POLYPROPYLENE FIBER REINFORCED CONCRETE DETENTION PONDS

Final Report

Experimental Features
Project No. OR 90-04

N.E. 181st Avenue Interchange Section
Columbia River Highway (Interstate 84)

By

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16. Abstract

In 1991, two Durafiber polypropylene fiber reinforced concrete lined detention ponds were constructed. The detention ponds are located on the north side of the 181st Avenue Interchange, on the Columbia River Highway (I-84), approximately ten miles east of Portland, Oregon.

The original design called for the detention ponds to be constructed with six-inch thick welded wire fabric reinforced concrete over an impermeable geomembrane. An alternate to this design, replacing the welded-wire fabric reinforced concrete with polypropylene fiber reinforced concrete, was proposed by the contractor through a no cost price agreement and approved by the Oregon Department of Transportation (ODOT) and Federal Highway Administration (FHWA). The replacement of welded-wire fabric reinforced concrete with polypropylene fiber reinforced concrete created no problems with respect to mixing, placing, workability, finishability, or visual appearance. The use of fiber reinforced concrete on this project resulted in a small cost reduction relative to the use of welded wire fabric reinforced concrete. However, as a result of the field observations made during the final site visit, it was concluded that the reinforcing fibers appeared to have provided no added value toward strengthening the ponds shotcreted layers; although, the ponds are performing satisfactorily.

ODOT Research Unit Staff should do the following: 1. If funds are available, the fiber reinforced concrete should continue to be monitored until it fails. 2. If polypropylene fiber reinforced concrete is used on another ODOT project, it should be evaluated.

17. Key Words	18. Distribution Statement
PAVEMENT CONCRETE, REINFORCEMENT, FIBERS	

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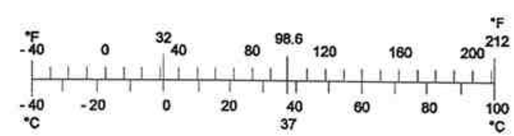
SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	millimeters squared	mm^2
ft^2	square feet	0.093	meters squared	m^2
yd^2	square yards	0.836	meters squared	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	kilometers squared	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	meters cubed	m^3
yd^3	cubic yards	0.765	meters cubed	m^3
NOTE: Volumes greater than 1000 L shall be shown in m^3.				
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams	Mg
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5(F-32)/9	Celsius temperature	°C

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	millimeters squared	0.0016	square inches	in^2
m^2	meters squared	10.764	square feet	ft^2
ha	hectares	2.47	acres	ac
km^2	kilometers squared	0.386	square miles	mi^2
		VOLUME		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	meters cubed	35.315	cubic feet	ft^3
m^3	meters cubed	1.308	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.205	pounds	lb
Mg	megagrams	1.102	short tons (2000 lb)	T
		TEMPERATURE (exact)		
°C	Celsius temperature	1.8 + 32	Fahrenheit	°F



* SI is the symbol for the International System of Measurement

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DISCLAIMER

Fiber Reinforced Concrete Detention Ponds

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1.0 INTRODUCTION

The use of steel fibers to improve the properties of concrete has been the topic of many studies. Concrete containing steel fibers has been shown to have increased resistance to crack propagation, higher tensile strength, and higher post-cracking ductility than concrete without steel fibers. Studies have shown that concrete reinforced with polypropylene fibers also exhibits these improved properties, as well as, improved resistance to temperature and shrinkage cracking (1, 2, 3). Steel fiber reinforced concrete has previously been used on Oregon Department of Transportation (ODOT) projects, however, the ODOT has not utilized polypropylene fiber reinforced concrete in construction.

This project involved the construction of two polypropylene fiber reinforced concrete lined detention ponds in 1991 (4). The original design called for the detention ponds to be constructed with a six-inch (15.24 cm) layer of welded-wire fabric reinforced concrete over an impermeable geomembrane. An alternate to this design, replacing the welded wire fabric reinforced concrete with polypropylene fiber reinforced concrete, was proposed by the contractor through a no cost price agreement. ODOT and Federal Highway Administration (FHWA) staff approved the contractor's proposal and decided to evaluate the material as an experimental features project.

