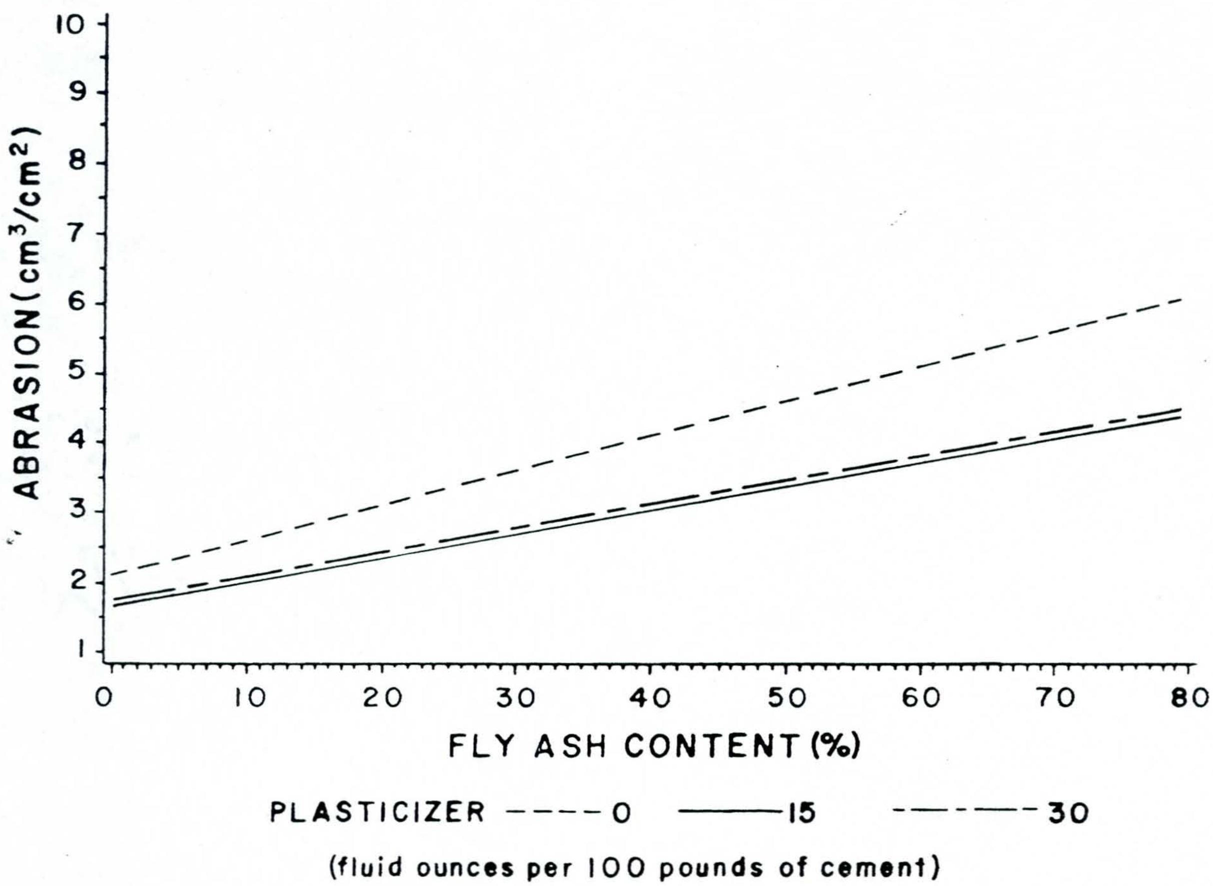

Figure 14. Abrasion Resistance at 180 days.

