EVALUATION OF PREFABRICATED EDGE DRAINS (PED) IN OHIO

Final Report

Submitted to

The Ohio Department of Transportation

By

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and

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Ohio Department of Transportation
Columbus, Ohio

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EXECUTIVE SUMMARY

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"Evalutaion of Prefabricated EdgeDrains in Ohio"

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Sponsoring Agency: Ohio Department of Transportation
1600 West Broad Street
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Research was conducted to evaluate prefabricated edge drain (PED) construction procedures and to assess the condition of PED installed in Ohio between 1988 and 1993. The research was to include querying department of transportation engineers, visual inspections of PED at several locations in Ohio and permittivity testing of the PED fabric.

Surveys designed to query department of transportation engineers about construction specifications, maintenance problems and pavement performance were sent to all states. Ohio Department of Transportation (ODOT) design and construction engineers in the 12 ODOT districts were also contacted. The condition of PED installed in Ohio was evaluated at six sites throughout Ohio by excavating short sections of PED for visual inspections using a video borescope with a 25-feet long fiber optic cable and a VCR video recorder. Permittivity testing of the PED fabric was conducted in the field on PED samples removed from the excavations.

This report summarizes results and conclusions from the survey and the field inspections of PED in Ohio. Specifications for installing PED vary considerably among the states using PED. ODOT specifications currently require placing the PED on the outside of the trench and using a granular backfill. Problems that have been reported include deformation of the PED core, compression of the filter fabric into the core, blinding and clogging of the filter, sedimentation of the core and blockage of drainage outlets. In most cases, the problems were considered minor. The problems cited above were observed at all six sites during the video borescope inspections. In spite of problems with the filter fabric, the permittivity of the filter fabric was not significantly reduced. The problems with PED result in reduced drainage capacity. However, the PED are effective in providing drainage provided the drainage outlets are not blocked. Construction specifications should be observed to minimize problems. Maintenance personnel should inspect drainage outlets on a regular basis to ensure that the outlets are not blocked.

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16. Abstract An investigation was conducted to evaluate prefabricated edge drain (PED) construction procedures and to assess the condition of PED installed in Ohio between 1988 and 1993. The research included a survey of department of transportation engineers in other states and Ohio Department of Transportation (ODOT) design and construction engineers. The condition of PED installed in Ohio was evaluated at six sites throughout Ohio by excavating short sections of PED for visual inspections and permittivity testing. A video borescope with a 25-feet long fiber optic cable was used to investigate the in situ condition of the PED. Permittivity testing of the PED fabric was conducted in the field on PED samples removed from the excavations.

Specifications for installing PED vary considerably among the states using PED. ODOT current specifications require placing the PED on the outside of the trench and using a granular backfill. Problems that have been reported include deformation of the PED core, compression of the filter fabric into the core, blinding and clogging of the filter, sedimentation of the core and blockage of drainage outlets. In most cases, the problems were considered minor. The problems cited above were observed at all six sites during the video borescope inspections. In spite of problems with the filter fabric, the permittivity of the filter fabric was not significantly reduced. The problems with PED result in reduced drainage capacity. However, the PED are effective in providing drainage provided the drainage outlets are not blocked. Construction specifications should be observed to minimize problems. Maintenance personnel should inspect drainage outlets on a regular basis to ensure that the outlets are not blocked.

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DISCLAIMERS

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CHAPTER 1

INTRODUCTION

The Ohio Department of Transportation (ODOT) has specified prefabricated edge drains (PED) for rehabilitation of interstate highways and they have been installed at several sites over the past ten years. PED are placed below the edges of pavements to intercept moisture as it enters the pavement edge joint and to conduct it away from pavement bases and subgrades. PED usually consist of a thin support core wrapped in a geosynthetic fabric wrap. The edge drain must have adequate strength to withstand lateral and vertical loads. The core must have adequate flow capacity to allow for timely drainage of the PED. The fabric material must be capable of passing fines in order to prevent blinding and clogging of the fabric while preventing coarse materials from passing through.

Specifications for installing prefabricated edge drains vary among the states using PED. Using equipment designed specifically for edge drain construction, the PED are placed and an initial backfill lift is placed simultaneously as a 4-inch wide trench is excavated. The PED is placed on either side of the trench. The trench backfilling is then completed using either the excavated material or a select aggregate with one or more lifts. The backfill is compacted to provide lateral support for the PED and vertical support for the pavement. Several investigations have been conducted on the PED in other states. Because of differences in construction specifications, including the use of excavated materials for backfilling, it is possible that there may be problems with edge drains as constructed in Ohio. Therefore, it was necessary to investigate PED that were installed in Ohio.

There was a need to investigate whether problems have occurred during the installation of PED or whether there are maintenance problems on pavements where PED have been installed. Construction problems include twisting or bending of the PED that results in structural damage to the core or occurrences leading to tearing of the fabric material. The backfill compactive effort should not result in damage or excessive compression of the edge drains. Problems that result in pavement distress, pumping of water from the edge joints or ponding of water along the pavement joint that would require maintenance need to be identified.

It was also necessary to investigate the condition of the edge drains and to determine if the drains are functioning properly. Partial or complete blinding or clogging of the fabric material can severely reduce drainage capability. Collapse of the supporting core will impede drainage and can lead to pavement distress. Breaches in the fabric material can result in erosion of the backfill material adjacent to the edge drains and subsequent pavement distress. Deposition of sediments in the drains impedes drainage. The drainage outlets must be maintained properly so that drainage from the PED will not be impeded.

The research included an investigation of experience with prefabricated edge drains. A two-page survey was sent to all state departments of transportation to query them about their experiences with PED. The survey included questions concerning PED construction, problems associated with PED and performance of pavements with PED. Research results from previous investigations on PED were requested. ODOT personnel were also contacted. Information from this research was beneficial in developing recommendations for PED use.

The research also required an evaluation of the condition of the PED. Information on projects where PED were installed in the past ten years was available from ODOT maintenance surveys and project reports. The condition of the PED was evaluated by excavating short sections of the PED for visual inspections and permittivity testing. A video borescope with a 25-feet long fiber optical cable was used to investigate the in situ condition of the PED. The permittivity testing was conducted in the field on PED samples removed from the excavations. A test apparatus was designed so a hydraulic gradient could be applied to the PED fabric to measure the permittivity of the fabric. The results of the permittivity testing were used to evaluate the effectiveness of the PED fabric material after years of being in place.

CHAPTER 2

RESEARCH OBJECTIVES

The objective of the research was to evaluate in-situ prefabricated edge drains (PED) in Ohio. PED have been specified by the Ohio Department of Transportation (ODOT) in highway rehabilitation projects since 1987. Other states have used PED in a variety of applications for several years. These states have conducted research on the use and construction of PED, however an in-situ evaluation was needed. This will help revise ODOT specifications and construction practices for future PED use. There is also a concern that pavements have experienced additional maintenance problems. An in-situ evaluation will yield the condition of the PED and if they are functioning properly. The primary objectives of this research are therefore:

1) a review of national experience including installation, performance and any pavement maintenance associated with PED, by using a literature review, survey and contacts with manufacturers;

2) contacting ODOT construction and maintenance personnel to determine problems that have occurred during construction and pavements maintenance requirements;

3) selection of pavements with PED at eight locations in Ohio and developing procedures for the video inspections and permittivity testing;

4) conduct field investigations of PED with video borescope and permittivity apparatus;

5) evaluate results of field investigations;

6) report results of research with recommendations for design and construction of PED.

CHAPTER 3

EXPERIENCE WITH PREFABRICATED EDGE DRAINS (PED)

3.1 Overview of PED

Prefabricated edge drains (PED) consist of a drainage core material wrapped in a filter material. The core provides support for the filter material and area for water to flow. The filter material is designed to retain the base materials while allowing minimum piping of fines into the drainage core. In order for the PED to be effective, the filter must be free from blinding or clogging and the core must have adequate drainage capacity to convey the water from the pavement. PED are used in place of longitudinal pipe underdrains or are placed along pavements as additional pavement drainage in rehabilitation projects, usually at a lower cost than longitudinal pipe underdrains.

Results from several studies on prefabricated edge drains were available before this project began. Goddard (1991) reported information on the design of prefabricated edge drains. Information on both the design of prefabricated edge drains and the costs of constructions has been reported (Highlands et al., 1991 and Koerner and Hwu, 1991). Laboratory testing to evaluate the structural capacity of vertical edge drains has been reported (Frobel, 1991). The thesis by Elsharief (1992) contains results of laboratory testing to determine the structural and flow capacities of vertical edge drains. Results of laboratory flow tests have also been reported by Stuart (1991). Dempsey (1988) reported results of flow tests conducted both in the laboratory and the field. A project, that included the measurement of flow from edge drains, was reported by Hinshaw (1988). Bodocsi et al. (1994) developed methods for testing the field permeability of pavement bases. Field investigations where video systems were used to evaluate PED were conducted in Kentucky (Allen and Fleckenstein, 1991), West Virginia (Baldwin, 1991) and Iowa (Steffens et al., 1991).

In spite of the wealth of information that is provided in the cited references, there is a need to evaluate prefabricated edge drains as constructed in Ohio. Problems that were reported in the other states were attributed to compression of the core possibly occurring during construction, blinding or clogging of the fabric material and inadequate flow capacity. The problems resulted in pavement distress, pumping of water from the edge joints or even ponding of water along the pavement joint. There are differences in construction specifications for PED, including the materials used for backfilling. Consequently, it is possible that there may be problems with PED in Ohio that have or have not occurred in other states. Therefore, information from other states on their experience with PED was sought.

3.2 ODOT PED Specifications

Construction and design specifications for PED in Ohio previously called for placement of the PED next to the pavement in a 4-inch wide trench that was cut at the longitudinal joint. The material properties of acceptable PED were described referring to ASTM standards (ASTM, 1992 a and b). Acceptable PED are listed by name and manufacturer. The specifications allowed the use of the excavated materials for the PED backfill. Specifications for splicing, fittings and outlet pipe were included. An example of ODOT specifications from construction plans is provided in Figure 3.1.

The ODOT current specifications on PED and outlet structure construction are given in Figure 3.2. The current specifications state that the PED is to be placed on the outside of the trench and backfilled with No. 8 natural aggregate. This revision was due to current national thought that it is necessary to provide an additional filter on the pavement side and to fill any voids that formed under the pavement during the trenching operation.

3.3 ODOT PED Locations

The locations of pavements with PED were obtained using ODOT maintenance surveys and project reports. A listing of all the pavements is provided in Table 3.1 by ODOT districts. The installations of the PED took place from 1989 to 1993. Therefore adequate time should have elapsed for the PED to experience problems caused by blinding or clogging of the filter or siltation of the PED. The total length of PED specified for installation was 6,620,889 linear feet (project length equal to 558 miles) at a total cost of $14.05 million dollars for an average of $2.12/liner foot. The start mile and end mile values in the table were calculated using a state map starting with mile zero at the southernmost or westernmost ends of the highways. In some cases the start and end mile could not be determined. The information in the tables was used in the field to locate the PED without any difficulty.

DESCRIPTION: The item shall consist of furnishing and installing a pipe underdrain system or prefabricated edge drain system in accordance with the specifications, details as shown on the plans, and as directed by the Engineer.

MATERIALS: The underdrain shall be a pipe underdrain system per item 605 or a prefabricated edge drain system meeting the following requirements. The prefabricated edge drain shall consist of a polymeric core with a minimum thickness of one inch wrapped in fabric meeting 712.09 Type A. The drain shall be flexible, rectangular in shape and of hollow construction. The core material shall be resistant to petroleum based chemicals, natural occurring soil chemicals, and road de-icing agents.

The core shall provide a minimum of 100 square inches unobstructed (one side only) drainage area per foot of width. Side walls of the core shall provide at least 5% open area to permit unobstructed flow through the filter and wall to the core.

The prefabricated edge drain shall have a minimum compressive strength of 6000 pounds per square foot with a maximum 20% compression in a parallel plate compression test (ASTM-D 695). The minimum (single side) core flow capacity shall be 10 gallons per minute per foot of width for a 0.1 gradient at 10 pounds per square inch bladder load per ASTM D4716.

In lieu of the above requirements the following products are acceptable prefabricated edge drains:

Hydraway Drain by Monsanto Company	Strip Drain 100 by Contech Construction Products, Inc.
PDS 25 by Prodrain Systems	AdvanEDGE by Advanced Drainage Systems, Inc.

CONSTRUCTION: The prefabricated edge drain shall be installed in a trench as shown on the plans and in accordance with the manufacturer's recommendations. The contractor has the option to backfill the trench with the excavated material or No. 8 natural aggregate. If the excavated material is used for the backfill it shall be placed in three (3) lifts minimum with each lift of uncompacted material not exceeding 8" in thickness. Each lift shall be compacted to 95% of the maximum dry weight density as determined by AASHTO T99. If No. 8 natural aggregate is used it shall be placed in one (1) or more lifts with a vibratory compactor run over the final lift to consolidate the aggregate prior to placing the asphalt plug. The first layer of the backfill material shall be placed simultaneously with the trenching operation to hold the edge drain flush against the trench wall.

The prefabricated edge drain shall be spliced as required prior to placement in the trench, using material furnished by the manufacturer and in accordance with the manufacturer's directions. All material required for the splices will supplied by the manufacturer, but any equipment required shall be furnished by the Contractor.

The underdrain outlets shall be placed in accordance with item 603 as directed by the Engineer, using outlet fittings. The manufacturer shall supply outlet fittings which will make the transition between the prefabricated edge drain and the outlet pipe. Fittings shall be installed as recommended by the manufacturer.

The outlets for the underdrain system shall be constructed as soon as possible after placement of the underdrain. The outlets on crack & seat projects shall be in place and functional prior to cracking and seating the existing pavement.

Figure 3.1 - ODOT Specifications for PED (Plans dated 3/20/91)

605.04 Prefabricated Edge Drain Construction. The prefabricated edge drain shall be installed against the outside wall of a 100 mm (4 inch) trench and backfilled adjacent to the pavement with durable No. 8 size gravel, stone or air-cooled blast furnace slag. The No. 8 aggregate shall be placed in one or more lifts with a vibratory compactor run over the final lift to consolidate the aggregate prior to placing the asphalt plug. The first layer of the backfill material shall be placed simultaneously with the trenching operation to hold the edge drain flush against the trench wall.

The prefabricated edge drain shall be spliced as required prior to placement in the trench, using material furnished by the manufacturer and in accordance with the manufacturer's directions. All material required for the splices will be supplied by the manufacturer, but any equipment required shall be furnished by the Contractor. Splices shall prevent separation of adjoining sections of the prefabricated edge drain panels

605.05 Underdrain Outlets. Pipe outlets shall be constructed concurrently with underdrains and paid for as Item 603 Conduits, Type F. All outlets on the slope shall have a precast reinforced concrete outlet as per 604.

The underdrain outlets shall be placed in accordance with 603 using outlet fittings. The manufacturer shall supply outlet fittings which will make the transition between the prefabricated edge drains and the outlet pipe. The outlets for underdrain systems shall be constructed as soon as possible after placement of the underdrain or prefabricated edge drain. The underdrain and outlets on crack and seat or rubblized projects shall be in place and functional prior to cracking and seating rubblizing the existing pavement.

The downstream end of any 100 mm (4 inch) underdrain conduit shall extend a minimum of 450 mm (18 inches) into the 150 mm (6 inch) Type F outlet.

Figure 3.2 - ODOT Specifications for PED (1/1/97)

Table 3.1 - Locations of PED in Ohio

YrProj	County	ODOT District	Quantity (lf)	Route	Mileage	Project Length (miles)	Start Mile	End Mile	Unit Price ($/lf)
900011	HAN	1	37798.	75	19.25	3.2	161.25	164.45	2.50
900929	WOO	2	1290.	75	4.81	5.1	170.81	175.91	5.00
900905	WOO	2	31990.	75	0.00	4.8	166	170.8	2.50
910430	OTT	2	98187	2	23.4	4.7	127.4	132.1	2.75
900829	WAY	3	46593.	30	6.44	5.4	146.44	151.84	2.82
		3		250	5.50		-	-	
910989	LOR	3	55115	57	12.13	4.1	12.13	16.23	2.5
		3		20	16.17		16.17	16.17	
910371	RIC	3	132127	71	0.04	6.8	159	165.8	2.45
901092	ASD	3	111179	30	8.54	5.8	134.54	140.34	1.95
910212	SUM	4	57584	8		4.2	0	4.2	2.0
918003	MAH	4	71442	680		4.5	201	205.5	3.96
920191	STA	4	50000	77	9.1	4.5	102.1	106.6	4.8
920814	SUM	4	24952	8	2.23	1.5	2.23	3.73	2.0
921127	TRU	4	66522	5	2.41	4.1	2.41	6.51	3.47
880341	LIC	5	32446.	70	9.55	6.4	121.55	127.95	3.02
880413	LIC	5	44006.	70			112	112	2.10
880413	LIC	5	48178.	70	29.93	6.4	141.93	147.33	2.65
890725	GUE	5	162931.	70	6.19	11.2	175.19	186.39	2.26
890594	LIC	5	495.	37			-	-	3.93
890594	LIC	5	495.	37			-	-	3.68
890594	LIC	5	495.	37			-	-	4.21
890594	LIC	5	495.	37	15.61	4.1	-	-	2.60
890725	GUE	5	61364.	70	6.19	11.2	175.19	186.39	2.26
890576	MUS	5	169432.	70	13.20	8.0	156.2	164.2	1.57
900662	GUE	5	4000.	70	0.00	6.1	169	175.1	2.54
900662	GUE	5	59624	70	0	6.1	169	175.1	1.87
900944	GUE	5	79412	77	9.26	5.2	45.26	50.46	1.8
880114	DEL	6	186790.	71	11.50	8.9	102.5	111.4	2.70
900453	FRA	6	48185.	71	18.04	7.6	109.04	116.64	1.85
908014	FRA	6	67018	270	52.16	3.4	137.16	140.56	2.75
910853	FRA	6	26521	270	12.26	4.8	97.26	102.06	2.55
910853	FRA	6	58689	270		2.8	85	87.8	2.3
920715	FRA	6	242101	270	37	6.5	122	128.5	1.7

Table 3.1 - Locations of PED in Ohio (Continued)

YrProj	County	ODOT District	Quantity (lf)	Route	Mileage	Project Length (miles)	Start Mile	End Mile	Unit Price ($/lf)
890688	MOT	7	30771.	75	13.88	2.2	53.88	56.08	3.35
900980	CLA	7	32654.	70	11.23	2.8	52.23	55.03	1.78
920661	MIA	7	846	36	17.29	0.5	17.29	17.79	0.50
920806	MOT	7	59586	75	16.09	3.8	56.09	59.89	1.67
920644	MOT	7	81057	75	6.13	4.3	46.13	50.43	2.15
920505	CLA	7	198050	40	15.66	11.9	60.66	72.56	2.09
890578	WAR	8	31072.	48	9.03	1.9	26.03	27.93	3.07
890211	GRE	8	65654.	35F	0.00	4.6	41	45.6	2.30
900232	PRE	8	142606.	70	6.30	7.3	6.3	13.6	1.94
900663	HAM	8	56049	275	10.57	5.5	10.57	16.07	2.17
900455	HAM	8	101080	275	0	7.9	0	7.9	1.68
900278	PRE	8	131173	70	0	6.3	0	6.3	1.86
900988	HAM	8	132512	74	11.1	5.9	11.1	17	1.75
910308	HAM	8	6850	275	22.81	6.1	22.81	28.91	3.45
910253	HAM	8	71327	52		10.8	0	10.8	2.22
910713	HAM	8	192455	74		8.6	0	8.6	1.7
910012	WAR	8	200095	71		9.2	19	28.2	2.1
920599	HAM	8	17104	275	36.6	3.2	36.6	39.8	2.6
921093	HAM	8	44732	75	14.26	2.2	14.26	16.46	1.87
930041	HAM	8	6860	71	19.17	1.5	19.17	20.67	3.0
930849	HAM	8	27914	562	1.18	1.8	1.18	2.98	2.8
930260	HAM	8	39827	75	4.21	5.6	4.21	9.81	4.0
930656	HAM	8	62203	75	9.75	4.5	9.75	14.25	2.08
930350	GRE	8	116158	675	9.48	8.2	59.48	67.68	1.65
890574	JAC	9	234924.	35	15.0	15.0	138.6	153.6	2.10
900414	SCI	9	5280.	52	16.74	2.1	148.74	150.84	4.90
910374	ROS	9	88383	35		4.1	64	68.1	1.7
910256	JAC	9	94465	32		6.1	104	110.1	1.73
920940	SCI	9	70143	52	26.8	4.7	158.8	163.5	2.1