The evaluation of the performance of the polypropylene fiber reinforced concrete detention ponds will be discussed in this report. Since the ponds were constructed, they have been under the jurisdiction of the ODOT District Maintenance 2B personnel. In preparing this final report, a series of interviews and site visits were made to evaluate the polypropylene fiber reinforced concrete.

2.0 PROJECT DESCRIPTION

2.1 PROJECT LOCATION AND CLIMATE

The project is located on the west and east sides of 181st Avenue, north of the Columbia River Highway (U.S. I-84), ten miles east of Portland in Multnomah County, Oregon as shown in Figure 2.1.

The project is in the Willamette Valley climatic region, which is characterized by mild wet winters and moderate dry summers. The average daily temperature of the coldest month (January) is about 37°F (2.7°C). The average daily temperature of the warmest month (July) is approximately 66°F (18.9°C). This area receives an average annual precipitation of 39 inches (99.1 cm).

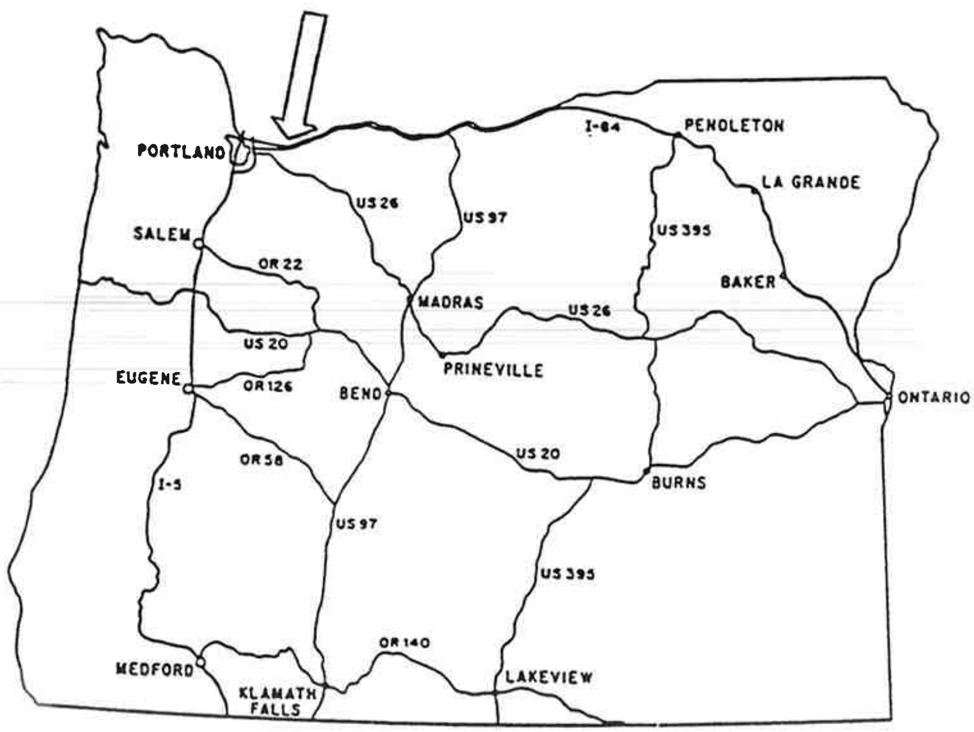

Figure 2.1: Project Location in Oregon

2.2 DESIGN

The detention ponds were designed to be elliptical in shape, approximately 400 feet (122 m) long and of variable width. The sides of the ponds slope 2:1 (horizontal:vertical). The east pond is four feet (1.2 m) deep and the west pond is eight feet (2.4 m) deep (see Appendix A for construction plans).

The original design called for a six-inch (15.2 cm) thick welded-wire fabric reinforced concrete layer to be placed over an impermeable polyethylene geomembrane. The contractor proposed the use of Durafiber polypropylene fibers as an alternate to welded wire fabric for use as reinforcement in the detention ponds. In the contractor's proposal, the following reasons were cited for the substitution:

1. The use of the fibers for reinforcement eliminates the danger of puncturing the impermeable membrane with the sharp edges on the steel reinforcement. The chairing system required to suspend the steel reinforcing also poses a potential puncture danger to the liner.