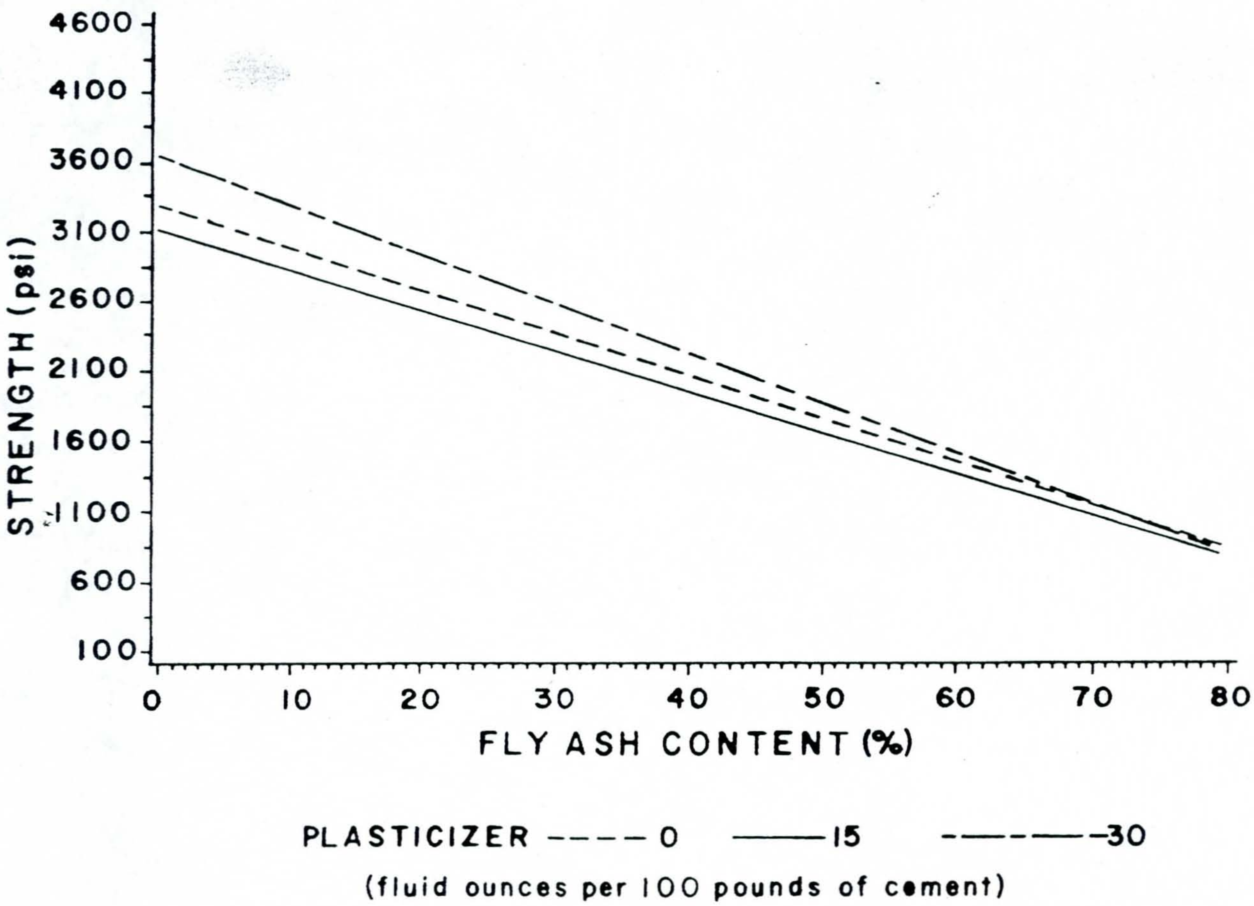

Figure 15. Compressive Strength at 28 days.