Table 3.1 - Locations of PED in Ohio (Concluded)

YrProj	County	ODOT District	Quantity (lf)	Route	Mileage	Project Length (miles)	Start Mile	End Mile	Unit Price ($/lf)
890642	MEG	10	28988.	7	6.15	2.6	-	-	1.66
900837	MEG	10	400.	7	0.00	6.1	58	64.1	
900642	WAS	10	8812.	7	14.05	6.2	108.05	114.25	3.34
900798	WAS	10	59979.	50	0.00	3.5	198	201.5	2.02
901012	WAS	10	500.	50	7.19	3.6	205.19	208.79	5.00
900468	MEG	10	700.	7	10.58	3.3	68.58	71.88	
900078	WAS	10	2486				0	0	
900078	WAS	10	197991	77	6.59	11.2	6.59	17.79	1.86
920284	WAS	10	63991	50	3.55	5	201.55	206.55	1.68
920084	ATH	10	114971	50	34.28	6.6	199.28	205.88	1.78
					7	1.38	-	-	
					32	33.95	-	-	
					50	35.9	215	250.9	
890768	COL	11	47968.	11	21.08	2.5	-	-	2.42
900398	COL	11	57260	7	0.37	3.2	140.37	143.57	3.0
900656	BEL	11	71276	70	16.69	3.7	214.69	218.39	2.18
910741	BEL	11	53849	70	20.37	3.4	218.37	221.77	2.84
910111	HAS	11	104854	22		10.1	0	10.1	2.2
910304	CUY	12	48296	90	0	2.8	156	158.8	2.5
920713	CUY	12	5000	237	5.59	1.2	5.59	6.79	1.0
930794	CUY	12	1937	90	18.63	5.1	174.63	179.73	1.0
930687	CUY	12	68548	271	0	3.7	228	231.7	2.4

3.4 Survey of ODOT Design and Construction Personnel

ODOT construction and design personnel from the 12 districts were contacted by telephone in order to question them about their experiences with PED. Maintenance personnel were also contacted in a few districts. The engineers contacted were questioned about PED installation problems, PED performance and design specifications used in their district. A summary of their responses is provided in Table 3.2. The major installation problem encountered was in compacting the backfill. It is difficult to compact the materials beside and above the PED without damaging the PED. The pavement may settle and crack without proper compaction. Another problem occurs where the PED is placed in existing longitudinal underdrain backfill. The sides of the trench collapse in the granular backfill. A common comment was that the PED can be installed very quickly with relative ease without significant problems. The PED installation can be speeded up if the excavated material is used for backfill. According to comments by the construction personnel, ODOT specifications requiring that the backfill be placed and compacted in 3 or more lifts (See Figure 3.1) are not followed.

Most districts have not excavated PED to inspect them for their condition. Two districts reported problems with pavement settlement and cracking. Twisting and J'ing of PED were mentioned as well as sedimentation and standing water. District 10 reported excavating a large section of PED for a road widening project and discovering that it was 70% blocked with silt. The amount of blockage was greater near the outlet. The outlet was clean. The problem may be with the fabric and the fines at the site. Pavement problems can occur if PED are silted. The silt retains water so the soil surrounding the PED also remains moist.

Most of the design engineers questioned stated that they were still using PED on rehabilitation projects according to ODOT specifications. Three districts stated that they do not allow the contractor to substitute pipe underdrains for PED while one district stated that they quit using PED. Some districts do not have rehabilitation jobs very often so the engineers are not familiar with PED design and construction specifications.

Table 3.2 - Survey of ODOT Design and Construction Personnel

ODOT District	PED Installation	PED Performance	Design /Specifications
1	Not many problems with installation. Difficult to compact backfill over PED without damaging PED.	Can see a depression over PED because of backfill. Some PED have sedimentation and standing water. Buckling of PED.	Used excav. material for backfill. No longer use PED for the past two years. For new construction use PU for both flexible and rigid..
2	Difficult to compact backfill beside PED.	Seems like there were some cracking and settlement problems. Some twisting and J'ing.	Use excavated material and 90% compaction. Compact bottom lift and then on top of PED.
3	At construction school.		PED required as per plan from 1997.
4	Did not have any problems.	None mentioned.	PED not used very much but allow for PED or PU.
5	Had problems initially but not now.	Will get back	Used excavated material, two or more lifts. Will use ODOT specs. in future.
6	Left message		Have not designed recently but will check with consultants.
7	No problems except difficulty with compacting backfill.	Have not discovered any problems.	Used on rehabilitation jobs but not recently. PED is specified with PU as option so PU usually installed.
8	Difficult to compact backfill over PED. PED trench collapsed in granular backfill.	Pavement shoulder has some cracking and settlement problems.	Have used underdrains recently. Specify PED only.
9	Not used for a long time. Does not recall problems. PED trench collapsed in one granular backfill.	Have not discovered any problems.	PED are required on rehabilitation projects. Use PU for new construction.
10	No big problems. Can be installed very quickly, especially if excavated material is used.	I-77 in Noble Cnty ~70% silted. Problem with fines??? Less problems if PU becomes blocked.	Mostly used PU for rehabilitation. Still specify PED. Use PU for new construction.
11	Will call		Specify PED or PU or just PED. Std. Drawing 1.2M (10-21-97)
12	Will e-mail responses.		Left message

3.5 Survey of Current DOT Experience

A two-page survey was designed to investigate current practices for PED use by other state departments of transportation. The survey included questions about PED construction (Section A), performance of PED (Section B) and performance of pavements with PED (Section C). The survey was reviewed and critiqued by ODOT engineers. The survey was then sent to departments of transportation in all states. An example of the survey is shown in Appendix A. Department of Transportation (DOT) engineers from 30 states responded to the survey. The responses to the survey are summarized in Appendix A in Tables A-1 through A-12. A summary and discussion of the responses follows for each survey question, with the number of responses in parentheses.

3.5.1 Section A - Prefabricated Edge Drain Construction

The questions on PED construction were developed to investigate where the state departments of transportation (DOT) have used PED and how the PED are installed. According to the Questions A.1 and A.2 in Table 3.3, PED are used primarily on interstate construction projects and they have received considerable use on new and rehabilitation projects. Some states use both PED under the pavement edge joints as well as longitudinal pipe underdrains (PU). Some states allow the contractor to use PU under the edge joints instead of PED which usually requires added expense to the contractor for the larger quantities of granular backfill that are required for pipe underdrains. All states that use PED have specifications for construction and payment for PED (See Question A.3). Some states changed their specifications to improve the performance of PED and reported information on previous (P) and current (C) specifications, as requested in the survey.

There are several manufacturers of PED. PED from at least nine different manufacturers have been installed in the states that responded to the survey (See Question A.4). Several states allow for the substitution of PED with longitudinal underdrain pipes. The PED have a needle punched nonwoven filter fabric surrounding the core. The cores vary between the manufacturers depending on the size and shape of the cusps. PED with cone shaped cusps are constructed with the cusps all facing towards one side. This side is more open, has more drainage a rea, but is weaker, open-face (weak) side. Most states specify that the weak side

Table 3.3 - Prefabricated Edge Drain Construction

A.1. PED use on DOT interstate projects:
Always **(1)** Seldom **(11)**
Often **(7)** Never **(11)** **Total (30)**

PED use on other projects:
Always **(0)** Seldom **(13)**
Often **(3)** Never **(14)** **Total (30)**

A.2. PED use:
New construction:
PED and longitudinal pipe drains **(6)**
PED only **(4)** or PU **(3)** **Total (13)**

Rehabilitation projects:
PED or longitudinal pipe or aggregate drains **(15)**
PED in addition to existing longitudinal pipe or aggregate drains **(1)** **Total (16)**

A.3. PED specifications (List current and previous requirements if different, when and why change made):
Sample specifications are attached **(11)**
Specifications summarized below (See questions 4 through 9 below.) **(15)**

A.4. Types of PED accepted: Brand names (Manufactures)
AdvanEdge (6) Akwadrain (3) Hitek 20 (1) Hydraway (8)
LD-30 (1) Miradrain (1) PDS 30 (3) Prodrain (1)
Stripdrain 100 (5)
Pipe underdrains accepted alternative **(5)**

A.5. Orientation of PED (Circle P for previous or C for current specification, if applicable):

Open-face (weak) side towards pavement/base	P **(5)**	C **(4)**
Open-face (weak) side away from pavement/base	P **(0)**	C **(2)**
Manufacturer's recommendation	P **(2)**	C **(2)**

A.6. Placement of PED(Circle P for previous or C for current specification, if applicable)

Adjacent to pavement/base with backfill on outside of PED	P **(4)**	C **(11)**
Against outside of trench with backfill between PED and pavement/base	P **(0)**	C **(2)**

A.7. Type of backfill (Circle P for previous or C for current specification, if applicable):

Selected granular backfill as specified	P **(1)**	C **(9)**
Excavated material, if granular	P **(1)**	C **(1)**
Excavated material	P **(0)**	C **(9)**

A.8. Compaction specifications (Circle P for previous or C for current specification, if applicable):
Number of lifts for natural material 1 (1), 2 (3), 3 (2)
Number of lifts for granular material 1 (3), 2 (4), 3 (2)
Degree of compaction 5000 lbs. force (2), 90% T-99 (1), specified by engineer (2)

A.9. Drainage outlets (Circle P for previous or C for current specification, if applicable):
Spacing of outlet pipes (in feet) 200 (1), 250 (5), 300 (3), 400 (1), 500 (4)

Outlet to:		
Existing longitudinal pipe underdrain	P **(0)**	C **(1)**
Precast concrete outlet	P **(2)**	C **(6)**
Catch basin or manhole	P **(0)**	C **(4)**

should face towards the pavement or base materials to provide better drainage for the pavement drainage layers (See Question A.5). There are at least two products that vary from the cone shaped cusps. Hydraway by Monsanto has posts with a grids on one side of the core. AdvanEdge by ADS has a corrugated core with slots making it much stronger and stiffer than PED with cuspated cores but with less drainage area on the sides.

The PED are placed in a 4-inch wide trench. Most states now place the PED adjacent to the pavement and base materials with the backfill on the outside of the PED (See Question A.6). A few states place the PED adjacent to the outside of the trench with the backfill between the pavement and base materials. Many states specify a select granular material for the backfill while other states allow the contractor to use the excavated material even if it is not a granular material (See Question A.7). A layer of backfill is placed beside the PED as it is placed in the trench to hold the PED in place. The backfill is then placed and compacted using one or more lifts (See Question A.8). Specifications for the degree of compaction are not very detailed.

Outlet pipes are connected to the PED at specified spacings to remove the water from the PED. The spacing can vary from a minimum of 200 feet to a maximum of 800 feet. The outlet spacing should depend on the pavement grade. Most states, however, specify an outlet spacing of from 250 to 500 feet (See Question A.9). The outlet pipes are connected to precast concrete outlets or to catch basins or manholes. Ohio specifies that the outlet pipes can be connected to existing longitudinal pipe underdrains (PU). Specifications for the outlet pipes state the requirements for placing and backfilling for the outlet pipes and for connecting the outlet pipes to the PED and the drainage outlets.

3.5.2 Section B - Field Performance of PED

Several of the responding states performed field evaluation studies of PED as described in Table 3.4. PED have been inspected during installation and sections of PED have been excavated for visual inspections during construction. PED were investigated after construction by pavement condition assessments, excavation and visual inspections and by using video borescopes (See Question B.1). The hydraulic capacity of the cores is reduced when PED structural problems occur. The problems generally occur when the PED or the

Table 3.4 - Field Performance of PED

B.1. Method of evaluation:

Construction inspection **(11)** — Excavation and visual inspection of PED (9)

Pavement condition assessment (7) — Video borescope (9)

B.2. PED structural problems: (F = failure PED to drain; M = major problems, drainage significantly reduced; M = minor problems, moderate drainage reduction; I = Insignificant drainage reduction)

	F	M	M	I
Twisting	(0)	(2)	(1)	(3)
J'ing	(1)	(2)	(4)	(2)
Core Compression	(0)	(3)	(4)	(1)
Fabric penetration of core	(1)	(2)	(4)	(5)

No problems observed (4)

B.3. PED material problems: (F = failure of PED to drain; M = major problems, drainage significantly reduced; M = minor problems, moderate drainage reduction; I = Insignificant, slight drainage reduction)

	F	M	M	I
Fabric tearing	(0)	(0)	(2)	(3)
Splicing	(0)	(0)	(2)	(3)
Outlet connection	(0)	(0)	(4)	(2)
Outlet conduit	(1)	(1)	(3)	(3)

No problems observed (6)

B.4. PED drainage problems: (F = failure of PED to drain; M = major problems, drainage significantly reduced; M = minor problems, moderate drainage reduction; I = Insignificant, slight drainage reduction)

	F	M	M	I
Fabric caking	(2)	(3)	(2)	(1)
Fabric clogging	(2)	(3)	(1)	(2)
Edge drain siltation	(2)	(3)	(5)	(2)
Outlet blockage	(0)	(6)	(4)	(2)

No problems observed (3)

B.5. Pavement problems associated with PED: (F = failure of pavement; M = major pavement damage; M = minor pavement damage; I = Insignificant pavement damage)

	F	M	M	I
Edge joint vertical movement	(0)	(2)	(3)	(1)
Piping of fines from edge joints	(0)	(0)	(2)	(3)
Edge joint opening	(0)	(1)	(3)	(1)
Pavement cracking	(0)	(2)	(1)	(2)

No problems observed (7)

or backfill is placed. Major problems occurred with twisting, J'ing, core compression and fabric penetration of the core, but most problems were considered minor or insignificant (See Question B.2). Some states have experienced no structural problems with PED. PED material problems caused by fabric tearing, splicing, outlet connections, and outlet conduits are minor or insignificant (See Question B.3). Failures and major problems were reported because of fabric caking, fabric clogging, edge drain siltation and outlet blockage (See Questions B.4). These problems cause impeded drainage from the pavement bases or standing water in the PED. Pavement problems associated with PED are identified by vertical or horizontal movements of the pavement joints, piping of fines from the joints or pavement cracking. Pavement problems are reportedly minor or insignificant (See Question B.5). Several states reported having no pavement problems associated with PED.

3.5.3 Section C - Pavement Performance With PED

Information from investigations on the performance of pavements with PED is shown in Table 3.5. Pavement performance studies comparing pavement performance data from pavements with and without PED are rare. Information from performance studies is difficult to evaluate since PED are frequently installed on rehabilitation projects that include joint repairs, asphalt overlays and other improvements. The responses regarding pavement performance indicate mixed results with some improvement and some worsening of pavement performance (See Question C.1). A few respondents indicated that bad pavement performance was caused by specific construction problems.

Space was provided on the survey for recommendations from the results of pavement performance studies. Many of the respondents provided very useful general comments on their DOT experience with PED (See Question C.2). From eleven states providing comments, four of the states have discontinued use of PED completely or do not recommend them, one state discontinued using particular products and fabric materials, and two of the states mentioned limited or reduced use. Three of the states that stopped using PED are using longitudinal pipe underdrains (PU) instead and some of the other states have only used PU. Conclusions and recommendations from this investigation are provided in Chapter 5.

Table 3.5 - Pavement Performance With PED

C.1. Pavement performance with PED

Sigificantly better than those without PED (2)
Slightly better (4)
About the same (2)
Worse (2)
Some are better, some are worse (1)
No studies have been done (5)

C.2. Recommendations from pavement performance studies

IL	Discontinue use of Monsanto and Contech due to structural problems. Discontinue use of heat-bonded, non-woven, polypropylene due to flow problems. Use sand backfill instead of in situ for backfill to help prevent clogging of geotextile. Evaluate conditions
IN	Indiana has stopped using PED (since Sep. 95). Instead of PED INDOT is using 4" group " K" pipe for drainage for rehabilitation projects.
IA	PED confined to granular base situations. Bedrock and Loess soils. We have had complete failure (rapid) due to fabric clogging from cement (deteriorated concrete) and from clay in high flow situations
KS	Attention to the details of outlet pipe must be made. Insure pipes are constructed to grade and plain and that outlets are above flow line of ditch.
KY	Lab, Flow/compression test indicates that significant reductions in flow can occur in open type panel drains (post or cuspated) when J'ing or fabric in tension occurs. Report KTC - 96 - 77 " Evaluation of edge drains on I64 Fayette, Scott, and Wood Counties.
ME	Used on one project only and no longer use.
MI	PED are performing well. Several specific recommendations on design and construction for PED in report.
NY	Some drains not working, no obvious cause may be inappropriate fabric for soil type. See attached policy.
OK	Stopped using unless open graded drainage layer is used in pavement. Provide clean out ports. Currently ODOT does not recommend use. Now using Trench/No. 57 Stone/Fabric Wrap/ 4" diameter slotted HDPE pipe at edge of driving lane. ADS drain performing well.
SC	Greatly reduced usage of PED in general due to concern about future maintenance. PED are only used where severe drainage problems are noted during rehabilitation.
WY	Stopped using because of concerns with PED performance. Use perforated pipe.

CHAPTER 4

FIELD INVESTIGATION OF PED IN OHIO

Field investigations of highway pavements with PED were conducted at six locations throughout Ohio. One ODOT district declined to participate in the field testing. At another location, the contractor had installed a 4-inch pipe underdrain instead of PED, an option that was permitted in the construction specifications. A short length of PED was exposed at each site by excavating through the pavement shoulder. The PED were then inspected using a video borescope. The video inspections were recorded using VCR equipment. A length of PED about 18 inches long was placed in an apparatus for testing the permittivity of the fabric on the side of the PED that was adjacent to the pavement. This chapter describes the visual inspections and permittivity test results from the field investigations.

4.1 Test Pit Construction

Test pits were constructed using ODOT district maintenance personnel and equipment. The asphalt berm was cut using a saw or a jackhammer before excavating the test pits. Test pits were excavated using a backhoe, being careful not to damage the PED. The excavated materials included the asphalt, granular subbase, PED trench backfill and subgrade soil. The size of the excavations varied from 3 to 6 feet long, direction parallel to PED, by 3 to 10 feet wide. The excavations were continued to the bottom of the PED. A minimum of 3 feet of edge drain was exposed. An 18-inch long section of the PED was removed for the video inspections and permittivity tests. The PED was replaced with a new section of PED. ODOT district maintenance personnel backfilled the test pits and replaced the asphalt pavement.

4.2 Procedures for Visual Inspections

The purpose of the visual inspections was to evaluate the condition of the PED. Sections of PED exposed by excavation of tests pits were examined for the presence of water, amount of material deposited on the fabric material, amount of silt in the PED, condition of the fabric material and the condition of the PED cores. Other information noted was the placement of the PED, backfill types and outlet condition. An Olympus video borescope with 25 feet of fiber optic cable was used for video inspections. The borescope was advanced in both directions from the excavations at several levels in the PED. The borescope camera was advanced the full cable length wherever possible except where obstructions were encountered or where sediments smeared the camera lens. The video borescope was used in the outlet pipes also. The video inspections were recorded using a VCR recording system. The video borescope equipment is owned by the ODOT and was operated by ODOT central office hydraulic engineers. The visual inspections are discussed later in this chapter.

4.3 Procedures for Permittivity Tests

An apparatus was designed and constructed for field testing of the permittivity of the PED fabric material. As originally proposed, researchers from The University of Toledo were to conduct in situ flow tests at the test sections to measure PED permittivity. The testing required drilling small-diameter holes in the pavement and inducing flow in the pavement base material, monitoring the flow conditions and measuring discharge from the PED. After careful consideration, it was concluded that a different type of field test would provide more accurate information on the flow properties of the PED fabric material. The major concern was that it would not be possible to make accurate measurements of the height of the water and the discharge of water. The computed results would not be satisfactory and may be subject to interpretation. Therefore, it was proposed to construct a permittivity apparatus that could be used to test short sections of PED in the field. Plans for the apparatus design and test procedures were submitted to and approved by ODOT engineers.