2. The impermeable membrane expands and contracts a great deal with temperature change, which may make it difficult to maintain proper separation between the membrane and the reinforcement as the membrane expands and buckles. Use of the fibers eliminates the requirement for separation between the membrane and the reinforcement.

3. The use of the fibers would expedite the placement process, reducing the construction time and the temperature deviation expansion problem.

ODOT and FHWA staff reviewed the contractor's proposal and approved this experimental features project to use Durafiber polypropylene fiber reinforced concrete as an "approved equal" to concrete reinforced with welded wire fabric.

3.0 CONSTRUCTION

Two commercial concrete mixes were used in the pond construction. The floors of both ponds were constructed with Ross Island Sand & Gravel Mix Design No. 4401B (Table 3.1), a class 3300, 3/4 inch (1.91 cm) minus mix, which was also used elsewhere on the project. In addition, 5000C (Table 3.1), a class 3300, pea gravel mix was developed for gunite applications. Durafiber polypropylene fibers, 3/4-inch (1.91 cm) in length, manufactured by Hill Brothers Chemical Company, were added to the commercial mixes at the manufacturer's recommended rate of 1-1/2 pounds (0.68 kg) of fibers per cubic yard (0.76 m^3) of concrete.

	4401B	**5000C**
Cement	490 lbs. (222 kg)	705 lbs. (320 kg)
Fly Ash	100 lbs. (45 kg)	---
Coarse Aggregate	1,850 lbs. (839 kg)	850 lbs. (386 kg)
Sand	1,118 lbs. (507 kg)	2,031 lbs. (921 kg)
Water	270 lbs. (122 kg)	282 lbs. (128 kg)
Air Content	5.5%	5.0%

Table 3.1: Commercial Concrete Mixes

The fibers were introduced into the truck mixers and then, the concrete was batched into the trucks (this method had been found most effective by the concrete contractor as a result of previous experiences with Durafiber). The concrete was mixed as usual and the fibers were distributed throughout the load. No additional mixing time or other measures were necessary. The fibers had little discernable effect on the plasticity of the concrete mixture. There was some resistance to slumping, but it was not significant.

The fiber reinforced concrete mixture was pumped into place for the pond floors and was gunited into place for the walls. There were no apparent problems with balling or clumping of fibers in the concrete mixture. The fibers appeared to be mixed uniformly throughout the concrete batches and remained well mixed as it was handled for placement. No modifications to standard equipment were required for placement and no problems were encountered as a result of the use of the fibers.

No special methods or tools were required for finishing operations. The finishers commented that it was just a different concrete mixture, requiring experience in dealing with slightly different finishing characteristics. The fiber reinforced concrete did not float as easily as other concrete mixes when a large float was used. According to the head finisher, this material is very susceptible to added surface moisture (e.g. rain). Surface moisture may wash the fibers and cause the surface fibers to ball. If the surface fibers ball, a high quality surface finish would be difficult to obtain.

Joints were scored transversely at thirty-foot (9 m) maximum spacing on the pond bottoms during the concrete finishing process with a two-inch (5 cm) deep by 1/4-inch (0.64 cm) wide blade fastened to a large float. A longitudinal joint 1-1/2 inch (3.8 cm) deep by 1/4-inch (0.64 cm) wide was saw cut the length of each pond, after the concrete was sufficiently set up. A construction joint was required around the bottom of each pond where the sides and the bottom meet. Details of construction joints are shown in Appendix A. The sides of the ponds were also scored at thirty-foot (9 m) maximum spacing with the bladed float during concrete finishing.

Approximately 920 cubic yards (703 m^3) of concrete were used to construct the ponds. Approximately 1,380 lbs. (626 kg) of fibers, at the manufacturers recommended rate of 1-1/2 lbs. (0.68 kg) per cubic yard, were used. The west pond required approximately 230 cubic yards (176 m^3) of concrete for the floor and 276 cubic yards (211 m^3) of gunite concrete for the sides. The east pond used approximately 230 cubic yards (176 m^3) of concrete for the floor and 138 cubic yards (106 m^3) of gunite concrete for the sides.