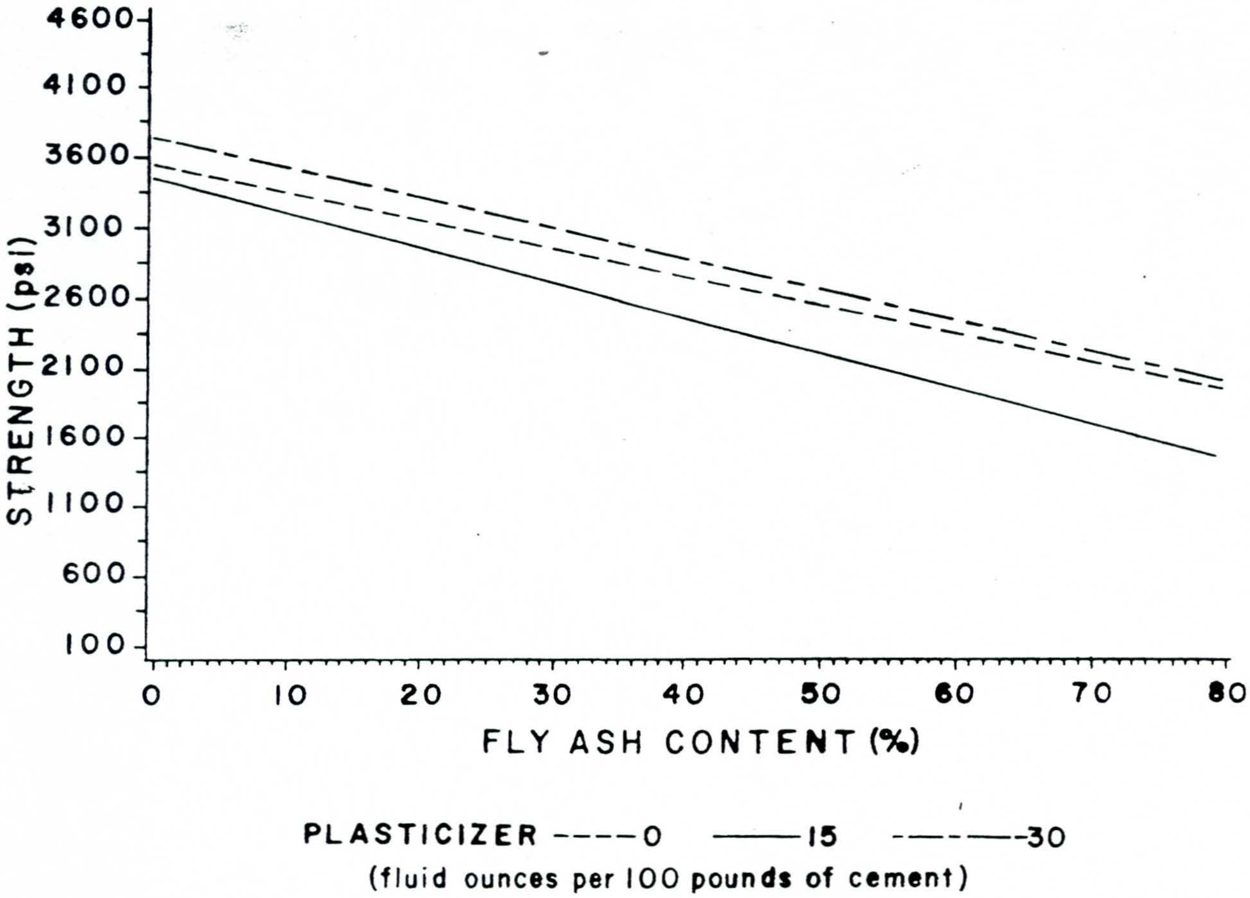

Figure 16. Compressive Strength at 180 days.