The permittivity apparatus consists of a box constructed with 1/2-inch thick PVC. Details of the permittivity apparatus are shown in Figure 4.1. The apparatus was designed to accept PED of varying dimensions. A fixed dividing wall with an opening cut out in the center was cemented in the box to form two flow compartments. Two smaller compartments were constructed in one end of the apparatus with overflow controls in the walls going to the flow compartments. The PED was placed against the fixed wall and a solid sheet of PVC was placed against the edge drain. A small-diameter tire inner tube was placed adjacent to the moveable sheet and pressurized to apply lateral pressure on the PED. Water was added to the box until the water level was above the PED. Flow was induced through the side of PED by adjusting the water levels in the flow compartments using the overflow controls and the discharge was measured. For the testing, five sets of measurements were taken at up to four different head differences beginning with small head differences. The head difference was increased successively until it was no longer possible to maintain a larger head difference. This reduced the amount of material washed out from the PED during the initial tests. The permittivity is calculated using the following equation (from ASTM D 4491-89).

$$\psi = Q R_t / h A t \tag{4.1}$$

Where

ψ = permittivity (S^{-1});
Q = quantity of flow (L^3);
H = head of water on the specimen, (L);
A = cross-sectional area of the test area of the specimen, L^2 (13.5 X 9.5 inches);
T = time for flow Q, (S);
R_t = temperature correction factor (R_t = 1.0 used).

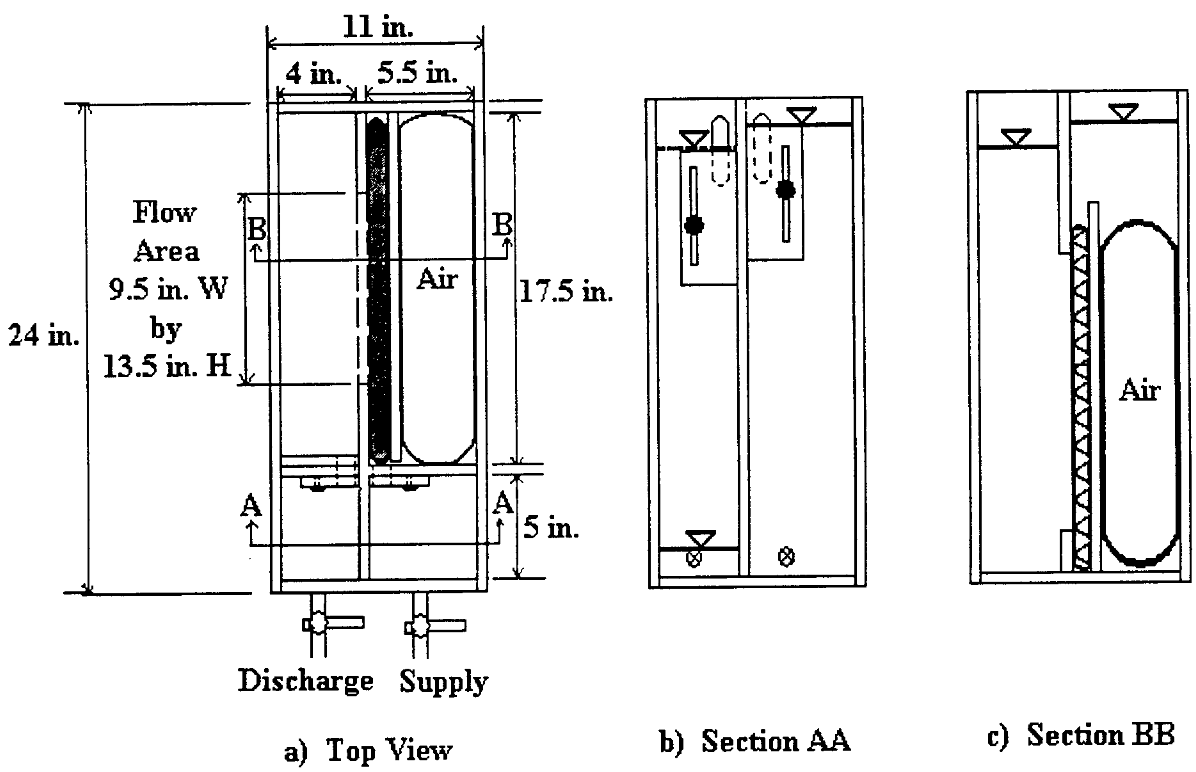


Figure 4.1 - Details of Permittivity Apparatus

4.4 Hancock County

4.41 Visual Inspection

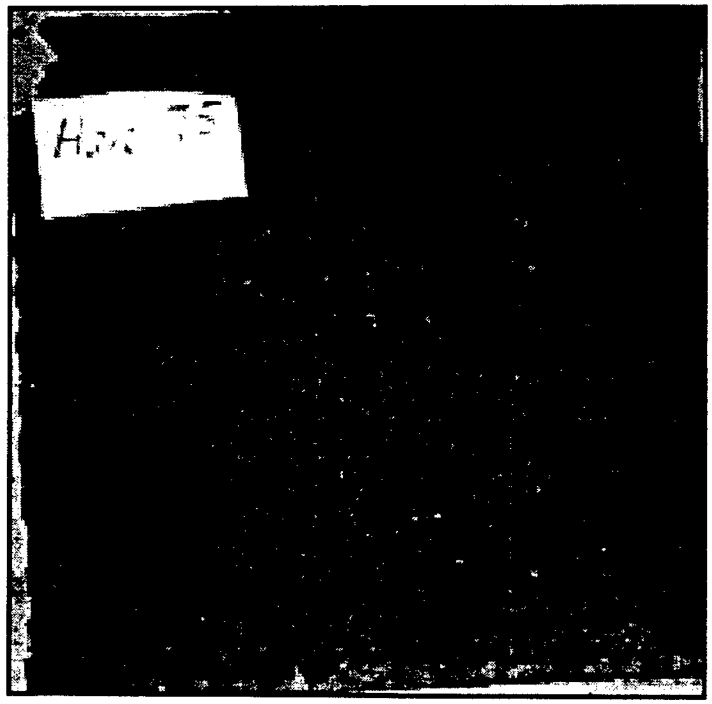
This project was completed in 1995 so it is the newest PED that was investigated for this research. Details of the visual and video borescope inspections are provided in Table 4.1. The PED was installed according to current ODOT specifications. The PED type was Prodrain. The PED appeared to be very clean except near the bottom where there was 1 1/2 inches of mud both inside and outside of the PED. The soil can be seen in the bottom row of cusps on the right hand side of the picture in Figure 4.2 b). There was some water in the outlet drain. The problem with the water may have been caused by an improper connection of the PED to the outlet drain. There was no damage to the core but there was some compression of the fabric into the core.

4.42 Video Borescope Inspection

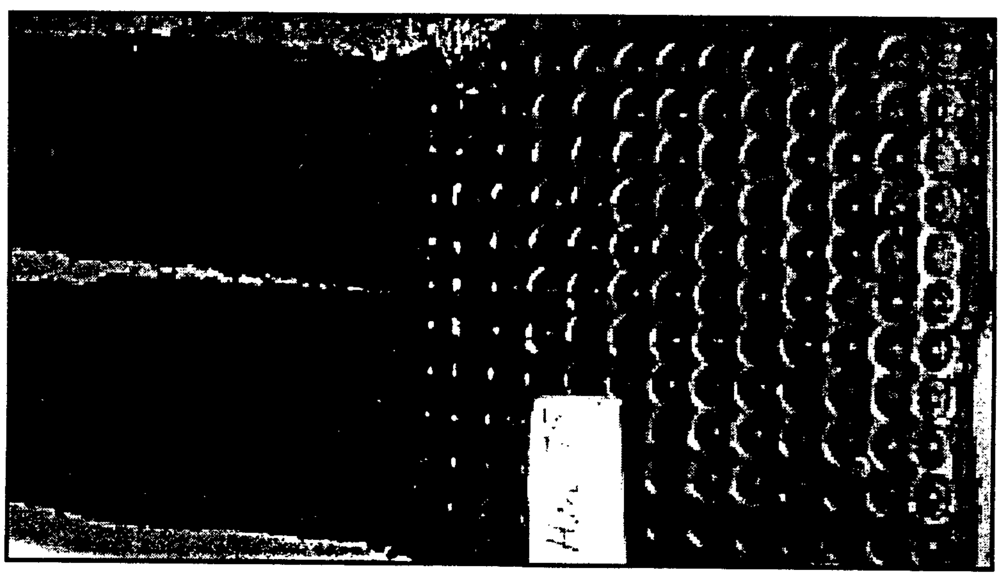
It was possible to advance the video borescope probe the full 25 feet without much difficulty because of the very good condition of the PED. The exceptions were the runs near the bottom of the PED where the outlet was encountered for one run and mud was encountered on the other run. From the video borescope pictures in Figure 4.3, it does not appear that there is any compression of the cores but it is obvious that the fabric has been compressed into the core.

Table 4.1 - Field Investigation of PED, Hancock County

Test Date: August 12, 1997	**Project:** HAN-75-3.31, Project 842(94)
Test Location: Hancock County, I-75, Southbound Lane, Station SLM 151.8	
Year of Construction: 1995	**Pavement:** Normal slope
Outlet: 800 feet downslope or south from PED	
Excavation Materials: 6 inch asphalt; 6 inch 304 subbase; brown silty clay.	
Location of PED: On outside of trench	**Backfill material:** No. 8's
Type of PED: Prodrain	
PED Description: 18 inches high by 1 inch wide, black fabric	
PED Placement: Cusps facing toward pavement	
Drainage Condition: No water outside or inside PED	
Presence of Fines: 4 inches of mud outside PED; bottom 1 1/2 inch inside PED	
Condition of PED: PED is very clean; no damage to core;	
some compression of fabric into core.	
Condition of Outlet: Some water in outlet; outlet not connected to PED	
Video Borescope Probe:	
Run Number: 1	**Probe Length:** 19 feet (encountered outlet)
Height From Bottom: 1 cusp or ± 11/2 inch	**Probe Direction:** north towards outlet
Run Number: 2	**Probe Length:** 25 feet
Height From Bottom: 4 cusp or ± 6 inches	**Probe Direction:** north towards outlet
Run Number: 3	**Probe Length:** 25 feet
Height From Bottom: 14 inches	**Probe Direction:** north towards outlet
Run Number: 4	**Probe Length:** 20 feet (mud on lens)
Height From Bottom: 2 cusps or ± 2 inches	**Probe Direction:** south
Run Number: 5	**Probe Length:** 25 feet
Height From Bottom: 6 cusps or ± 7 inches	**Probe Direction:** south

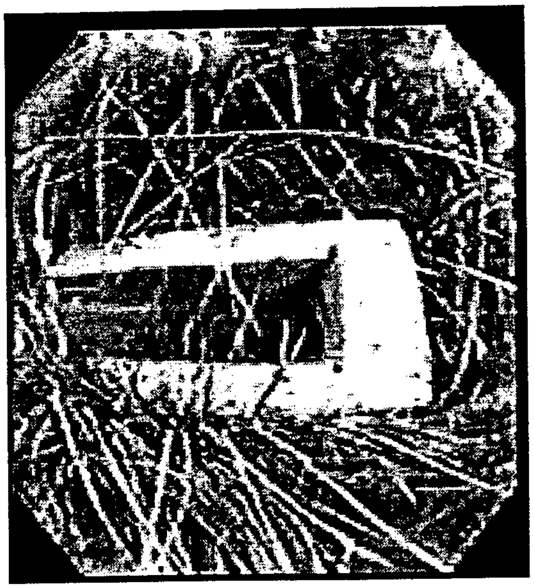


a) PED Sample from Excavation



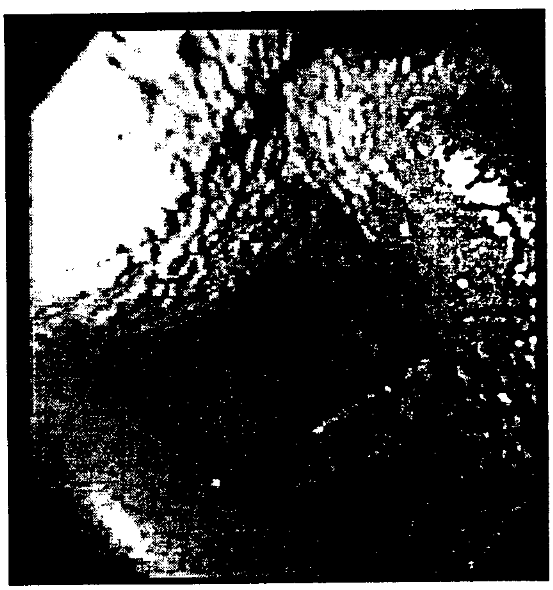
b) PED with Core Exposed

Figure 4.2 - PED Pictures, Hancock County



HAN - Run 0, Outlet Structure

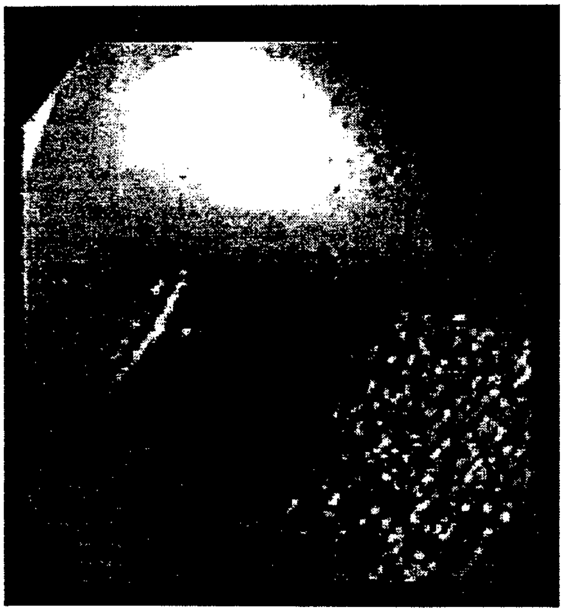
HAN - Run 1, Entering PED



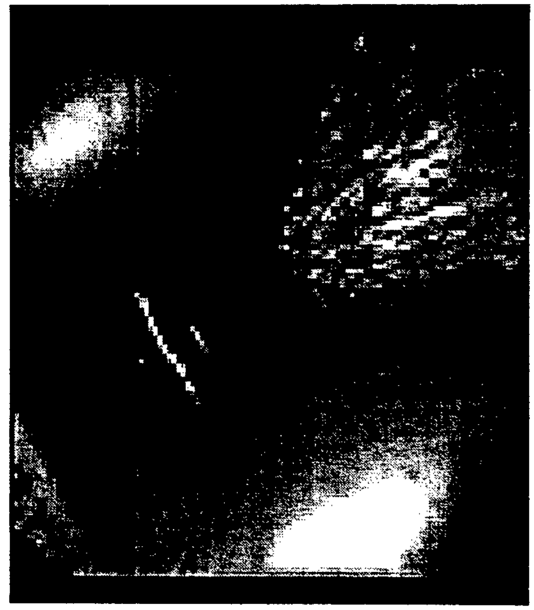
HAN - Run 1, PED Compression

HAN - Run 2, PED Compression

Figure 4.3 - Video Borescope Pictures, Hancock County

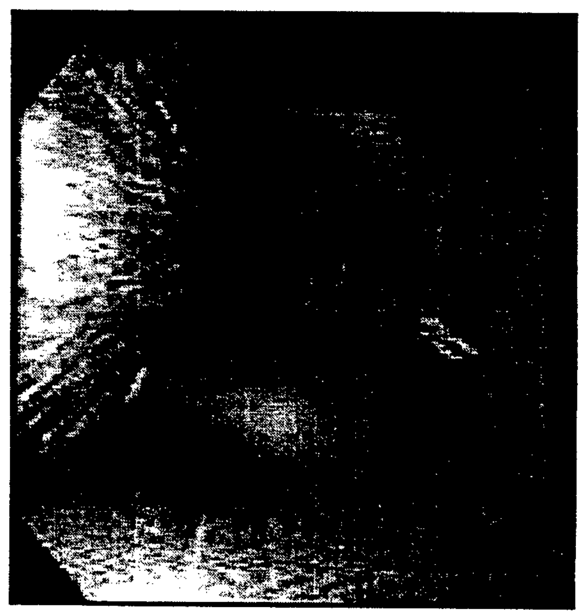


HAN - Run 2, PED



HAN - Run 3, Entering PED

HAN - Run 3, PED Compression



HAN - Run 3, PED Compression

Figure 4.3 - Video Borescope Pictures, Hancock County (Concluded)

4.43 Permittivity Test

Permittivity testing was conducted at the test site using the test apparatus as described in Section 4.2. The results of the testing are shown in Figure 4.4 and Table 4.2. The sample of PED used for the testing was very clean. Therefore it was very difficult to maintain a head difference of 3 mm. Consequently, there is considerable data scatter in the plot with no consistent trend of increasing or decreasing permittivity with change of head difference. A test apparatus with better controls over the hydraulic conditions would be required for the permittivity testing. The results of this test are compared with tests on PED samples obtained from manufacturers in Chapter 5.