The finished appearance of the fiber reinforced concrete is very similar to a normal concrete mixture. Small amounts of fibers were visible on the concrete surface. Photographs of the project are provided in Appendix B.

The increase in cost of adding fibers to the supplied mix was $7.50 per cubic yard ($9.81 per m^3). Additional jobsite labor costs may be considered negligible for the placement and finishing of the fiber reinforced concrete.

4.0 EVALUATION

1. Mixing and Placement Methods

The fibers were introduced into the truck mixer and then, the concrete was batched into the trucks. The fibers appeared to be uniformly distributed during mixing and placing the concrete. No special equipment was required for mixing and placing the fiber reinforced concrete. No problems occurred as a result of the use of the fibers.

2. Workability and Finishability

No special tools or modified methods were required for finishing the fiber reinforced concrete. The finishers indicated that it was just a different concrete mix with slightly different finishing characteristics. This material is susceptible to added surface moisture such as rain, which washes the fibers and may cause surface balling of the fibers resulting in finishing problems. If the surface fibers ball, a high quality finish is not possible.

3. Visual Appearance

The finished appearance is similar to a normal shotcreted concrete mixture. Small amounts of fibers were visible on the surface of the finished concrete. Photographs of the ponds are located in Appendix B.

4. Amount and Degree of Shrinkage (Temperature) Cracking

Both the East and West ponds showed evidence of lateral, longitudinal, and web-like cracking along the sides of each pond. The length of these cracks most often runs the full depth of the ponds' sloping sides from the top edge to the concrete slab at the base. It is difficult to determine an acceptable amount or degree of shrinkage cracking because there is not a control section. The ODOT Structural Materials Engineer, on site for the final inspection, mentioned that the use of synthetic reinforced fibers in the shotcrete provided no overall reinforcing benefit. He further stated that unreinforced shotcrete often performed better than what was being exhibited here with the use of polypropylene fibers as a reinforcement material.

5. Overall Performance

According to the ODOT Structural Materials Engineer, the overall performance of adding synthetic fibers to the shotcrete is questionable. As a result of his observations, he indicated that the reinforcing fibers appeared to have provided no added value toward strengthening the ponds shotcreted layers(*5*). Very similar work was done by the Arizona Department of Transportation to test the constructibility and performance of synthetic fibers in reinforcing shotcrete. They reported "the test results indicate that at the levels of reinforcement used for this project (used at manufacturers recommended amounts) the fibers provide no measurable advantage over plain shotcrete(*6*)."

6. Final Installation and Material Costs

The construction price agreement called for substituting Durafiber reinforced concrete for welded-wire fabric reinforced concrete in the detention ponds. The final installation and material cost pertaining to Durafiber reinforced concrete was $17,812.00 versus welded-wire fabric reinforced concrete at $20,000.00; this amounted to a $2,188.00 price reduction. Inclusion of the fibers added $7.50 per cubic yard ($9.81 per m^3) to the concrete cost. This additional cost was more than offset by the reduction in cost resulting from not using the welded-wire mesh reinforcement. There were no additional placing and finishing costs resulting from the use of the fibers.

5.0 CONCLUSIONS AND RECOMMENDATIONS

5.1 CONCLUSIONS

The replacement of welded wire fabric reinforced concrete with polypropylene fiber reinforced concrete created no problems with respect to mixing, placing, workability, finishability, or visual appearance during construction. The use of fiber reinforced concrete on this project resulted in a small cost reduction relative to the use of welded-wire fabric reinforced concrete.

There are many cracks in the detention ponds, however, the ponds are performing satisfactorily. Without a shotcreted control section, such as traditional welded-wire fabric, or with using plain shotcreting techniques, it is difficult to determine the overall performance of the Durafiber synthetic fiber reinforced concrete. The ODOT Structural Materials Engineer indicates that the reinforcing fibers appeared to have provided no added value toward strengthening the ponds shotcreted layers.

5.2 RECOMMENDATIONS

Based on the recommendations of the Structural Materials Engineer, Durafiber polypropylene fibers should not be specified for shotcrete. The addition of fibers did not improve the performance of the shotcrete.