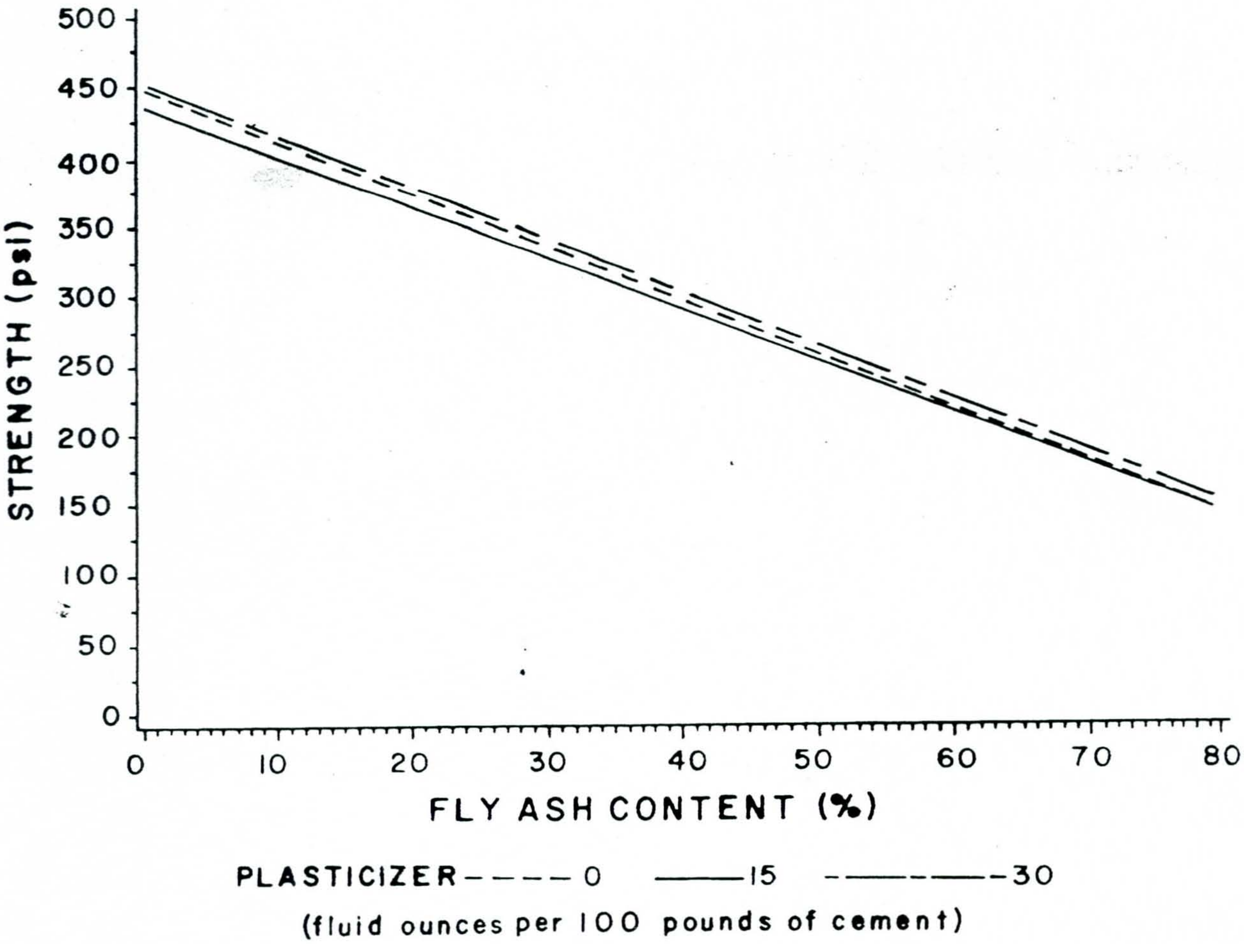

Figure 17. Flexural Strength.

The second aspect of the evaluation and analysis is the periodic inspection of the installed fabric form mat. A visual survey of the mat was conducted once a month for three years following the installation. The survey was to determine if there is any abrasion, cracking, or noticeable fabric deterioration. Special attention was focused on finding evidence of possible chemical, biological or physical degradation that may have occurred due to exposure of the mat to ultraviolet radiation and other environmental elements.

The physical appearance of the fabric form mat essentially remains the same. In the summer of 1987, the fabric upper layer appears to be performing well with little ultraviolet degradation noted. The moderately abrasive bedload of coarse sands and small gravel which vary in size from 0.5 to 2 in has not noticeably affected the fabric or the grout along the bottom of the ditch channel.

Figure 10 shows the present condition of the installed fabric form mat.

COST ANALYSIS

The cost of a fabric form installation will vary depending on the fabric manufacturer's current price, types of fabric and fabric form, rates of local labor, type and composition of the grout, and amount of site preparation required.

On this project, a cost analysis indicated that the fabric form mat ditch liner, in-place, 4 inches thick, was \$15 per yd^2 (1982). This compared to conventional Class C (ODOT Spec. 701) concrete ditch liner in-place and 4 inches thick at \$17 per yd^2. A savings of \$2 per yd^2 was realized and for a 955 yd^2 installation, ODOT saved \$1,910.00 as shown in Table 7.

TABLE 7. Comparative Costs

	\$ Cost/yd^2	Area yd^2	Total \$ Cost
Conventional Cement Ditch Liner	17	955	\$16,235
Fabric Form with FA-Cement	15	955	14,325
Total Savings			\$ 1,910

Based on the total cost of installation as shown above, it can be established that FA-PC grouts, used in geotextile fabric forms is an economical and cost effective approach to erosion control along highways and near bridges.

CONCLUSIONS

The performance of the fabric form mat installed by the Research Division of ODOT has been satisfactory, not only from an engineering perspective but from a conceptual and utility point of view. The installation is not only unique in its use of FA, but has shown that fabric form using the FA - PC grout filler, is a beneficial procedure for construction or maintenance activities.

Since the installation, erosion in the area has been considerably reduced and flood waters properly channelized. Not only is erosion along the channel presently controlled, there are no indications of any failures like cracking or abrasion.