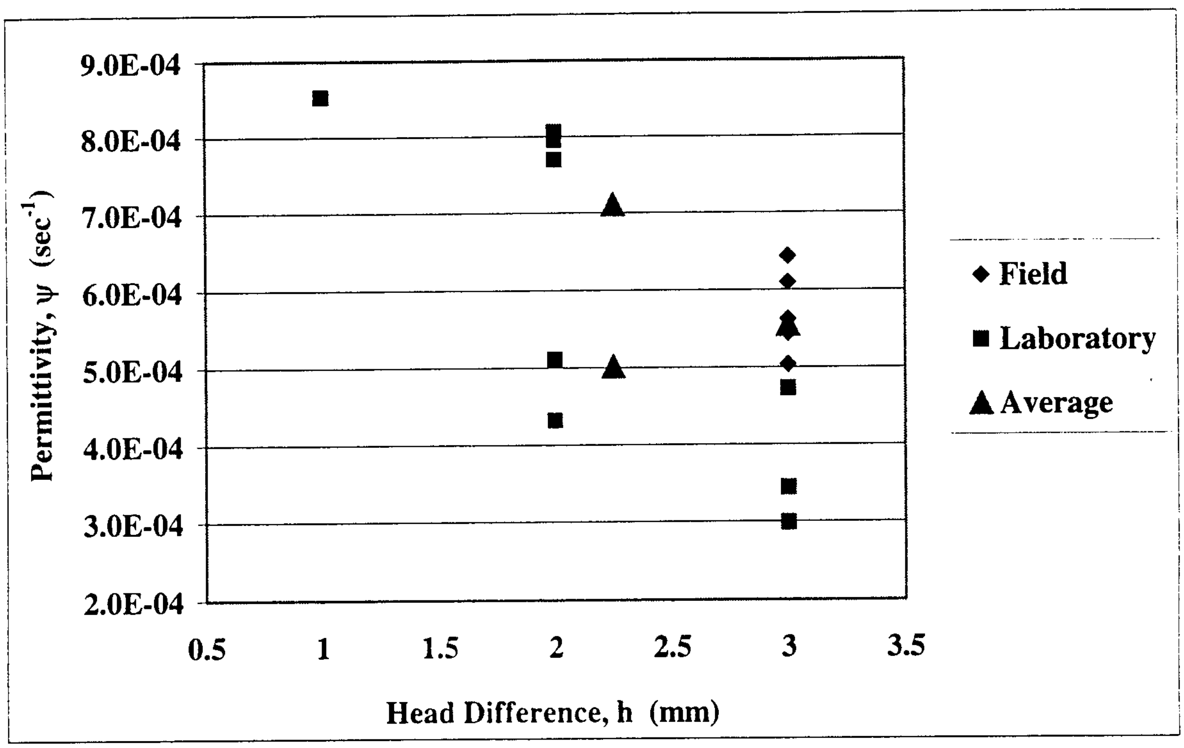


Figure 4.4 - Permittivity Test, Hancock County

Table 4.2 - Permittivity Calculations, Hancock County

Permittivity of Prefabricated Edge Drains (After ASTM D4491)
Location: Hancock County, I-75 Southbound
Project: HAN-75-3.31, Project 842(94)
Manufacturer/Type of Edge Drain: ProDrain
Notes: Edge drain is very clean except bottom 1 1/2" has some fines. New design with # 8 stone backfilled behind drain. Fine grained subgrade soil. Some standing water in outlet. Apparently outlet not connected to edge drain as specified. Date August 12, 1997

P = Q R / h A t		A =	83545 mm² (245 mm X 341mm)			h = h_2 - h_1		
Trial	**Q (mm^3)**	**t (sec)**	**R_t**	**h_1 (cm)**	**h_2 (cm)**	**Q R_t / A t (mm/sec)**	**h (mm)**	**ψ (sec^{-1})**
1	1000	6.2	1.0	7.8	8.1	0.001931	3	6.4E-04
2	810	5.3	1.0	7.8	8.1	0.001829	3	6.1E-04
3	900	6.6	1.0	7.8	8.1	0.001632	3	5.4E-04
4	1010	8.0	1.0	7.8	8.1	0.001511	3	5.0E-04
5	930	6.6	1.0	7.8	8.1	0.001687	3	5.6E-04
Ave.						**1.66E-03**	**3.0**	**5.5E-04**
1	800	11.1	1	5.7	5.9	0.000863	2	4.3E-04
2	700	8.2	1	5.6	5.8	0.001022	2	5.1E-04
3	720	10.1	1	5.7	5.8	0.000853	1	8.5E-04
4	870	10.1	1	5.4	5.7	0.001031	3	3.4E-04
5	830	11.1	1	5.6	5.9	0.000895	3	3.0E-04
Ave.						**9.50E-04**	**2.3**	**5.0E-04**
1	950	7.1	1	5.7	5.9	0.001602	2	8.0E-04
2	810	6.1	1	5.7	5.9	0.001589	2	7.9E-04
3	700	5.2	1	5.7	5.9	0.001611	2	8.1E-04
4	900	7.6	1	5.7	6	0.001417	3	4.7E-04
5	810	6.3	1	5.6	5.8	0.001539	2	7.7E-04
Ave.						**1.54E-03**	**2.3**	**7.1E-04**
					Average	**1.09E-03**	**2.31**	**5.9E-04**

4.5 Ottawa County

4.51 Visual Inspection

Testing was conducted at two locations on this project. Details on the visual and video borescope inspections are provided in Tables 4.3 and 4.4 for Test No. 1 and 2, respectively. The PED was installed according to previous ODOT specifications. Monsanto Hydraway was the type of PED used. The PED was not clean. There was about 7 inches of mud inside and outside of the PED (See Figure 4.5). Water flowed from the PED and filled the trench for Test No. 2. There was J'ing in the bottom of the PED and some compression near the top of the PED. The fabric was compressed into the core in the middle six inches of the PED.

4.52 Video Borescope Inspection

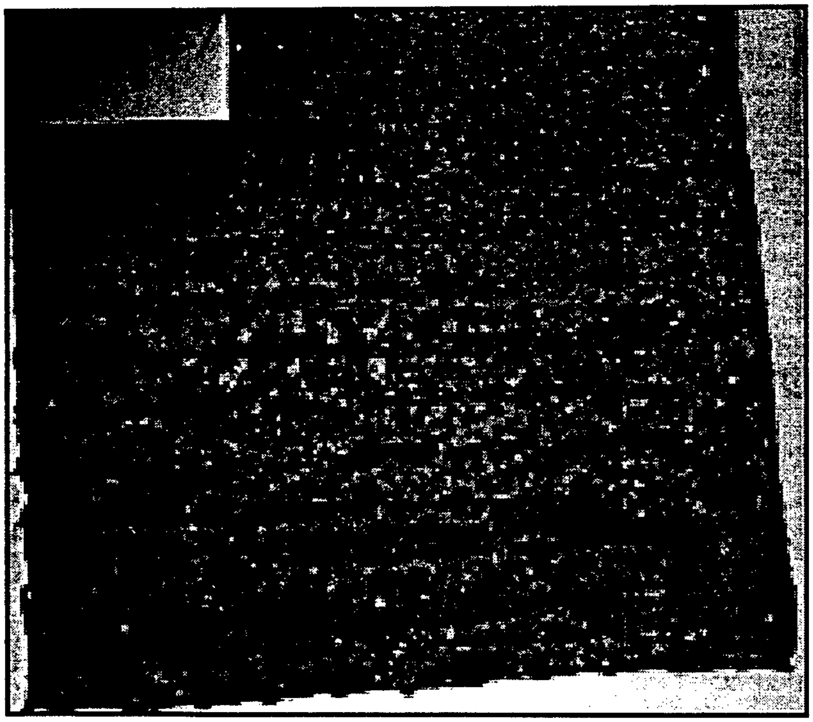
It was not possible to advance the video borescope probe very far either because the outlet was encountered or the PED was crushed. The damage to the PED can be seen in the video borescope pictures in Figure 4.6. The PED appears to be near collapse in many of the pictures. The cusps are deformed and the fabric is compressed into the core. There are some soft sediments in the core on the inside of the fabric and on the posts. The outlet is in very good condition with a small amount of water flowing into it.

Table 4.3 - Field Investigation of PED, Ottawa County (Test No. 1)

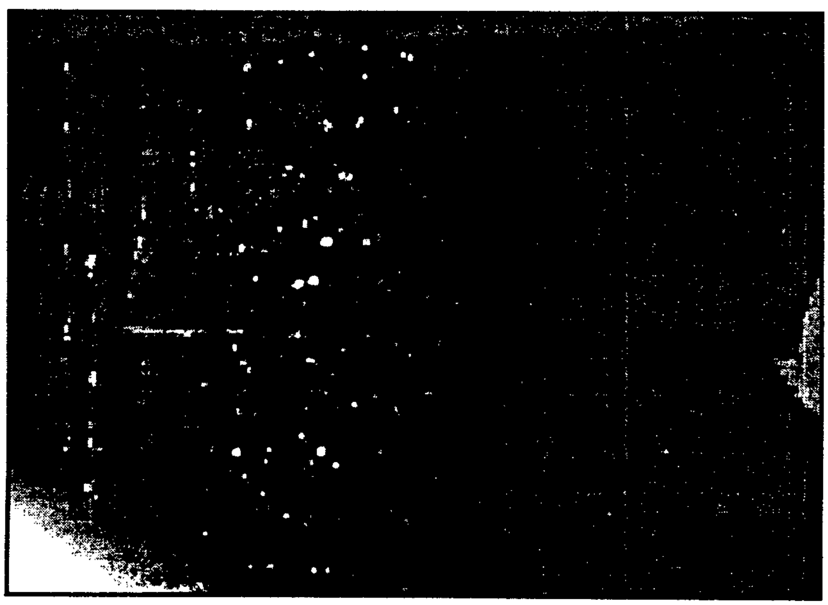
Test Date: August 13, 1997	**Project:** OTT-2-23.4, Project 430(91)
Test Location: Ottawa County, US 20, Westbound Lane, Station SLM 23.91	
Year of Construction: 1992	**Pavement:** Normal slope, shoulder settled
Outlet: 3 feet downslope or west from PED excavation	
Excavation Materials: 9 inch asphalt; 6 inch 304 subbase; brown silty clay.	
Location of PED: On inside of trench	**Backfill material:** Excavated material
Type of PED: Monsanto Hydraway	
PED Description: 18 inches high by 3/4 inch wide, black fabric	
PED Placement: Cusps facing toward shoulder	
Drainage Condition: No water outside PED; standing water inside PED	
Presence of Fines: ±7 inches of mud outside PED; bottom ±7 inches inside PED	
Condition of PED: PED partially crushed with cusps pushed up in the top and bottom 6 inches; middle 6 inches look good; compression of fabric into core.	
Condition of Outlet: Significant flow from outlet; outlet connection to PED is very good.	
Video Borescope Probe:	
Run Number: 1	**Probe Length:** 11/2 feet (encountered outlet)
Height From Bottom: 2 inches	**Probe Direction:** west towards outlet
Run Number: 2	**Probe Length:** 11/2 feet (encountered outlet)
Height From Bottom: 5 inches	**Probe Direction:** west towards outlet
Run Number: 3	**Probe Length:** 11/2 feet (encountered outlet)
Height From Bottom: 8 inches	**Probe Direction:** west towards outlet
Run Number: 4	**Probe Length:** 18 feet (PED crushed)
Height From Bottom: 14 inches	**Probe Direction:** east
Run Number: 5	**Probe Length:** 3 feet (PED crushed)
Height From Bottom: 17 inches	**Probe Direction:** east

Table 4.4 - Field Investigation of PED, Ottawa County (Test No. 2)

Test Date: August 13, 1997	**Project:** OTT-2-23.4, Project 430(91)
Test Location: Ottawa County, US 20, Westbound Lane, Station SLM 23.92	
Year of Construction: 1992	**Pavement:** Normal slope, shoulder settled
Outlet: 3 feet downslope or west from PED excavation	
Excavation Materials: 9 inch asphalt; 6 inch 304 subbase; brown silty clay.	
Location of PED: On inside of trench	**Backfill material:** Excavated material
Type of PED: Monsanto Hydraway	
PED Description: 18 inches high by 3/4 inch wide, black fabric	
PED Placement: Cusps facing toward shoulder	
Drainage Condition: No water outside PED; water flowed from PED and filled trench.	
Presence of Fines: ±7 inches of mud outside PED; bottom ±7 inches inside PED	
Condition of PED: PED partially crushed with cusps pushed up in the top and bottom 6 inches; middle 6 inches look good; compression of fabric into core.	
Condition of Outlet: Some flow from outlet.	
Video Borescope Probe:	
Run Number: 1	**Probe Length:** 3 feet (encountered outlet)
Height From Bottom: 8 inches	**Probe Direction:** west towards outlet
Run Number: 2	**Probe Length:** 1 foot (top crushed)
Height From Bottom: 16 inches	**Probe Direction:** west towards outlet
Run Number: 3	**Probe Length:** 1 foot (PED crushed)
Height From Bottom: 12 inches	**Probe Direction:** west towards outlet
Run Number: 4	**Probe Length:** 5 feet (mud on lens)
Height From Bottom: 4 inches	**Probe Direction:** east
Run Number: 5	**Probe Length:**8 feet (crushed, mud & water)
Height From Bottom: 7 inches	**Probe Direction:** east
Run Number: 6	**Probe Length:** crushed above seven inches
Height From Bottom:	**Probe Direction:** east



a) PED Sample from Excavation



b) PED with Core Exposed

Figure 4.5 - PED Pictures, Ottawa County

OTT(1) - Run 1, Entering PED

OTT(1) Run 1, EOR Near Outlet

OTT(1) - Run 2, Entering PED

OTT(1) - Run 2, EOR PED Collapse

Figure 4.6 - Video Borescope Pictures, Ottawa County

OTT(1) - Run 3, Entering PED

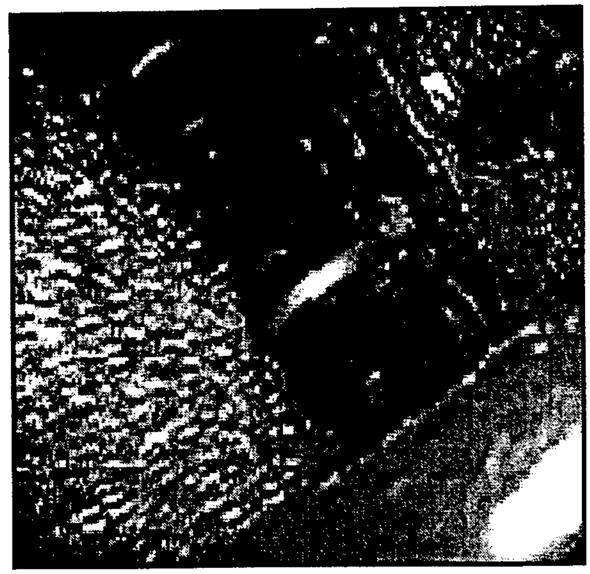
OTT(1) Run 3, PED Collapse

OTT(1) - Run 4, Entering PED

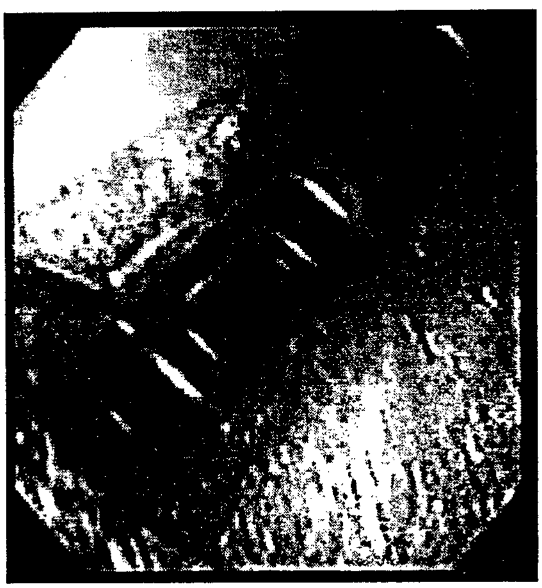
OTT(1) - Run 4, EOR PED Collapse

Figure 4.6 - Video Borescope Pictures, Ottawa County (Continued)

OTT(1) - Run 4, Entering PED



OTT(1) Run 4, PED Compression



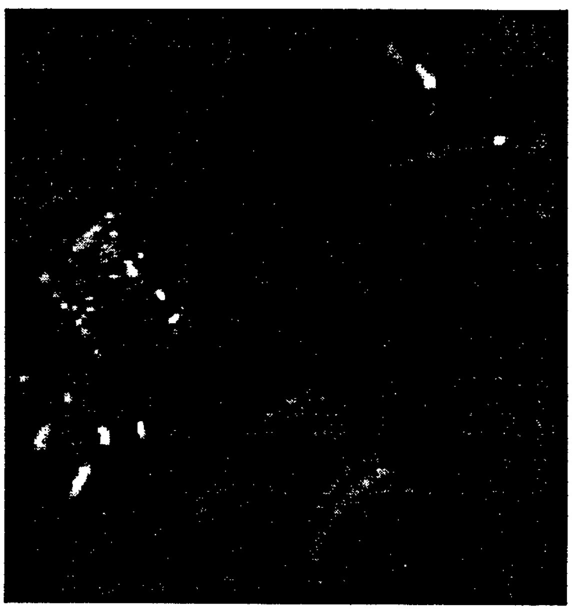
OTT(1) - Run 4, PED Compression

OTT(1) - Run 4, EOR PED Compression

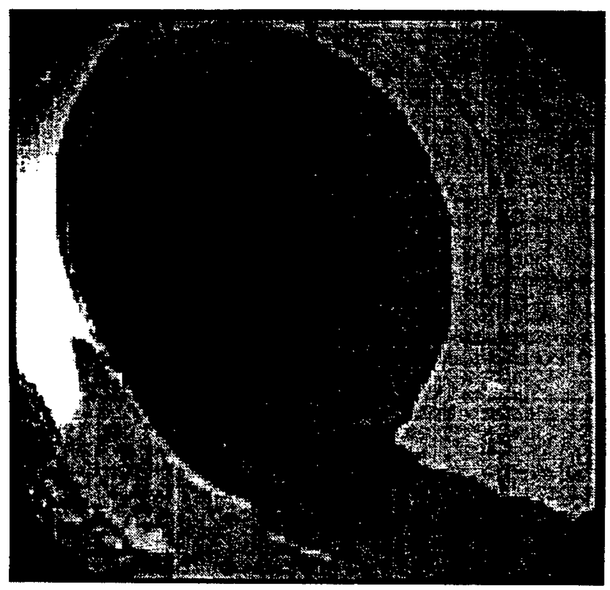
Figure 4.6 - Video Borescope Pictures, Ottawa County (Continued)

OTT(1) - Run 5, PED Compression

OTT(1) Run 5, PED Compression

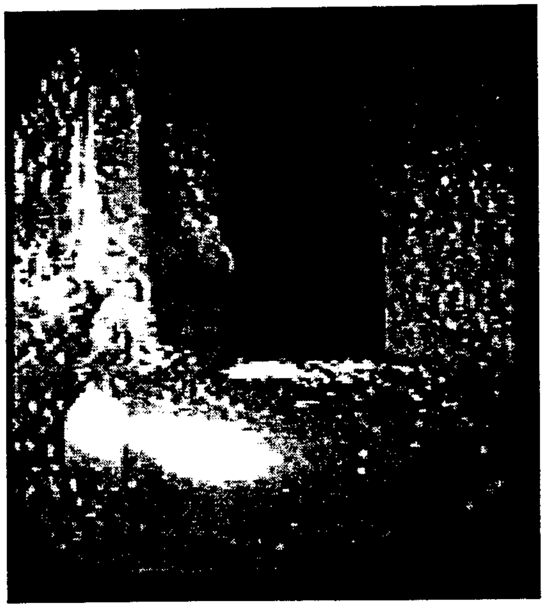


OTT(1) - Run 4, PED Outlet



OTT(1) - Run 4, PED Outlet

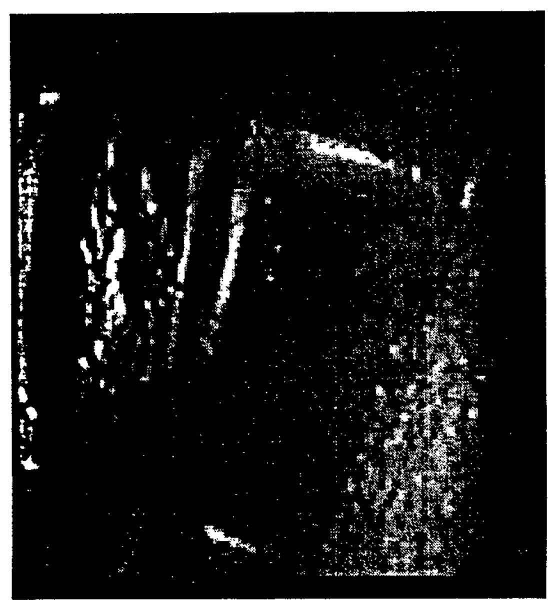
Figure 4.6 - Video Borescope Pictures, Ottawa County (Continued)



OTT(2) - Run 2, Entering PED

OTT(2) Run 3, Entering PED

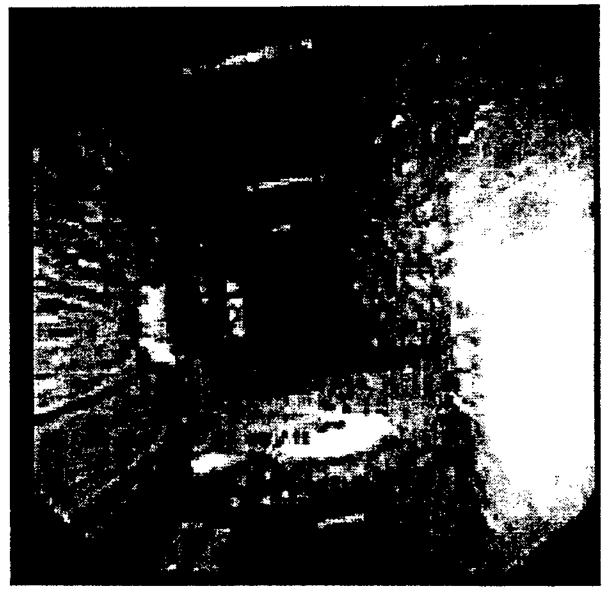
OTT(2) - Run 3, PED Compression



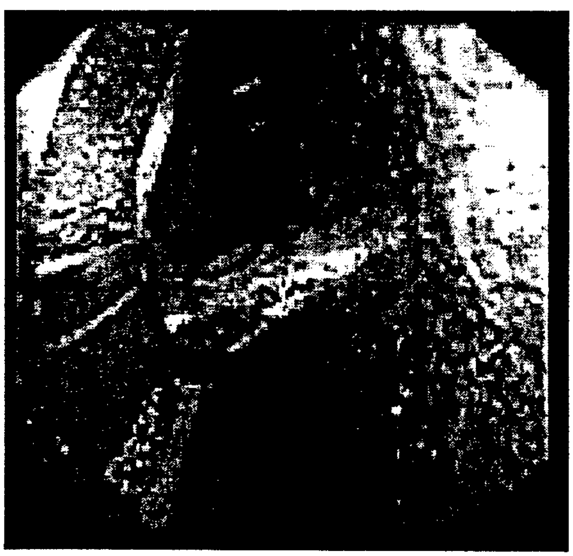
OTT(2) - Run 4, PED Compression

Figure 4.6 - Video Borescope Pictures, Ottawa County (Continued)

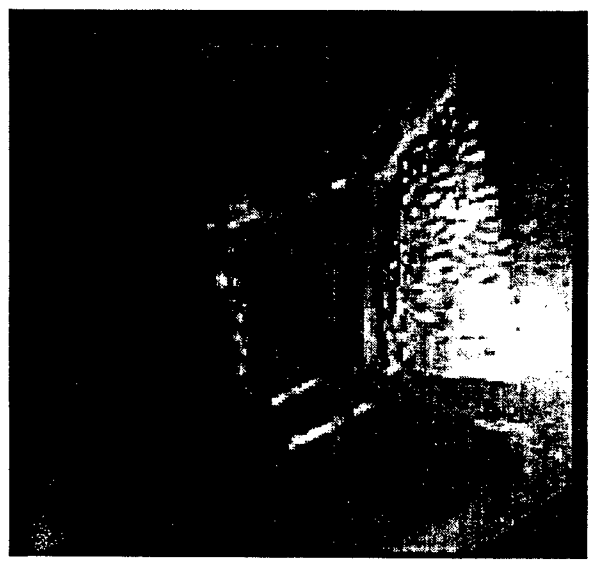
OTT(2) - Run 4, EOR PED Compression



OTT(2) Run 5, Entering PED



OTT(2) - Run 5, PED Crushing



OTT(2) - Run 5, EOR PED Crushing

Figure 4.6 - Video Borescope Pictures, Ottawa County (Concluded)

4.53 Permittivity Test

The results of the testing are shown in Figure 4.7 and Table 4.5. There were two samples of PED tested, one from each excavation. The samples were very dirty both inside and out. The tests were conducted by establishing a small head difference across the fabric material and measuring the discharge rate. After five trials at low head differences, the discharge level was adjusted so that there would be a larger head difference and the testing was repeated. Since the fabric material was so dirty, it was possible to maintain head differences of up to 12 mm. According to Figure 4.7, the permittivity decreases as the head difference increases.