In addition, ODOT Research Unit staff should do the following:

1. If funds are available, the polypropylene fiber reinforced concrete should continue to be monitored until it fails.

2. If polypropylene fiber reinforced concrete is used on another ODOT project, it should be evaluated.

6.0 REFERENCES

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5. Johnston, K. *Personal conversation*. Oregon Department of Transportation (ODOT), Materials Unit, Salem, OR, 29 October 1993.

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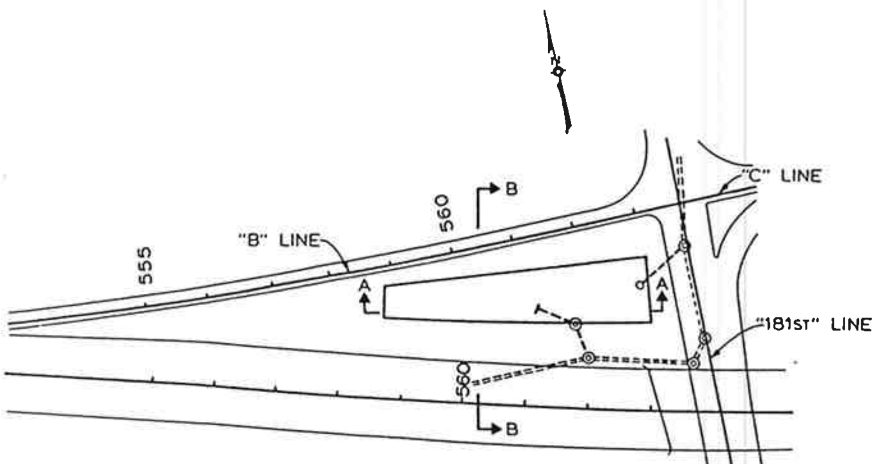
APPENDIX A

CONSTRUCTION PLANS

DETENTION POND SYSTEM DETAILS

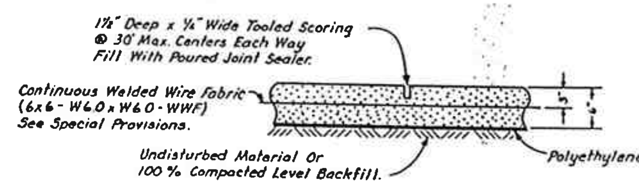
21V-162

N.E. 181ST AVE. INTCHGE. SEC. COLUMBIA RIVER HIGHWAY MULTNOMAH COUNTY				SHEET No. 2B-6
FED. ROAD DIV. No.	STATE	PROJECT NUMBER	FISCAL YEAR	TOTAL SHEETS
10	OREGON	I-84-1(12)10		

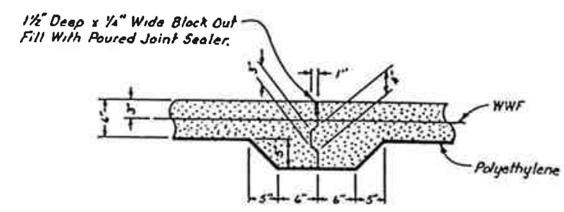


PLAN

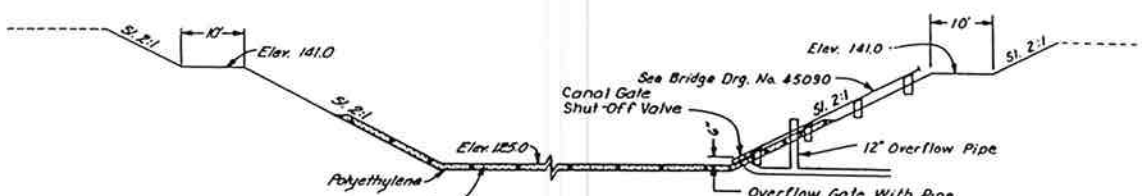
NOTE:
Min Splice Length For This 6x6 - W6 x W6 - WWF Is 8".