The fabric form experiment has shown that, FA can be used successfully in certain proportions when mixed with PC to produce a strong durable grout mix. In this particular experiment, the data indicate that FA-PC mixes with 50:50 ratio provide the most favorable results when all the dependent variables, i.e. abrasion resistance, flexural strengths and compressive strengths were considered.

Geotextile fabric forms using FA-PC mixtures have the following comparative advantages over conventional PC concrete ditch liners:

1. It is more economical. The cost of materials and labor are lower and more predictable.

2. It is versatile. It can be installed on dry land and under water without having to control the amount and level of the water.
3. There is no need for forms.
4. There is no need for smooth grading.
5. It can be shaped to fit any type of topography, including obstacles such as pipelines, poles, boulders and rough slopes with trenches and ditches.
6. It is able to adapt and conform to tight working places.
7. It is quicker to install and the grout setting time can be controlled by FA content.
8. The mat can be made thicker or thinner by changing the length of the drop stitches.
9. It has a low maintenance requirement.
10. It is not only a concrete form but it also acts as a reinforcement structure with resistance to cracking.
11. Hydrostatic pressure relief is easily provided with the aid of plastic weephole tubes inserted through the fabric panels.
12. Bleeding is controlled by allowing excess mix water through the woven fabric openings to produce a desirable low water-cement ratio grout.
13. There is no need for any finishing.
14. There is no need for a curing membrane.
15. There is no need for jointing.

The installed fabric form mat has shown little detrimental effects, the light gray color of the fabric remains essentially the same. The 13 test sections are structurally and physically stable after four years. This application, using FA-PC mixtures, has corroborated other research and engineering results about the advantages that a FA-PC mixture in fabric form has when compared to conventional ditch liners.(14)

A user of a conventional liner is normally concerned with the strength, workability, uniformity, setting time, drying, finishability, abrasion resistance, shrinkage and cracking potential of the liner. Fabric form using FA-PC mixture, based on this demonstration, exhibited good potential for improving these engineering characteristics. It was shown to be easier and less costly to install than conventional concrete liner. Several years of observations are needed to put to rest the doubt and concern about FA-PC durability, long term effects of freeze-thaw, abrasion resistance, flexural strength and its general use as a means of controlling erosion.

It has been four years since the installation (1983). The mat has proven to be effective in controlling erosion and flood damage at the site. Here, it has reduced sedimentation, eliminated erosion and brush growth. It was installed under flowing water with minimum equipment and no apparent pollution to the water. Furthermore, fabric form proved not only to be practical but it is cost effective, easier and faster to install, and it is economically feasible to adopt for slope protection, erosion control and other related routine maintenance operations.

The designed grout mixes have performed well and met the expected strength requirements, but information is still needed on the long term durability of FA-PC grout. Periodic sampling and testing is needed to establish an accurate and comparative relationship between the laboratory unconfined compression tests and the in-place compressive strengths of the installed fabric form grout.

RECOMMENDATIONS

The fabric form demonstration has shown that the installation of fabric forms is a practical and feasible technique with predictable lower costs than conventional PC ditch liners. All the design grout mixes met manufacturers suggested strength requirements. Fabric form grouts containing Class C FA are recommended for ditch erosion control.

The fabric form site should be monitored annually and core samples taken periodically for 10 years. This will allow adequate time for a long term strength and performance evaluation of the test sections.

Concern about ultraviolet degradation of either fabric seems unwarranted, since both fabrics showed no visible sign of degradation in the four years since installation. It is recommended that either fabric be considered for use.

Finally it is recommended that ODOT consider further fabric form research using: filter point fabrics, thicker mat sections, reinforced and articulated block mats.

A recommended specification on fabric form using FA-PC is included in the Appendix.

13. Oklahoma Department of Highways Standard Specification for Highway Construction, Section 701, Oklahoma City, Oklahoma, pp. 333-335, 1976.

14. Pildysh, Mikhail and Wilson, Ken, "Cooling Ponds Lined with Fabric-Formed Concrete", Concrete International, September, 1983.

15. "Use of Fly Ash for Portland Cement Concrete and Stabilized Base Construction" Federal Highway administration (FHWA Notice N5080.4) January 17, 1974.

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2. "Coal Ash Utilization: Fly Ash, Bottom Ash and Slag", Pollution Technology Review, Noyes Data Corporation, Park Ridge, N.J., 370, 1978.

3. Convey, N.N., "Required Quality Control for Fly Ash in Portland Cement Concrete", Journal of the American Concrete Institute, Vol 4, No. 7, pp. 11-15, July 1982.