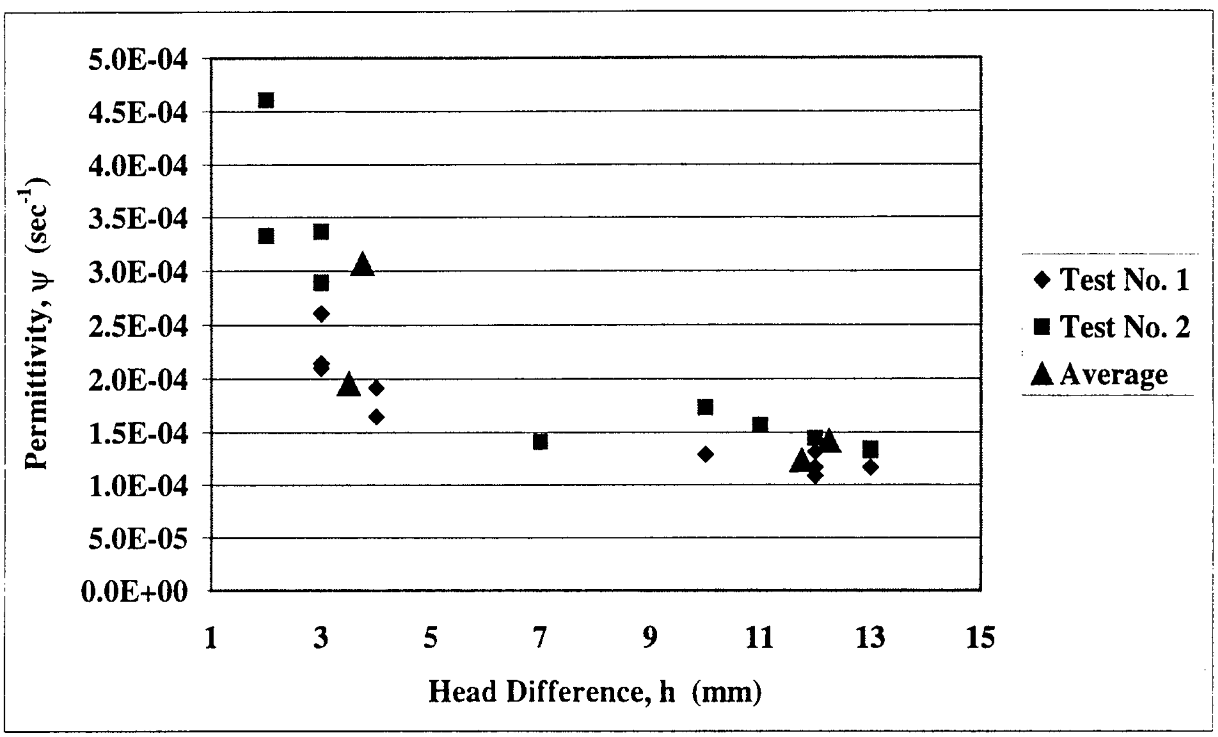


Figure 4.7 - Permittivity Test, Ottawa County

Table 4.5 - Permittivity Calculations, Ottawa County

Permittivity of Prefabricated Edge Drains (After ASTM D4491)
Location: Ottawa County, S. R. 2, Westbound, Test No. 1 and 2
Project: OTT-2-23.4, Project 430(91)
Manufacturer/Type of Edge Drain: Monsanto Hydraway
Notes: Edge drain has fines in bottom 6 to 8" but is not completely blocked. Filter cloth has fines on both sides. Edge drain is partially collapsed near the top and bottom and the filter material is compressed into the core. Fine grained subgrade soil.
Significant flow from outlet. Date: August 13, 1997

$P = Q R / h A t$ $A = 83545\ mm^2$ (245 mm X 341mm) $h = h_2 - h_1$

Trial	Q (mm^3)	t (sec)	R_t	h_1 (cm)	h_2 (cm)	$Q R_t / A t$ (mm/sec)	h (mm)	ψ (sec^{-1})
1	810	12.4	1	9.2	9.5	0.000782	3	2.6E-04
2	910	16.5	1	9.1	9.5	0.00066	4	1.7E-04
3	680	10.6	1	9.1	9.5	0.000768	4	1.9E-04
4	710	13.2	1	9.2	9.5	0.000644	3	2.1E-04
5	780	14.8	1	9.2	9.5	0.000631	3	2.1E-04
Ave.						**6.76E-04**	**3.5**	**2.0E-04**
1	850	7.8	1	10.5	11.7	0.001304	12	1.1E-04
2	820	7	1	10.2	11.4	0.001402	12	1.2E-04
3	750	5.7	1	10.2	11.4	0.001575	12	1.3E-04
4	860	8.0	1	10.8	11.8	0.001287	10	1.3E-04
5	900	7.1	1	10.2	11.5	0.001517	13	1.2E-04
Ave.						**1.45E-03**	**11.8**	**1.2E-04**
1	500	9.0	1	7.3	7.5	0.000665	2	3.3E-04
2	810	9.6	1	6.8	7.1	0.00101	3	3.4E-04
3	830	10.1	1	6.5	7.2	0.000984	7	1.4E-04
4	710	9.8	1	6.8	7.1	0.000867	3	2.9E-04
5	970	12.6	1	6.8	7.0	0.000921	2	4.6E-04
Ave.						**9.46E-04**	**3.8**	**3.1E-04**
1	940	6.5	1	7.1	8.1	0.001731	10	1.7E-04
2	890	6.1	1	6.8	8.1	0.001746	13	1.3E-04
3	850	5.9	1	6.8	7.9	0.001724	11	1.6E-04
4	780	5.4	1	6.8	8.0	0.001729	12	1.4E-04
5	990	6.9	1	6.8	8.1	0.001717	13	1.3E-04
Ave.						**1.73E-03**	**12.3**	**1.4E-04**
					Average	**1.29E-03**	**9.97**	**2.1E-04**

4.6 Warren County

4.61 Visual Inspection

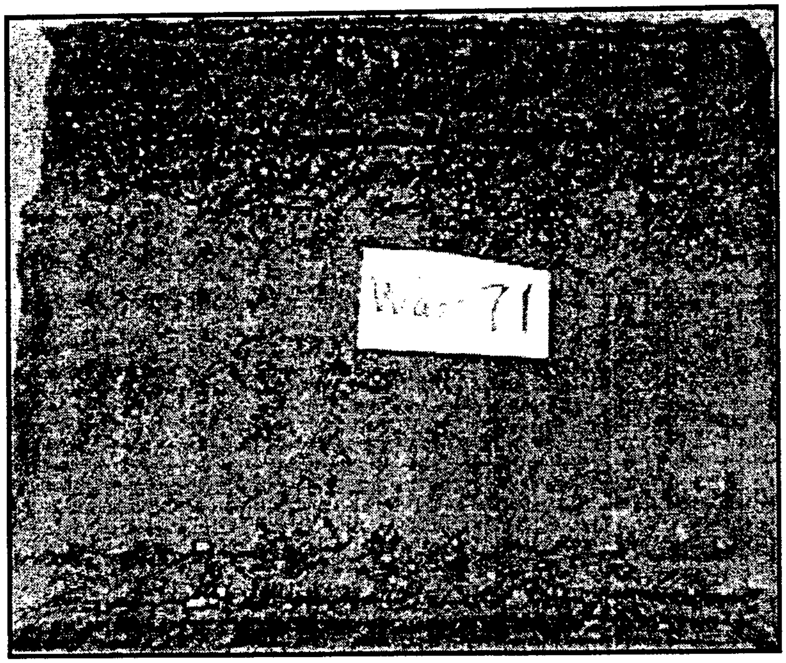
Details on the visual and video borescope inspections are provided in Table 4.6. The PED was installed according to previous ODOT specifications. Monsanto Hydraway was the type of PED used. The PED had 6 inches of mud on the fabric and two inches inside the PED. (See Figure 4.8). Water flowed from the PED and filled the trench to a depth of 8 inches. The PED was crushed 4 inches near the bottom and 1 to 4 inches from the top. The fabric was compressed into the core.

4.62 Video Borescope Inspection

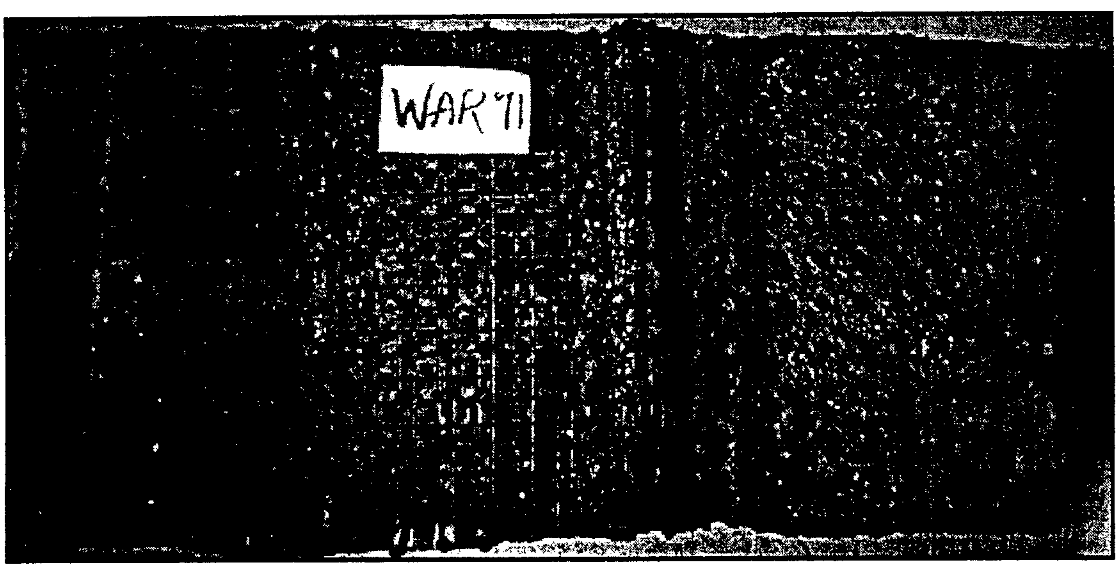
It was not possible to advance the video borescope probe very far before the lens was covered with mud. The PED was not probed below a height of 6 inches from the bottom. The video borescope pictures in Figure 4.9 shows that the cusps are deformed and that the PED has collapsed. The fabric is compressed into the core. There are some soft sediments in the core on the inside of the fabric and on the posts. There was no outlet nearby.

Table 4.6 - Field Investigation of PED, Warren County

Test Date: August 18, 1997	**Project:** WAR-71-19.0, Project 12(90)
Test Location: Warren County, I-71, Northbound Lane, Station SLM ± 3.0	
Year of Construction: 1991	**Pavement:** Normal crown, constant grade.
Outlet: Could not locate.	
Excavation Materials: 4 inch asphalt and 4 inch asphalt plug; sand subbase; silty clay.	
Location of PED: On inside of trench???	**Backfill material:** Excavated material???
Type of PED: Monsanto Hydraway	
PED Description: 18 inches high by 3/4 inch wide, black fabric	
PED Placement: Cusps facing toward pavement	
Drainage Condition: No water outside PED; water flowed from PED to a depth of 8 inches.	
Presence of Fines: 6 inches of mud outside PED; bottom 2 inches inside PED	
Condition of PED: PED crushed 4 inches near bottom and 1 to 5 inches	
from the top of PED.	
Condition of Outlet: None	
Video Borescope Probe:	
Run Number: 1	**Probe Length:** 1 foot (lens covered)
Height From Bottom: 6 inches	**Probe Direction:** south
Run Number: 2	**Probe Length:** 1 foot (lens covered)
Height From Bottom: 8 inches	**Probe Direction:** south
Run Number: 3	**Probe Length:** 1 foot (lens covered)
Height From Bottom: 6 inches	**Probe Direction:** north
Run Number: 4	**Probe Length:** 1 foot (lens covered)
Height From Bottom: 8 inches	**Probe Direction:** north
Run Number: 5	**Probe Length:** 1 foot (lens covered)
Height From Bottom: 8 inches	**Probe Direction:** north
Run Number: 6	**ProbeLength:**25feet (no video,lens covered)
Height From Bottom: 12 inches	**Probe Direction:** south
Run Number: 7	**ProbeLength:**25feet (no video,lens covered)
Height From Bottom: 12 inches	**Probe Direction:** south?



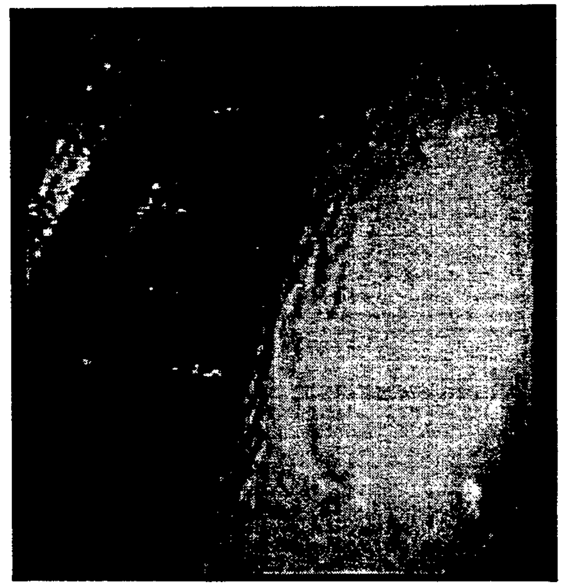
a) PED Sample from Excavation



b) PED with Core Exposed

Figure 4.8 - PED Pictures, Warren County

WAR - Run 1, Entering PED



WAR - Run 1, EOR PED Compression

WAR - Run 3, Entering PED

WAR - Run 3, EOR PED Compression

Figure 4.9 - Video Borescope Pictures, Warren County

WAR - Run 4, Entering, PED Compr.

WAR - Run 4, Entering, PED Compr.

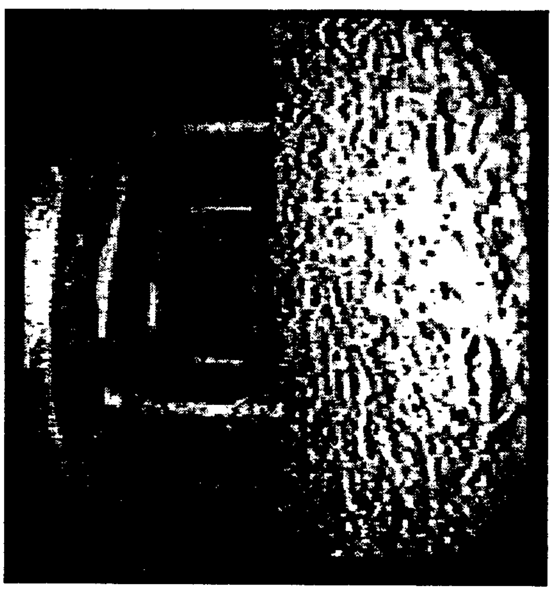
WAR - Run 5, PED

WAR - Run 5, PED

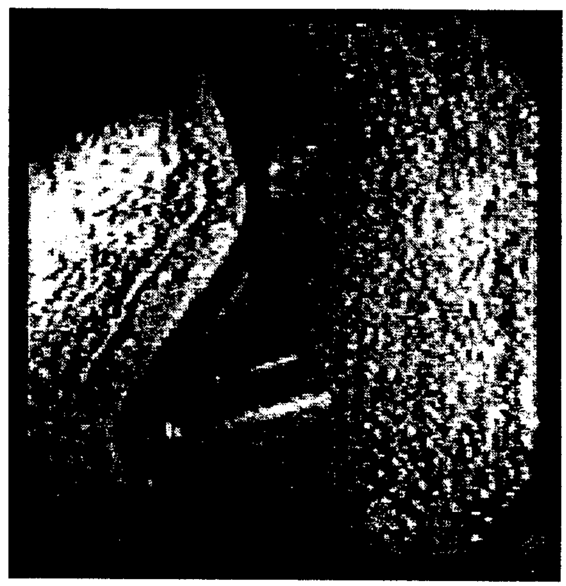
Figure 4.9 - Video Borescope Pictures, Warren County (Continued)

WAR - Run 6, Entering PED

WAR - Run 6, Entering PED



WAR - Run 6, PED Compression



WAR - Run 6, PED Collapse

Figure 4.9 - Video Borescope Pictures, Warren County (Concluded)

4.63 Permittivity Test

The results of the testing are shown in Figure 4.10 and Table 4.7. The PED sample was very dirty with fines on both sides of the fabric. Because of condition of the fabric it was possible to establish up to 27 mm of head difference. According to Figure 4.10, the permittivity decreases as the head difference increases.