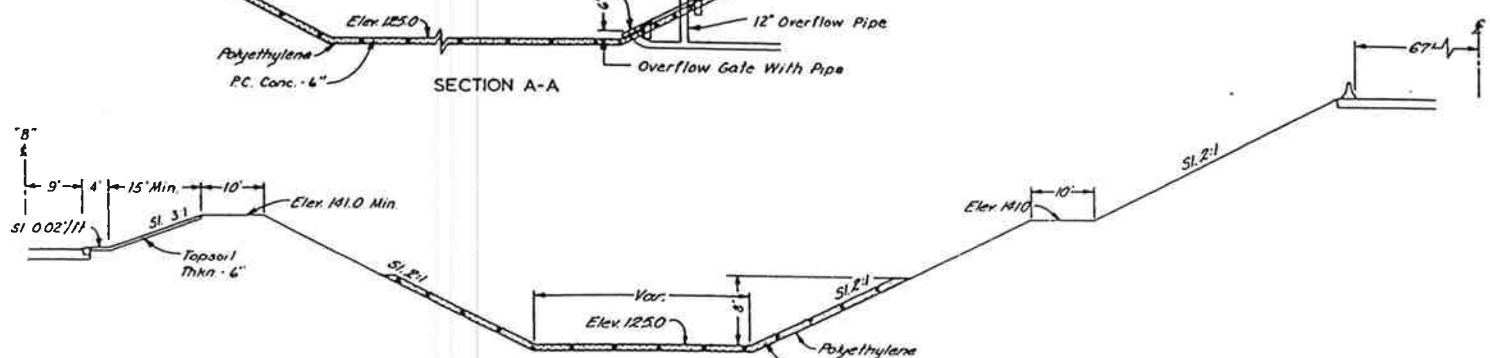
DETENTION POND CONCRETE SLAB



CONSTRUCTION JOINT



SECTION A-A

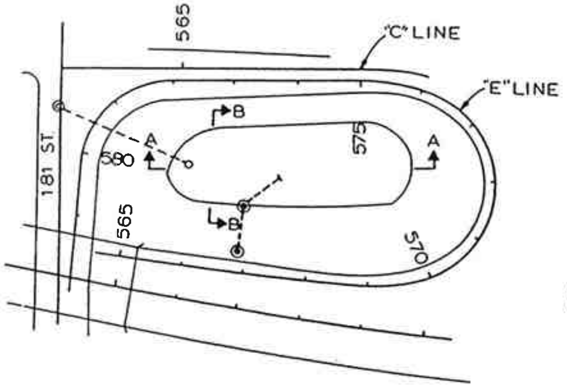


SECTION B-B

DETENTION POND SYSTEM DETAILS

21V-162

N.E. 181ST AVE. INTCHGE. SEC. COLUMBIA RIVER HIGHWAY MULTNOMAH COUNTY				Sheet No. 2B-7
Fed. Road Div. No.	State	Project Number	Fiscal Year	Total Sheets
10	OREGON	I-84-1(12)10		



NOTE :
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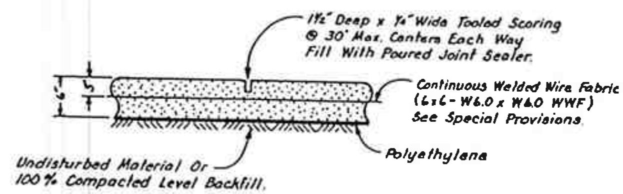
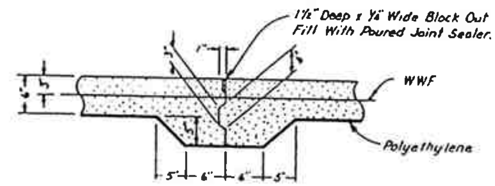