4. Cook, Jane E. "Research and Application of High Strength Concrete Using Class C Fly Ash", Concrete International, pp. 72-80, July 1982.

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6. "Fabric Forms for Concrete: A fabric forming process for concrete that has captured the imagination and value-appreciation of Engineers and Contractors worldwide", Publication by Construction Techniques, Inc.; Cleveland, Ohio.

7. "Fly Ash Facts for Highway Engineers: Technology Transfer U.S. DOT Demonstration Projects Program", pp. 10, (FHWA-DP-59-8) Federal Highway Administration, July, 1986.

8. Lamberton, Bruce, "Fabric Formed Revetment Technology Opens New Engineering Opportunities" Geotechnical Fabric Report 1986.

9. Lane, R. O., "Effect of Fly Ash on Freshly Mixed Concrete", Concrete International, pp. 50-52, October, 1983.

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11. Meininger, R. C., "Use of Fly Ash in Cement and Concrete: Report of Two Recent Meetings", Concrete International, pp. 52-57, July, 1982.

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APPENDIX

OKLAHOMA DEPARTMENT OF TRANSPORTATION
SPECIAL PROVISION
FOR
FABRIC FORMED CONCRETE MAT

These Special Provisions revise, amend and where in conflict, supersede applicable Sections of the Standard Specification for Highway Construction, Edition of 1976 and the Supplement thereto, Edition of 1984.

650.01. DESCRIPTION. This work shall consist of placing a two layered geotextile fabric form mat on a prepared surface and filling the placed mat with a pumpable aggregate, Portland cement and/or Portland cement and fly ash, and water slurry grout. The fabric formed concrete mat shall be installed at the locations and in accordance with the cross-sections, lines and configurations shown on the Plans.

650.02. MATERIALS. (a) Fabric and Spacer Cord. The fabric forming material shall consist of multiple panels of a woven double layer geotextile, joined together to form a mat with regularly spaced cord drop stitches between the fabric layers. Both upper and lower fabric layers shall be made of identical material.

The composition of the fabric shall be at least 85% polyolefins, polyamides, polyester or a combination of these. The spacer cord drop stitches, of uniform length, shall be located between the two fabric layers to control the Plan thickness of the mat.

The fabric and spacer cords shall exhibit the following properties:

Test	Requirements	Method
Tensile Strength (min.)	200 lbs.	ASTM D 1682
Burst Strength (min.)	450 psi	ASTM D 3786
Puncture Strength (min.)	80 lbs.	ASTM D 751*
Seam Breaking Strength (min.)	160 psi	ASTM D 1683
Spacer Cord Strength (min.)	100 lbs.	ASTM D 2256
Spacer Cord (thickness dim.)	4-6 ins.	--
Abrasion Resistance (min.)	55 lbs.**	ASTM D 3884
Coefficient of Permeability (min.)	0.02 cm/sec.	ASTM D 4491
U. V. Resistance	90% strength***	ASTM D 4355
AOS (US Sieve Number)	35 - 70	CW 02215

* Tension testing machine with ring clamp; steel ball replaced with a 5/16" diameter solid steel cylinder centered within the ring clamp.

** 1000 revolutions, 1 kg load/wheel (Taber)

*** Strength retained after 500 hrs. in a xenon weatherometer

1. Acceptance. The Contractor shall furnish a Type A Materials Certification for the fabric form and spacer cord in accordance with Subsection 106.12. A three square yard sample of the fabric with spacer cord shall be furnished by the Contractor to the Engineer from each lot or shipment.

(b) Grout. The grout shall consist of a mixture of Portland cement, fly ash (optional), fine aggregate and water; proportioned and mixed to provide a readily pumpable slurry.

A suggested range of ingredients for a cubic yard of slurry is listed below:

Component	Unit(lbs.)
Portland Cement/Fly ash	900-1000
Aggregate	2000-2200
Water	500-650
Air Entrainment	6% ± 1%

A Job-Mix Design including the use of fly ash or other admixtures shall be submitted by the Contractor to the Engineer for approval.

1. Portland cement shall conform to AASHTO M 85 Type I. When a portion of the cement is substituted with Class C fly ash it shall conform to ASTM C 618. A maximum of 50% fly ash may be substituted by weight of Portland cement.