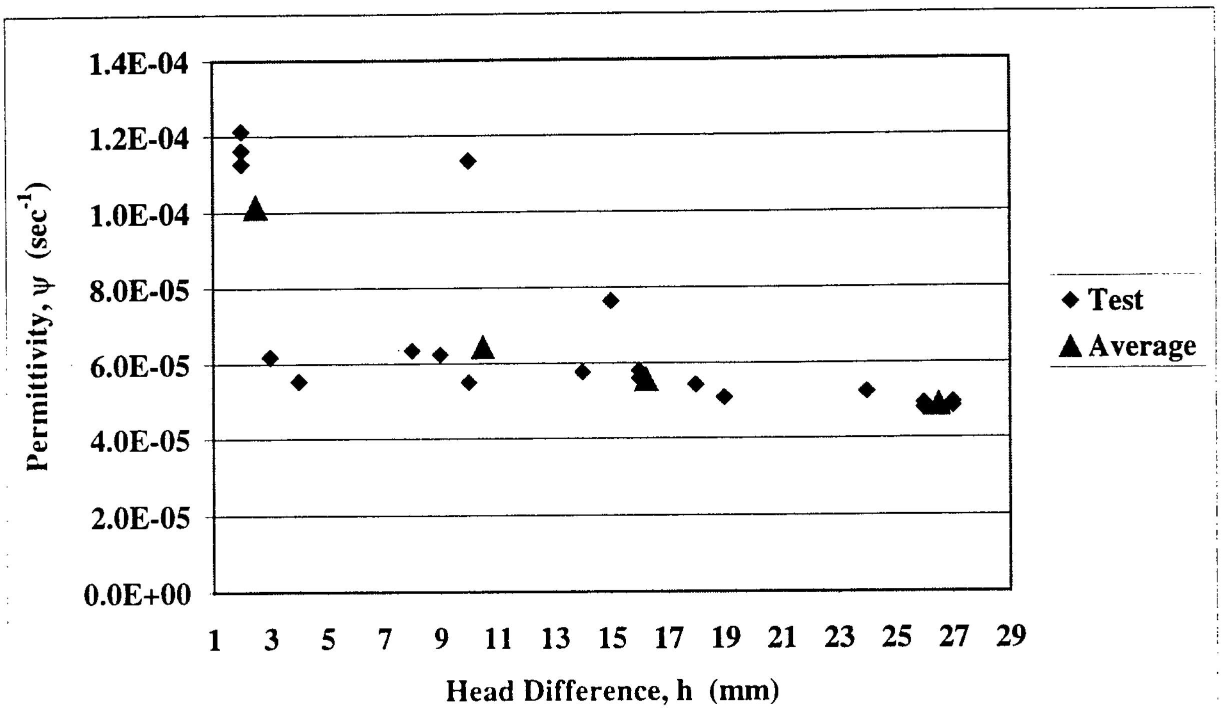


Figure 4.10 - Permittivity Test, Warren County

Table 4.7 - Permittivity Calculations, Warren County

Permittivity of Prefabricated Edge Drains (After ASTM D4491)
Location: Warren County, I-71 Northbound
Project: WAR-71-23, Project 12(90
Manufacturer/Type of Edge Drain: Monsanto Hydraway
Notes: Edge drain has fines in bottom 6 to 8" but is not completely blocked. Filter cloth has fines on both sides. Edge drain is partially collapsed and filter material is compressed into core near the bottom and the top. Fine grained subgrade soil.
Water flowed from drain. Date: August 18, 1997

P = Q R / h A t **A = 83545 mm^2 (245 mm X 341mm)** **$h = h_2 - h_1$**

Trial	Q (mm^3)	t (sec)	R_t	h_1 (cm)	h_2 (cm)	$Q R_t / A t$ (mm/sec)	h (mm)	ψ (sec^{-1})
1	330	21.3	1	6.9	7.2	0.000185	3	6.2E-05
2	420	22.7	1	6.8	7.2	0.000221	4	5.5E-05
3	480	23.7	1	6.8	7.0	0.000242	2	1.2E-04
4	540	27.8	1	6.9	7.1	0.000233	2	1.2E-04
5	520	27.6	1	6.9	7.1	0.000226	2	1.1E-04
Ave.						**2.30E-04**	**2.5**	**1.0E-04**
1	730	7.7	1	5.9	6.9	0.001135	10	1.1E-04
2	680	7.1	1	5.5	7	0.001146	15	7.6E-05
3	680	14.5	1	6.0	6.9	0.000561	9	6.2E-05
4	620	13.5	1	6.9	7.9	0.00055	10	5.5E-05
5	640	15.1	1	7.4	8.2	0.000507	8	6.3E-05
Ave.						**6.91E-04**	**10.5**	**6.4E-05**
1	840	10.3	1	5.5	7.3	0.000976	18	5.4E-05
2	720	9.3	1	5.4	7.0	0.000927	16	5.8E-05
3	700	10.4	1	5.8	7.2	0.000806	14	5.8E-05
4	710	9.5	1	5.4	7.0	0.000895	16	5.6E-05
5	750	9.3	1	5.2	7.1	0.000965	19	5.1E-05
Ave.		860				**8.98E-04**	**16.3**	**5.6E-05**
1	860	8.2	1	5.4	7.8	0.001255	24	5.2E-05
2	790	7.1	1	5.2	7.9	0.001332	27	4.9E-05
3	840	7.7	1	5.1	7.8	0.001306	27	4.8E-05
4	810	7.8	1	5.0	7.6	0.001243	26	4.8E-05
5	800	7.5	1	5.1	7.7	0.001277	26	4.9E-05
Ave.						**1.29E-03**	**26.5**	**4.9E-05**
					Average	**7.12E-04**	**10.19**	**7.4E-05**

4.7 Athens County

4.71 Visual Inspection

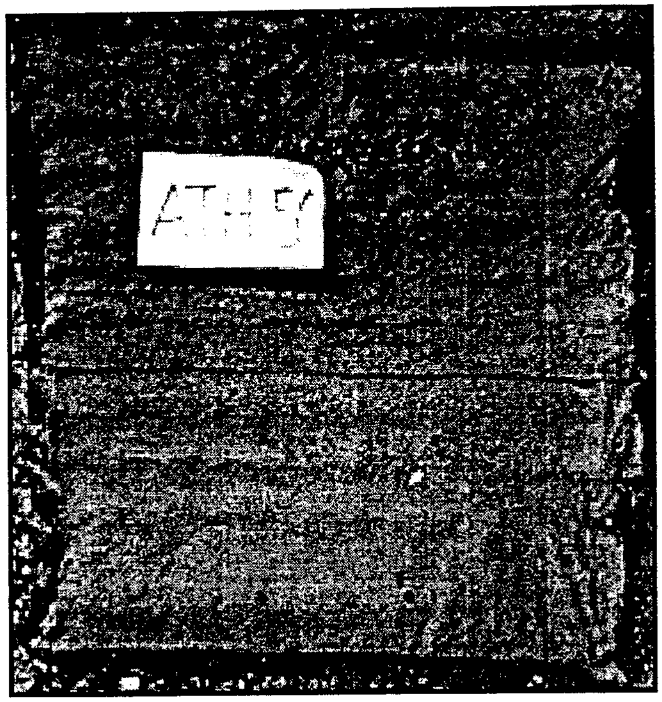
Details on the visual and video borescope inspections are provided in Table 4.8. The PED was installed in 1992 according to previous ODOT specifications. The PED type was Hydraway. There were 2 inches of mud inside and outside of the PED and 6 to 8 inches of fines in the PED (See Figure 4.11). Water flowed from the PED and filled the trench during the excavation. There was J'ing in the bottom of the PED. The fabric was compressed into the core.

4.72 Video Borescope Inspection

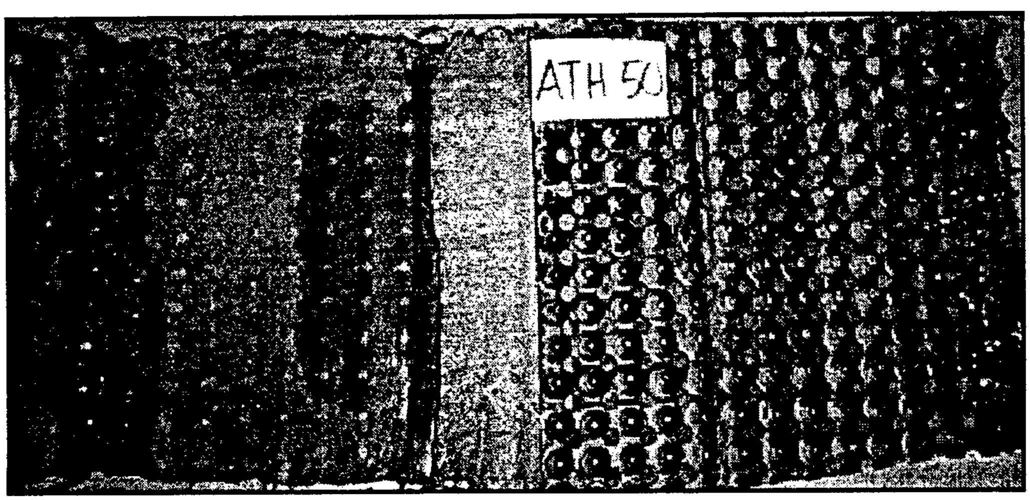
It was only possible to advance the video borescope probe the full 25 feet in the top half of the PED. At lower heights the lens was covered with mud. The video borescope pictures in Figure 4.12 show deformation of the cusps, crushing of the core and compression of the fabric into the core. There are some soft sediments in the core on the inside of the fabric and on the posts. There was no outlet nearby.

Table 4.8 - Field Investigation of PED, Athens County

Test Date: August 19, 1997	**Project:** ATT-50-34.28, Project 84(91)
Test Location: Athens County, US 50, Westbound Lane, Station SLM 36.50	
Year of Construction: 1992	**Pavement:** Normal slope, in sump near river.
Outlet: Could not locate.	
Excavation Materials: 10 inch asphalt; sand subbase; silty clay.	
Location of PED: On inside of trench???	**Backfill material:** Excavated material???
Type of PED: Hydraway	
PED Description: 18 inches high by 1.2 inch wide, black fabric	
PED Placement: Cusps facing toward pavement	
Drainage Condition: No water outside PED; water flowed and filled trench when excavated.	
Presence of Fines: 2 inches of mud outside PED; bottom 2 inches inside PED	
Condition of PED: Bottom of PED was jayed one cusp.	
Condition of Outlet: None	
Video Borescope Probe:	
Run Number: 1	**Probe Length:** 1 foot (lens covered)
Height From Bottom: 3 inches	**Probe Direction:** east
Run Number: 2	**Probe Length:** 1 foot (lens covered)
Height From Bottom: 6 inches	**Probe Direction:** east
Run Number: 3	**ProbeLength:**25 feet(no video,lens covered)
Height From Bottom: 12 inches	**Probe Direction:** east
Run Number: 4	**Probe Length:** 1 foot (lens covered)
Height From Bottom: 4 inches	**Probe Direction:** west
Run Number: 5	**Probe Length:** 1 foot (lens covered)
Height From Bottom: 7 inches	**Probe Direction:** west
Run Number: 6	**ProbeLength:**25feet (no video,lens covered)
Height From Bottom: 15 inches	**Probe Direction:** south



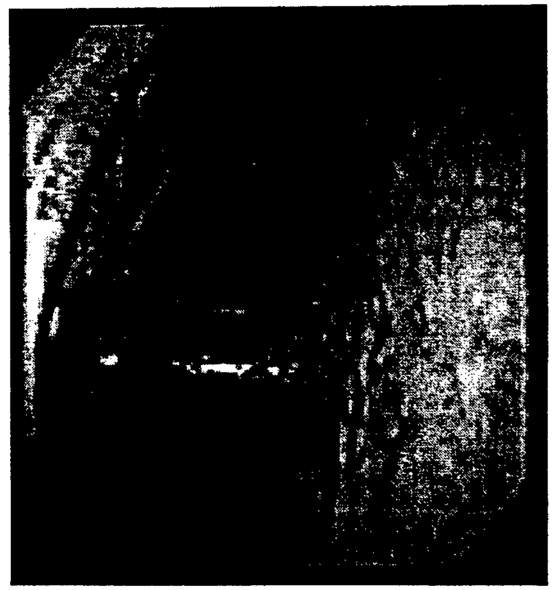
a) PED Sample from Excavation



b) PED with Core Exposed

Figure 4.11 - PED Pictures, Athens County

ATH- Run 1, PED Compression



ATH - Run 3, Entering PED

ATH - Run , Entering PED

ATH - Run , PED Compression

Figure 4.12 - Video Borescope Pictures, Athens County

ATH- Run , Entering PED

ATH - Run , Entering PED

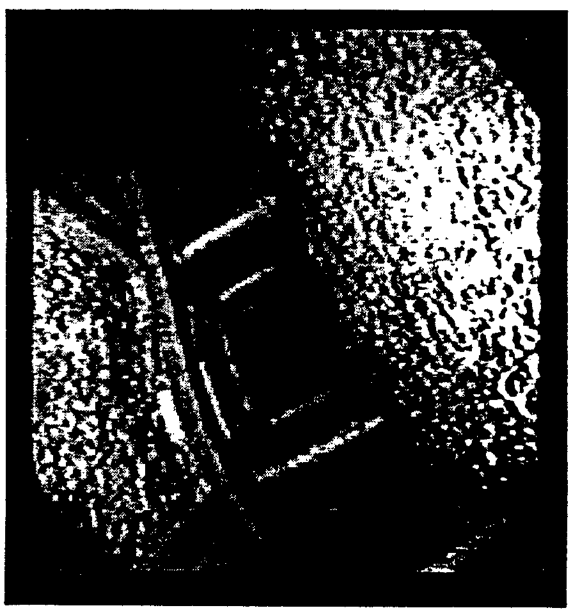
ATH - Run , Entering PED

ATH - Run , Entering PED

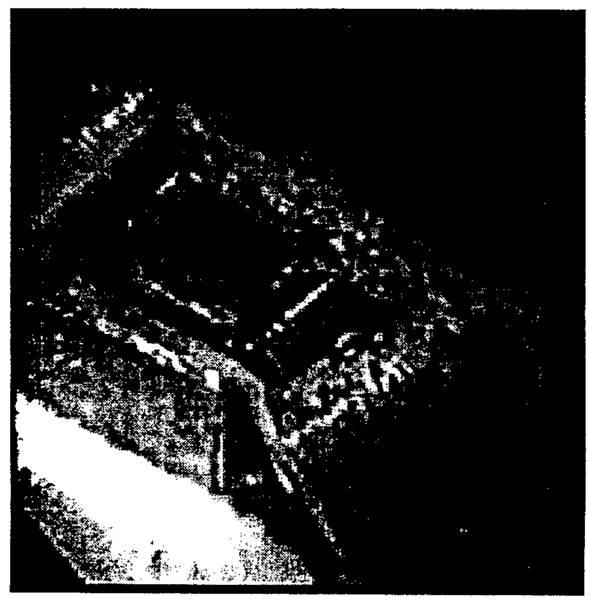
Figure 4.12 - Video Borescope Pictures, Athens County (Continued)

ATH- Run , PED Collapse

ATH - Run , PED Compression



ATH - Run , PED Compression



ATH - Run 6, Entering PED

Figure 4.12 - Video Borescope Pictures, Athens County (Concluded)

4.73 Permittivity Test

The results of the testing are shown in Figure 4.13 and Table 4.9. The samples were dirty both inside and out however it was only possible to establish up to 7 mm of head difference. As shown in Figure 4.10, there is considerable variation in the test data. There is no consistent trend between permittivity and head difference.

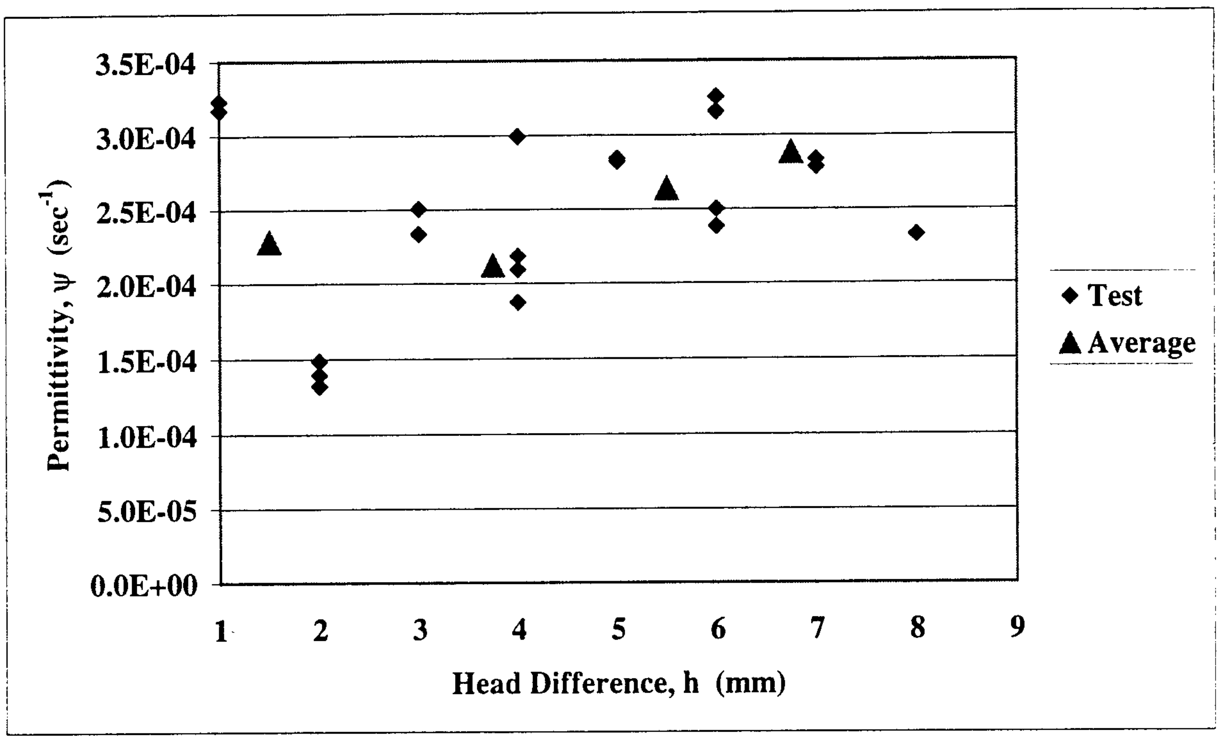


Figure 4.13 - Permittivity Test, Athens County

Table 4.9 - Permittivity Calculations, Athens County

Permittivity of Prefabricated Edge Drains (After ASTM D4491)
Location: Athens County, U.S. Route 50, Westbound
Project: ATH-50-36, Project 84(91)
Manufacturer/Type of Edge Drain: Hydraway
Notes: Edge Drain has fines in Bottom 6 to 8' but is not completely blocked. Filter has some fines on both sides. Edge drain is partially collapsed and filter material is compressed into core.
Fine grained subgrade soil.
Water flowed from drain.
Date: August 19, 1997

$P = Q R / h A t$ A = 83545 Mm^2 (245 mm X 341mm)

$h = h_2 - h_1$

Trial	Q (mm^3)	t (sec)	R_t	h_1 (cm)	h_2 (cm)	$Q R_t / A t$ (mm/sec)	h (mm)	ψ (sec^{-1})
1	590	23.8	1.0	7.1	7.3	0.000297	2	1.5E-04
2	450	19.3	1.0	7.0	7.2	0.000279	2	1.4E-04
3	480	21.7	1.0	7.1	7.3	0.000265	2	1.3E-04
4	470	17.4	1.0	7.2	7.3	0.000323	1	3.2E-04
5	490	18.5	1.0	7.2	7.3	0.000317	1	3.2E-04
Ave.						**2.96E-04**	**1.5**	**2.3E-04**
1	590	9.4	1	7	7.3	0.000751	3	2.5E-04
2	620	8.5	1	6.9	7.3	0.000873	4	2.2E-04
3	550	9.4	1	6.9	7.2	0.0007	3	2.3E-04
4	580	8.3	1	6.9	7.3	0.000836	4	2.1E-04
5	570	9.1	1	6.9	7.3	0.00075	4	1.9E-04
Ave.						**7.90E-04**	**3.8**	**2.1E-04**
1	670	6.7	1	7	7.4	0.001197	4	3.0E-04
2	890	7.1	1	6.7	7.3	0.0015	6	2.5E-04
3	820	6.9	1	6.6	7.1	0.001422	5	2.8E-04
4	800	6.7	1	6.6	7.2	0.001429	6	2.4E-04
5	790	6.7	1	6.7	7.2	0.001411	5	2.8E-04
Ave.						**1.44E-03**	**5.5**	**2.6E-04**
1	730	4.4	1	6.7	7.4	0.001986	7	2.8E-04
2	800	4.9	1	6.7	7.3	0.001954	6	3.3E-04
3	760	4.8	1	6.7	7.3	0.001895	6	3.2E-04
4	880	5.4	1	6.7	7.4	0.001951	7	2.8E-04
5	730	4.7	1	6.7	7.5	0.001859	8	2.3E-04
Ave.						**1.91E-03**	**6.8**	**2.9E-04**
					Average	**8.03E-04**	**3.61**	**2.3E-04**

4.8 Jackson County

4.81 Visual Inspection

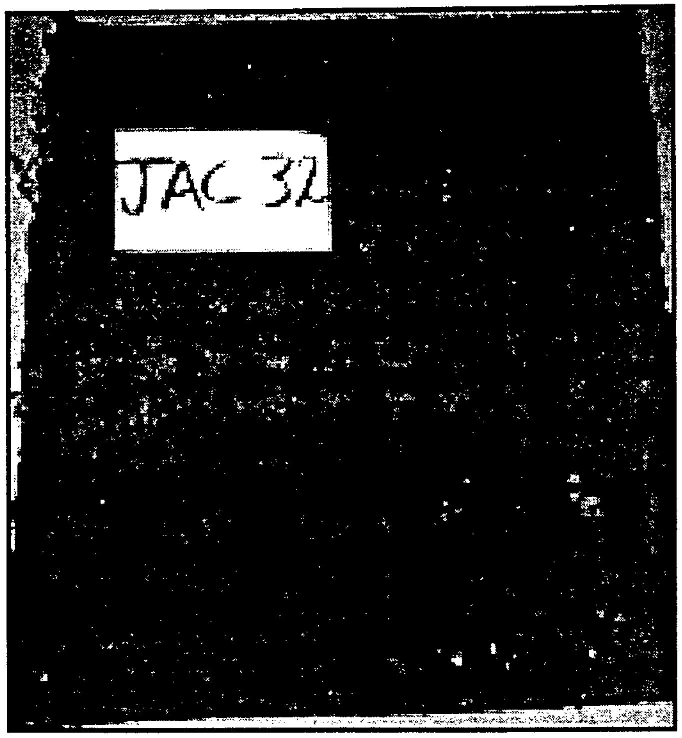
Details on the visual and video borescope inspections are provided in Table 4.10. The PED was installed in 1991 according to previous ODOT specifications. The PED type was Prodrain. There was 4 inches of mud inside and outside of the PED. (See Figure 4.14). Water flowed from the PED. There was J'ing in the bottom and top of the PED. The fabric was compressed into the core. There was an organic plug in the end of the outlet so a large volume of water flowed from the outlet when the blockage was removed.