DETENTION POND CONCRETE SLAB



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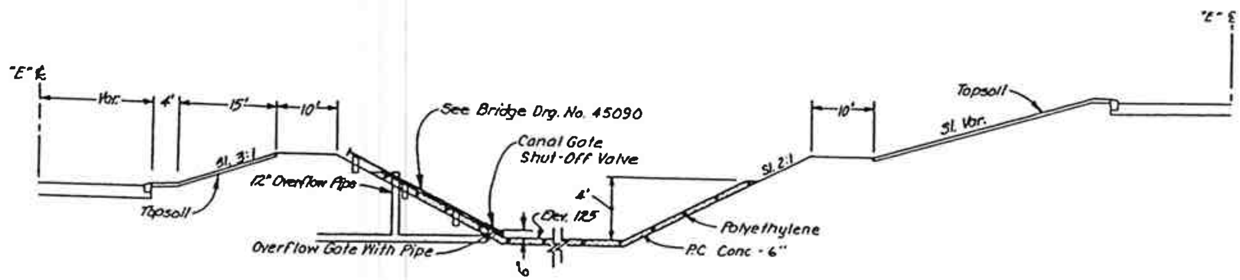
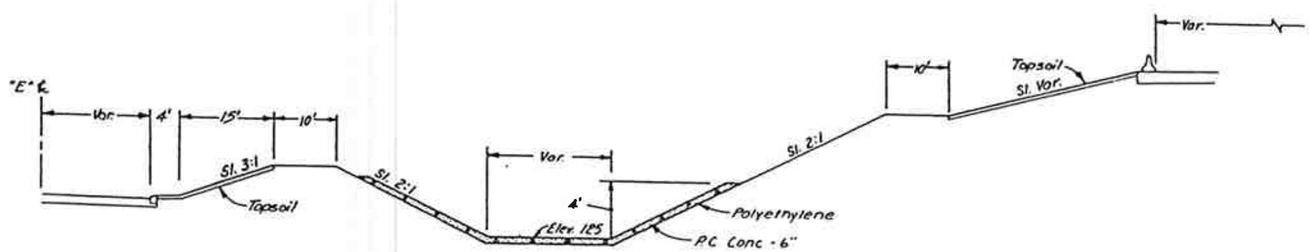


SECTION A-A



SECTION B-B

APPENDIX B

PHOTOGRAPHS

Figure B.1: Final site visit, West Pond, looking east

Figure B.2: Final site visit, East Pond, looking east

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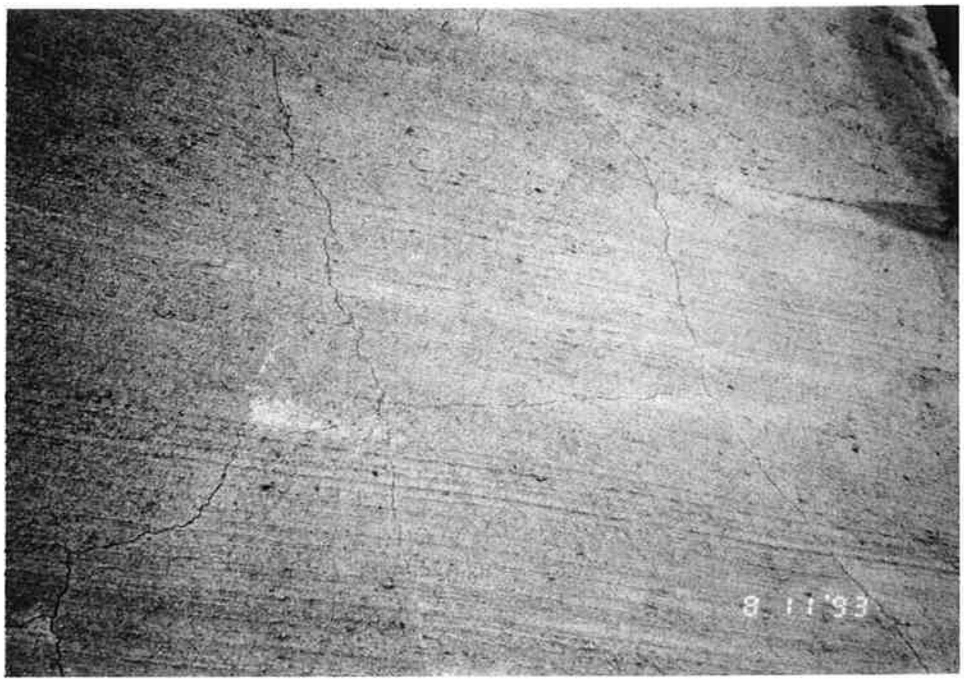

Figure B.3: Final site visit, East Pond web-like cracking