2. Aggregates shall meet the requirements of Subsection 701.05 for concrete aggregates, except for the gradation. The aggregates shall be well graded from the maximum size which can be readily pumpable with approved equipment.

3. Water shall conform to Subsection 701.04.

4. Air entraining agents conforming to Subsection 701.03 shall be used.

5. Grout fluidifiers, if used shall conform to Subsection 701.03.

6. Acceptance. 6.1. Air content of the grout shall be 5.0% to 7.0% when tested in accordance with AASHTO T 152 or T 196.

6.2. Cylinders shall be cast and tested in accordance with AASHTO T-22 requiring a minimum compressive strength of 2000 psi at 28 days.

650.03. EQUIPMENT. (a) Fabric Sewing Machine. A Fischbein "Model E" portable electric sewing machine or its equivalent shall be used for sewing the fabric.

(b) Batching and Mixing Equipment. The batching equipment and mixer shall meet the requirements of Subsection 509.03.

(c) Grout Pump. The grout pump shall have a minimum capacity of 12 cubic yards per hour through a 2 inch hose. A Mayco Model C-30 or its equivalent will be satisfactory.

650.04. CONSTRUCTION METHODS. (a) Inspection and Storage of Fabric. Following the receipt of the rolls of fabrics, they shall be inspected and stored in a clean, dry, protected area where they will not be subjected to mechanical damage or wetness.

(b) Surface Preparation. The surface to be protected by the fabric formed concrete mat shall be prepared and shaped to an extent that it is stable. Hand digging tools may be used in areas of steep slopes, power and utility lines or tight spots where heavy digging machinery cannot be used.

(c) Anchor Trenches. Trenches shall be dug at locations shown on the Plans, or as may be approved by the Engineer to serve as anchors for the mat. These trenches may be dug with hand tools or by machine. The minimum depth of the anchor trenches shall be 12 inches.

(d) Fabric Placement. Fabric panels shall be unrolled in the direction of the flow of water with the upper edges anchored in the trenches. Adjacent fabric panels shall be joined together by seaming prior to grout injection. Only machine sewn seams shall be allowed in joining the fabric panels.

After the edges of the fabric panels are placed in the trench they shall be anchored by filling the upper fabric edges with grout.

(e) Field Seam. Any two layers may be extended to adjacent panels by joining edge to edge by double seaming with the fabric manufacturers recommended thread of nylon, polyester or polypropylene that has been treated with U-V inhibitor.

The fabric layers shall be joined by using a double sewn "J" seam (Federal Standard Type SSn-1) or "Butterfly" seam (Federal Standard Type SSd-1). Care must be taken to make sure that the fabric panel edges are clean, even and have been completely penetrated by the stitch during sewing.

(f) Drainage Device. Hydrostatic relief weepholes shall be provided and installed in a manner acceptable to the Engineer or in accordance with the Plans. To prevent passage of fine soil particles through the weepholes, pieces of nonwoven geotextile meeting the requirements of AASHTO M 288 shall be attached at the bottom of the weephole tubes prior to their assembly and placement.

(g) Mixing Grout. Materials used for preparing the slurry grout shall be measured and mixed in accordance with Subsections 509.03 and 509.04, except as provided for herein. Mixing time shall be at least one minute. Continuously agitated grout may be held in the mixer for a maximum of 2.5 hours in temperatures below 70°F and no more than 2.0 hours in temperatures exceeding 70°F.

(h) Grouting. Grout shall be injected through holes cut into the top layer of the fabric panels. Hole spacing in the fabric shall be subject to approval by the Engineer. The end of the grout hose shall be inserted and pumping commenced allowing grout to flow into the mat. The holes in the fabric left when the hose is withdrawn shall be plugged with cloth until the grout has taken a set. Excessive pressure on the fabric is to be avoided. Only approved mixing and pumping equipment shall be

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used in preparation and handling of the slurry grout. Oil, rust and dust or debris shall be removed from the mixing drum, stirring mechanism and other parts of the equipment that are in direct contact with the slurry grout.

650.05. METHOD OF MEASUREMENT. This work as completed and accepted shall be measured at the contract unit price per square foot of fabric formed concrete mat.

650.06. BASIS OF PAYMENT. Accepted quantities of fabric formed concrete mat as measured above will be paid for at the contract unit price per square foot for:

FABRIC FORMED CONCRETE MAT SQ. FT.

which shall be full compensation for furnishing all materials, equipment, labor and incidentals required to complete the work as specified.