4.82 Video Borescope Inspection

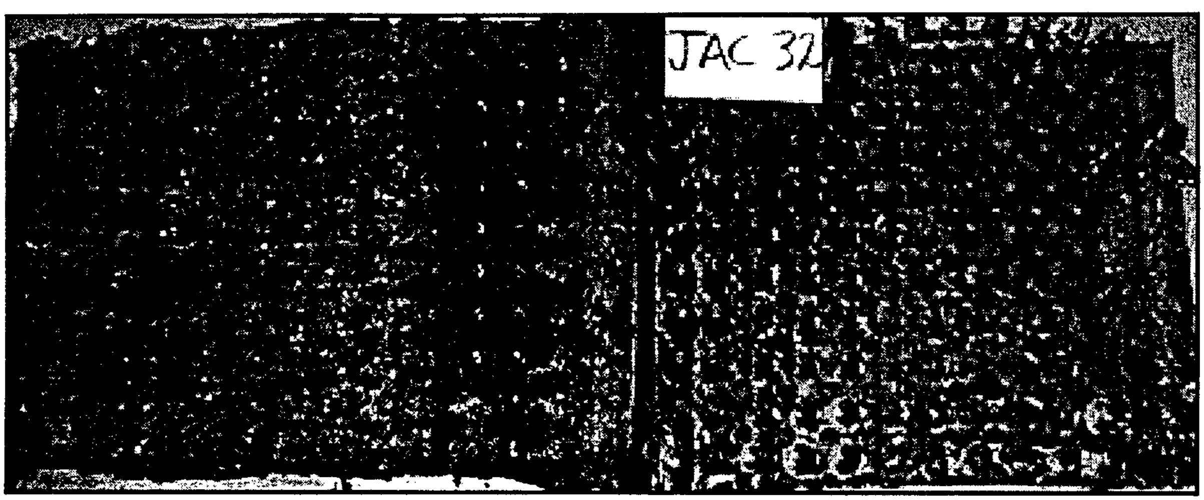
It was possible to advance the video borescope probe the full 25 feet near the top and the bottom of the PED. At other locations the probe encountered mud and deformed cusps. The video borescope pictures in Figure 4.15 shows cusps blocking the probe, crushing of the core and compression of the fabric into the core. There are some soft sediments in the core on the inside of the fabric and on the cusps. The picture from the outlet shows a high volume of flow.

Table 4.10 - Field Investigation of PED, Jackson County

Test Date: August 21, 1997	**Project:** JAC-32-6.40, Project 256(90)
Test Location: Jackson County, US 32, Eastbound Lane, Station SLM 7.1	
Year of Construction: 1991	**Pavement:** Normal slope, down grade
Outlet: 12 feet down grade from excavation..	
Excavation Materials: 12 inch asphalt; 6 inch 304 subbase; brown clay.	
Location of PED: On inside of trench???	**Backfill material:** Excavated material
Type of PED: Prodrain	
PED Description: 16 1/2 inches high by 1 1/2 inch wide, black fabric	
PED Placement: Cusps facing toward pavement	
Drainage Condition: No water outside PED; 2 inches of water from inside PED.	
Presence of Fines: 4 inches of mud outside PED; bottom 3 to 4 inches inside PED	
Condition of PED: Bottom of PED was jayed one cusp, top jayed two cusps.	
Condition of Outlet: Outlet covered so that, when grass plug was removed with a shovel, water flowed from outlet at a depth of 1/2 inch for 1 hour.	
Video Borescope Probe:	
Run Number: 1	**Probe Length:** 4 feet (cusp blocked)
Height From Bottom: 15 inches (3rd space)	**Probe Direction:** west
Run Number: 2	**Probe Length:**6 inch (blocked,lens covered)
Height From Bottom: 6 inches (2nd space)	**Probe Direction:** west
Run Number: 3	**ProbeLength:**12 inch(blocked,lens covered)
Height From Bottom: 12 inches (6th space)	**Probe Direction:** west
Run Number: 4	**ProbeLength:**25 feet(8 ft of video then mud)
Height From Bottom: 12 inches (6th space)	**Probe Direction:** west
Run Number: 5	**ProbeLength:**25 feet(1 ft of video then mud)
Height From Bottom: 16 inches (2nd space)	**Probe Direction:** east
Run Number: 6	**ProbeLength:**12 feet(8 ft then mud, cusp)
Height From Bottom: 14 inches (3rd space)	**Probe Direction:** east
Run Number: 7	**ProbeLength:**14 feet(8 ft then mud, cusp)
Height From Bottom: 13 inches (4th space)	**Probe Direction:** east
Run Number: 8	**ProbeLength:**25 feet(1 ft then mud)
Height From Bottom: 3 inches (3rd space)	**Probe Direction:** east
Run Number: 9	**ProbeLength:**15 feet then pipe crushed.
Height From Bottom: bottom of outlet pipe	**Probe Direction:**



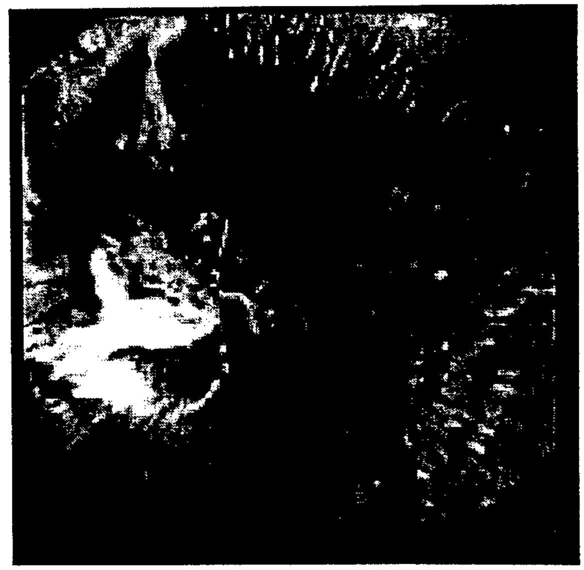
a) PED Sample from Excavation



b) PED with Core Exposed

Figure 4.14 - PED Pictures, Jackson County

JAC - Run 1, Entering PED



JAC - Run 3, PED Compression

JAC - Run , PED Compression

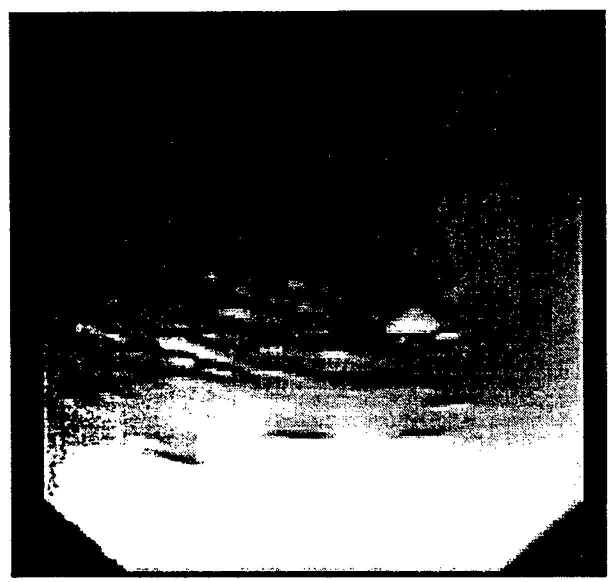
JAC - Run , PED Compression

Figure 4.15 - Video Borescope Pictures, Jackson County

JAC - Run , PED Compression

JAC - Run , PED Compression

JAC - Run , PED Compression



JAC - Run 9, Outlet pipe

Figure 4.15 - Video Borescope Pictures, Jackson County (Concluded)

4.83 Permittivity Test

The results of the testing are shown in Figure 4.16 and Table 4.11. The samples were dirty and it was possible to establish up to 19 mm of head difference. The variation in permittivity shown in Figure 4.16 is small. The permittivity decreased as the head difference increased.

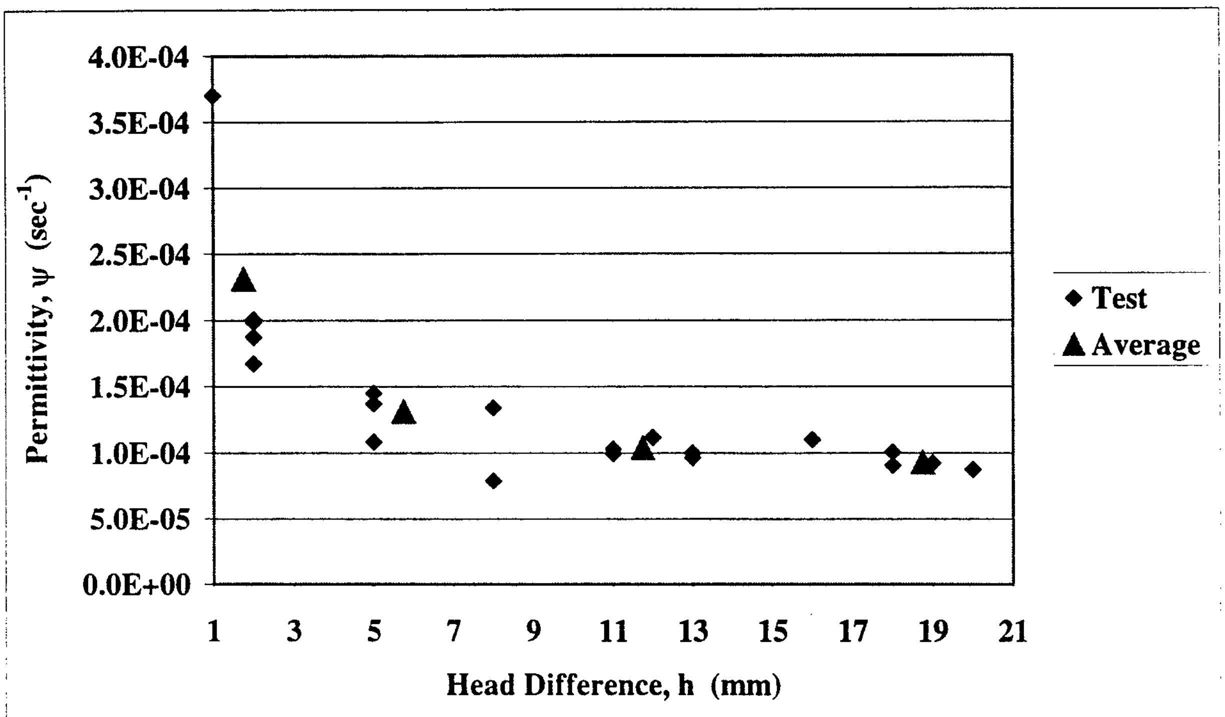


Figure 4.16 - Permittivity Test, Jackson County

Table 4.11 - Permittivity Calculations, Jackson County

Permittivity of Prefabricated Edge Drains (After ASTM D4491)
Location: Jackson County, U.S. Route 32, Eastbound
Project: JAC-32-7, Project 256(90)
Manufacturer/Type of Edge Drain: ProDrain
Notes: Edge drain has fines in bottom 6 to 8" but is not completely blocked. Filter cloth has fines on both sides. Edge drain is partially collapsed and filter material is compressed into core. Fine grained subgrade soil. Standing water in outlet. Date: August 19, 1997

$P = Q R / h A t$ A = 83545 mm^2 (245 mm X 341mm) $h = h_2 - h_1$

Trial	Q (mm^3)	t (sec)	R_t	h_1 (cm)	h_2 (cm)	$Q R_t / A t$ (mm/sec)	h (mm)	ψ (sec^{-1})
1	680	20.3	1	6.3	6.5	0.000401	2	2.0E-04
2	640	20.7	1	6.2	6.3	0.00037	1	3.7E-04
3	570	20.4	1	6.1	6.3	0.000334	2	1.7E-04
4	650	19.6	1	6.2	6.4	0.000397	2	2.0E-04
5	680	21.7	1	6.2	6.4	0.000375	2	1.9E-04
Ave.						**3.69E-04**	**1.8**	**2.3E-04**
1	860	16.3	1	5.8	6.6	0.000632	8	7.9E-05
2	770	8.6	1	5.5	6.3	0.001072	8	1.3E-04
3	690	11.4	1	6.0	6.5	0.000724	5	1.4E-04
4	670	11.7	1	6.0	6.5	0.000685	5	1.4E-04
5	560	12.4	1	6.3	6.8	0.000541	5	1.1E-04
Ave.						**7.56E-04**	**5.8**	**1.3E-04**
1	660	6.3	1	5.5	6.8	0.001254	13	9.6E-05
2	840	7.5	1	5.4	6.6	0.001341	12	1.1E-04
3	690	7.3	1	5.8	6.9	0.001131	11	1.0E-04
4	770	7.1	1	5.5	6.8	0.001298	13	1.0E-04
5	730	8.0	1	5.8	6.9	0.001092	11	9.9E-05
Ave.						**1.22E-03**	**11.8**	**1.0E-04**
1	750	5.1	1	5.7	7.3	0.00176	16	1.1E-04
2	750	5.1	1	5.5	7.4	0.00176	19	9.3E-05
3	820	5.6	1	5.4	7.4	0.001753	20	8.8E-05
4	750	5.5	1	5.7	7.5	0.001632	18	9.1E-05
5	830	5.5	1	5.5	7.3	0.001806	18	1.0E-04
Ave.						**1.74E-03**	**18.8**	**9.3E-05**
					Average	**7.50E-04**	**6.22**	**1.6E-04**

4.9 Licking County

4.91 Visual Inspection

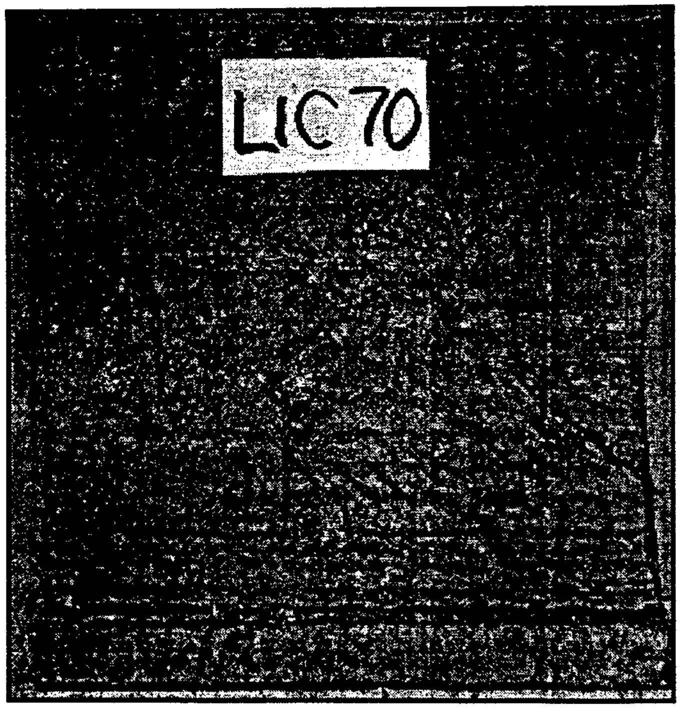
Details on the visual and video borescope inspections are provided in Table 4.12. The PED was installed in 1989 according to previous ODOT specifications. This is one of the oldest sections of highway in the state of Ohio where PED was installed. The PED type was Monsanto Hydraway. There was no mud inside or outside of the PED and no standing water in the PED (See Figure 4.17). There was J'ing in the bottom and the top of the PED. The fabric was compressed into the core. There was some mud in the outlet.

4.92 Video Borescope Inspection

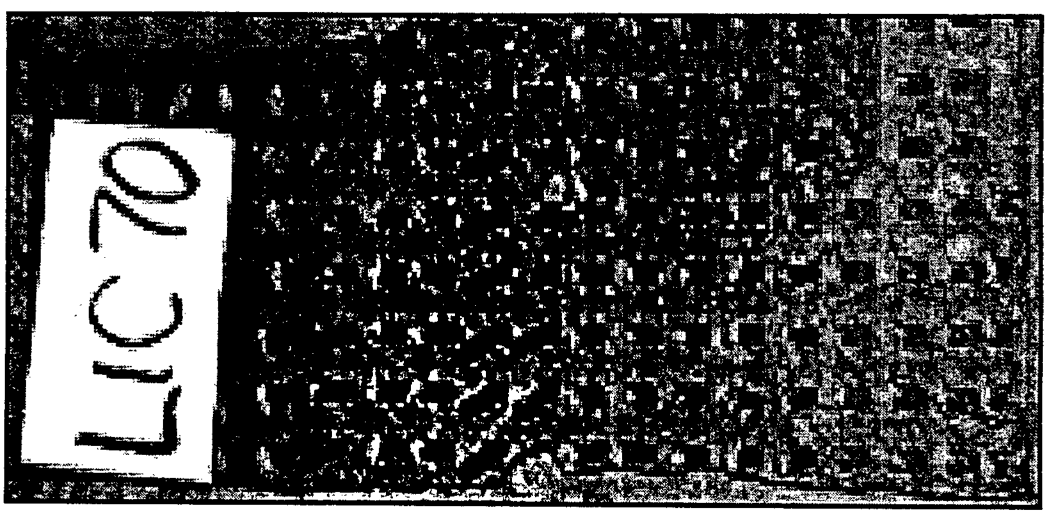
It was only possible to advance the video borescope probe the full 25 feet near the top of the PED. At lower heights the probe encounter the outlet or cusps. The video borescope pictures in Figure 4.18 show deforming of the cusps, blocking of the cusps and compression of the fabric into the core. There are some soft sediments in the core on the inside of the fabric and on the posts. The outlet connection looks very clean.

Table 4.12 - Field Investigation of PED, Licking County

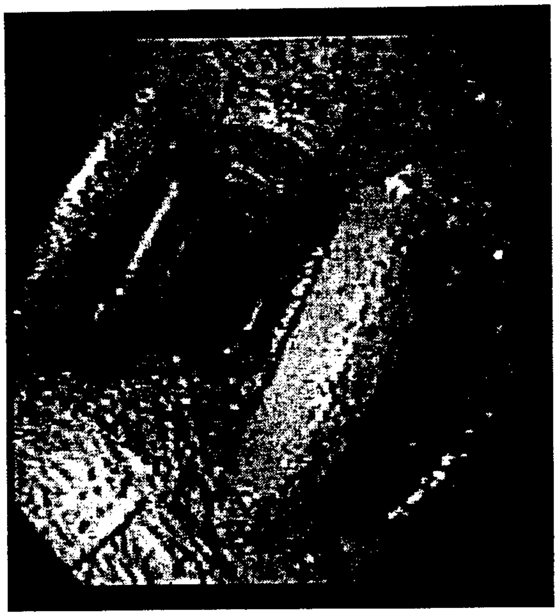
Test Date: October 22, 1997	**Project:** LIC-70-9.55, Project 341(88)
Test Location: Licking County, I-70, Eastbound Lane, Station SLM 125.5	
Year of Construction: 1989	**Pavement:** Normal slope, down grade.
Outlet: 20 feet down grade from excavation, 6 inch CMP, to former tipping bucket station.	
Excavation Materials: 15 inch asphalt; 6 inch 304 subbase; clay.	
Location of PED: On inside of trench???	**Backfill material:** Excavated material
Type of PED: Monsanto Hydraway	
PED Description: 18 inches high by 1.3 inch wide; fabric type 1, black	
PED Placement: Cusps facing toward pavement	
Drainage Condition: No water outside PED; no water inside PED.	
Presence of Fines: No mud outside or inside PED.	
Condition of PED: Bottom three cusps and top one cusp jayed.	
Condition of Outlet: Some mud in outlet.	
Video Borescope Probe:	
Run Number: 1	**Probe Length:** 15 feet (4 feet, lens covered)
Height From Bottom: 3 inches	**Probe Direction:** east
Run Number: 2	**Probe Length:** 21 feet to outlet
Height From Bottom: 9 inches	**Probe Direction:** east
Run Number: 3	**Probe Length:** 15 feet (drain crushed)
Height From Bottom: 16 inches	**Probe Direction:** east
Run Number: 4	**Probe Length:** 21 feet to outlet
Height From Bottom: 14 inches	**Probe Direction:** east
Run Number: 5	**Probe Length:** 4 feet (lens covered)
Height From Bottom: 3 inches	**Probe Direction:** west
Run Number: 6	**Probe Length:** 21 feet (8 feet,lens covered)
Height From Bottom: 7 inches	**Probe Direction:** west
Run Number: 7	**Probe Length:** 25 feet
Height From Bottom: 12 inches	**Probe Direction:** west
Run Number: 8	**Probe Length:** 25 feet
Height From Bottom: 16inches	**Probe Direction:** east



a) PED Sample from Excavation



b) PED with Core Exposed



LIC - Run 1, Entering PED

LIC - Run 1, PED Compression

LIC - Run 2, Entering PED

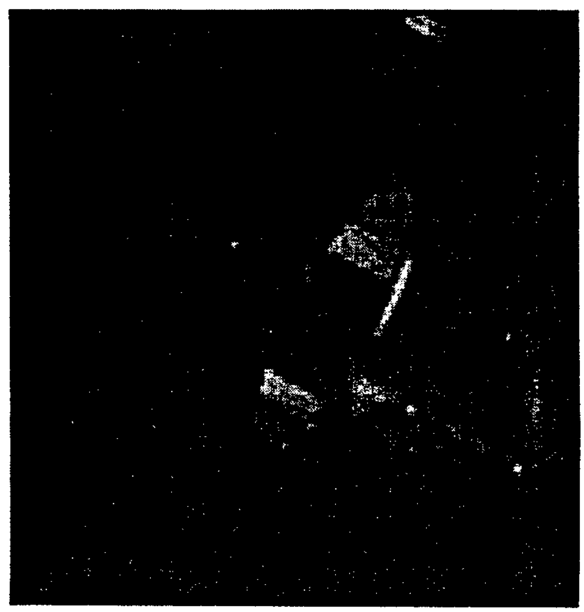
LIC - Run 2, Outlet Connection

Figure 4.18 - Video Borescope Pictures, Licking County

LIC - Run 3, Entering PED

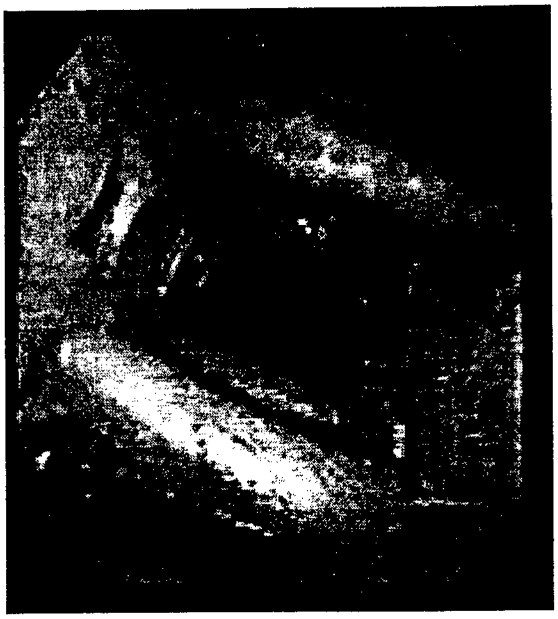
LIC - Run 3, EOR PED

LIC - Run 4, Entering PED

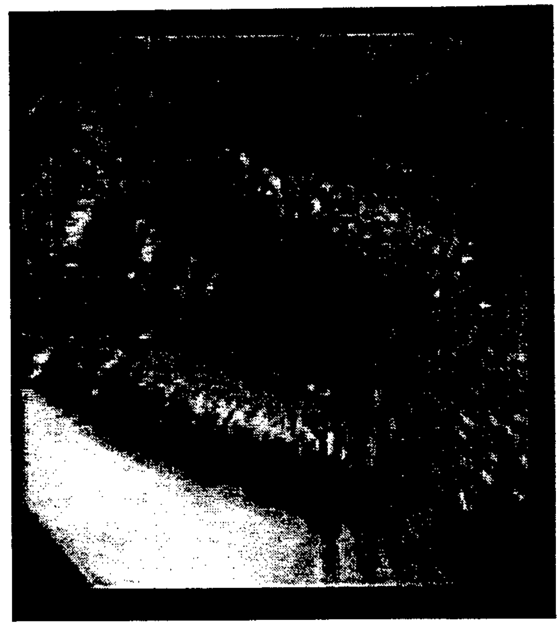


LIC - Run 4, Outlet Connection

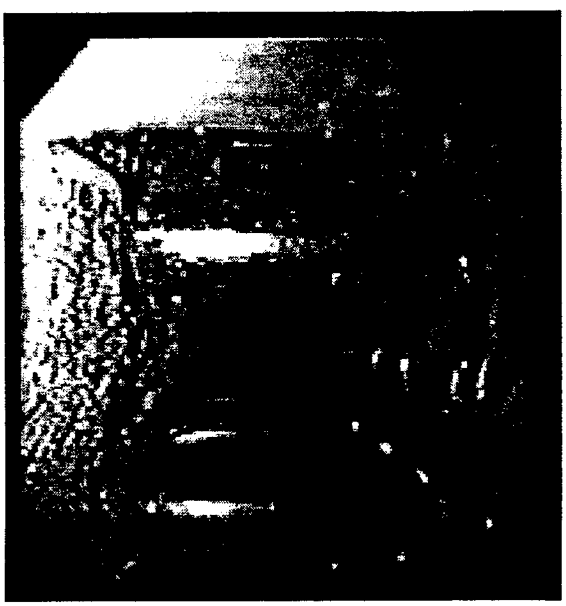
Figure 4.18 - Video Borescope Pictures, Licking County (Continued)



LIC - Run 5, Entering PED



LIC - Run 5, EOR



LIC - Run 6, PED Compression

LIC - Run 6, PED Compression

Figure 4.18 - Video Borescope Pictures, Licking County (Continued)

LIC - Run 7, Entering PED

LIC - Run 7, PED Compression

LIC - Run 7, PED Compression

LIC - Run 7, EOR PED Compression

Figure 4.18 - Video Borescope Pictures, Licking County (Concluded)

4.93 Permittivity Test

The results of the testing are shown in Figure 4.19 and Table 4.13. The sample appeared to be very dirty. However, it was only possible to establish 5 mm of head difference. There is significant variation in the data shown in Figure 4.19. In spite of the variation, the permittivity can be seen to decrease as the head difference increases.

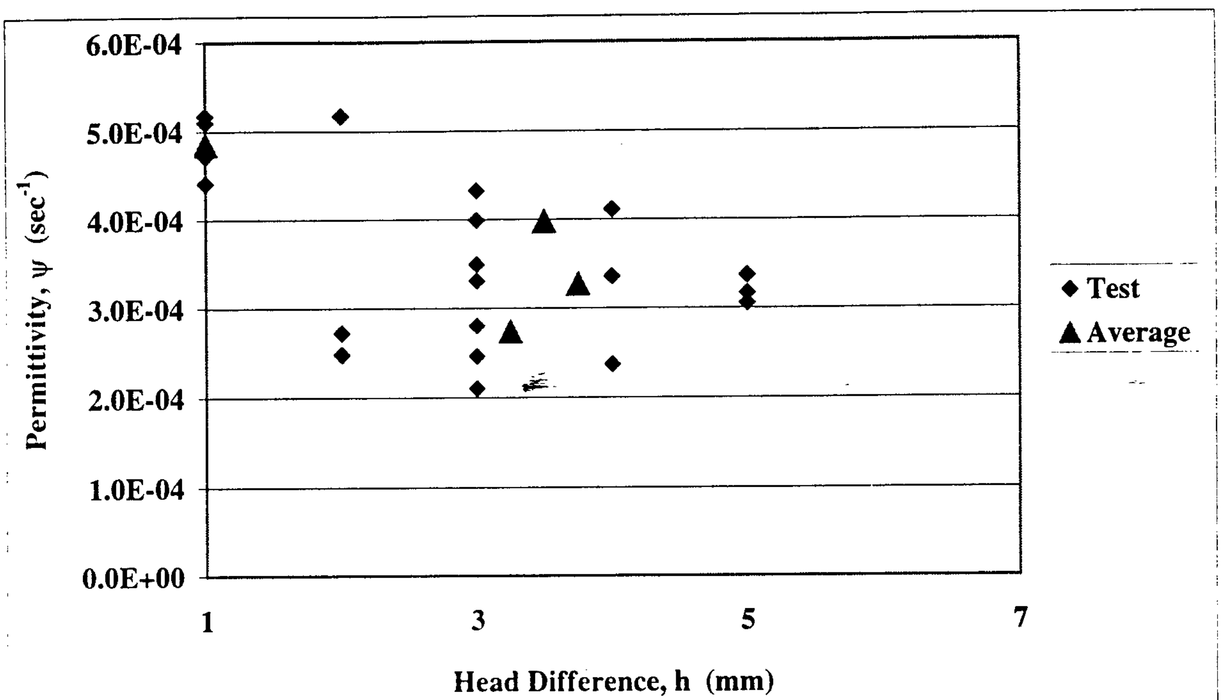


Figure 4.19 - Permittivity Test, Licking County

Table 4.13 - Permittivity Calculations, Licking County

Permittivity of Prefabricated Edge Drains (After ASTM D4491)
Location: Licking Jackson County, I-70, Eastbound
Project: LIC-70-9.55, Project 505(92)
Manufacturer/Type of Edge Drain: Monsanto Hydraway
Notes: Edge drain has fines in bottom 6" but is not completely blocked.
Edge drain is partially collapsed and filter material is compressed into core near the bottom and the top.
Fine grained subgrade soil.
No water in edge drain or outlet.
Date: October 22, 1997

P = Q R / h A t **A = 83545 mm²** **(245 mm X 341mm)** **$h = h_2 - h_1$**

Trial	Q (mm^3)	t (sec)	R_t	h_1 (cm)	h_2 (cm)	$Q R_t / A t$ (mm/sec)	h (mm)	ψ (sec^{-1})
1	650	14.3	1	4.9	5.1	0.000544	2	2.7E-04
2	700	16.2	1	4.9	5.0	0.000517	1	5.2E-04
3	730	19.8	1	4.9	5.0	0.000441	1	4.4E-04
4	710	18	1	4.9	5.0	0.000472	1	4.7E-04
5	690	16.2	1	4.9	5.0	0.00051	1	5.1E-04
Ave.						**4.85E-04**	**1.0**	**4.9E-04**
1	720	17.4	1	5.7	5.9	0.000495	2	2.5E-04
2	820	9.9	1	5.2	5.5	0.000991	3	3.3E-04
3	710	11.5	1	5.2	5.5	0.000739	3	2.5E-04
4	720	9.1	1	5.1	5.5	0.000947	4	2.4E-04
5	800	11.4	1	5.1	5.4	0.00084	3	2.8E-04
Ave.						**8.79E-04**	**3.3**	**2.7E-04**
1	690	6.9	1	5.5	5.8	0.001197	3	4.0E-04
2	770	7.1	1	5.4	5.7	0.001298	3	4.3E-04
3	700	8.1	1	5.6	5.8	0.001034	2	5.2E-04
4	880	6.9	1	5.0	5.5	0.001527	5	3.1E-04
5	830	7.4	1	5.4	5.8	0.001343	4	3.4E-04
Ave.						**1.30E-03**	**3.5**	**4.0E-04**
1	820	6.2	1	6	6.5	0.001583	5	3.2E-04
2	600	11.4	1	6.4	6.7	0.00063	3	2.1E-04
3	880	6.4	1	6	6.4	0.001646	4	4.1E-04
4	770	8.8	1	6.3	6.6	0.001047	3	3.5E-04
5	900	6.4	1	6	6.5	0.001683	5	3.4E-04
Ave.						**1.25E-03**	**3.8**	**3.3E-04**
					Average	**8.40E-04**	**2.89**	**3.9E-04**

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 Overview

The purpose of this research project was to investigate prefabricate edge drains (PED). The research included a survey of Department of Transportation (DOT) engineers in Ohio and other states. The survey provided useful information on design and construction practices by other state DOT and the performance of the PED. The survey of ODOT construction and design engineers detailed experience with PED in Ohio. The research included visual inspections and testing at six locations throughout Ohio including the use of a video borescope and permittivity testing of the PED fabric material. The visual inspections and permittivity testing were used to evaluate the in situ condition of the PED. The field investigations were important in evaluating the condition and performance of the PED in Ohio. Specific recommendations for design and construction specifications are provided in this chapter based on conclusions from this research.

5.2 Summary

Conclusions from this research are based on the surveys and the inspections that were performed for this research. Therefore, the research results were presented in Chapter 3 and 4 with very little discussion regarding conclusions or recommendations. This section summarizes the results of the research and the next section contains specific conclusions and recommendations for the design and construction of PED.

5.21 ODOT Telephone Survey

ODOT design and construction personnel are generally satisfied with PED. Since PED are installed in a narrow trench, they can be installed very quickly and more economically compared to conventional pipe underdrains. The districts have not encountered many construction problems. The major problem is in backfilling around and over the PED. It is difficult to ensure that proper compaction is achieved. Two districts noted that pavement shoulders above the PED have settled and cracked because of improper compaction of the backfill. ODOT construction personnel do not inspect the PED after they have been installed. ODOT maintenance personnel are responsible for dealing with problems occurring after construction.

Previous and current specifications for backfilling the trench require a minimum of 3 lifts and 95% compaction. These specifications are not always followed. Instead an initial backfill is placed with the PED to hold the PED in place and then the trench backfilling is completed using one additional lift. ODOT construction personnel expressed doubts that it is possible to compact the material beside the PED or are concerned that excess compaction of the material above the PED will damage the PED. Several construction personnel indicated that pavement rehabilitation projects occur infrequently so they are not familiar with construction specifications.

5.22 DOT Survey

A two-page survey was sent to state Department of Transportation (DOT) engineers to question them about PED construction, performance of PED and performance of pavements with PED. The responses to the survey are discussed in Chapter 4 and summarized in Appendix A in Tables A-1 through A-12. Responses were returned from 30 states. Of the 30 responses, only eight states currently use PED frequently and the other states are evenly divided between seldom or never using PED. The major use for PED is on rehabilitation projects although some states use PED for new construction. Ohio specifies pipe underdrains (PU) for new construction. Some states allow the contractor to use PU in place of PED.

There is variation among the state DOT specifications for constructing with PED. Some of the states have modified their specifications based on their experiences with PED. States have specified and continue to specify products that are acceptable products. Some products are not allowed because of structural problems with the core or problems with the filter. According to a study in Kentucky, the flow capacity of the core is reduced significantly if the core and the filter fabric is compressed (See Table 3.4). Two states reported fabric clogging due to a clayey soil and to cement from deteriorated concrete. Conversely, Michigan reported no problems with filter clogging from soil or cement (Barnhart, 1996). Most states prefer that the open-face side be placed adjacent to the pavement to improve drainage from below the pavement. The states are equally divided as to whether the excavated material or a select granular backfill be used. Specifications for the backfill compaction vary from 1 to 3 lifts. Less information is available on the compactive effort that is required. Outlet pipes are required at spacings varying from 200 to 500 feet. The pipes are typically connected to precast concrete outlets or manholes. Some states expressed concern about maintenance of the outlets. The state of Michigan requires permanent markers to reduce damage to the outlets and so that they can be maintained more easily.

Considerable effort was expended by the states to evaluate the performance of PED. According to Table A-6, twelve states conducted field investigations that included either excavating the PED or examining PED with a borescope or both. Of these states, six of the states (IL, KY, MI, NY, OH, OK) reported that PED are often or always used for new construction or rehabilitation projects (See Table A-1). In evaluating the PED for structural problems, two failures and several major problems were reported. The problems were more frequently classified minor or insignificant indicating that there would not be a major reduction of the flow capacity of the cores. Minor or insignificant material problems were attributed to fabric tearing or damage to splices or drainage connections. The most common problems reported were due to fabric caking, fabric clogging, PED siltation and outlet blockage. These problems reportedly led to failure of the PED to drain or a significant reduction in drainage. Permittivity testing was conducted on the fabric material for this research in order to address some of these concerns. The types of pavement problems reported for this research included opening or movement of the joints, piping of the fines from the joints and pavement cracking. These problems were more often considered minor or insignificant. It would be difficult to determine if pavements have experienced problems because of PED without conducting extensive field evaluations.

The major objective for using PED is to increase pavement performance. Pavement performance will be increased if the PED are effective in removing water from below the pavements. The responses to a question on pavement performance were mixed with a slight edge to improved performance. Most states have not attempted to evaluate the effects of PED on pavement performance. It is a very complicated task because of the large amount of testing and pavement evaluation that must be conducted and because PED are most often installed on rehabilitation projects which often include other improvements such as joint repair and pavement overlays. One study conducted in Kentucky (Fleckenstein and Allen, 1996) concluded that pavement performance can be improved and pavement life can be significantly increased for most cases if the PED are installed properly.

5.23 Visual and Video Borescope Inspections

Visual inspections were conducted to investigate the condition of the PED by excavating a trench through the pavement shoulder. The PED were located under the pavement edge joint at all test sites as required by the specifications. Samples of PED approximately 17 inches long were removed and pictures were taken as shown in the figures in Chapter 4. All PED experienced some amount of J'ing near the bottom varying from just the bottom row of cusps to 3 or 4 rows. Some of the PED experienced compression in the top rows. The PED fabric material was compressed into core on all the PED. The PED left an impression of the rows of cusps in the soil when the sample was removed for permittivity testing. There was moist silt on the inside and wet soil on the outside of all of the PED varying from 2 inches high to 7 inches high. The moisture might be a high water mark in the PED indicating the maximum height of standing water in the PED. Water ran out of the PED after it was excavated at four of the sections. The outlet drain was blocked at one of the sections and it was not possible to locate the outlets at the other two sections. Either the outlet drains were not installed according to specifications or the outlets were damaged at some time after construction.

The video borescope probe was advanced the full 25 feet as long as the lens was not covered with silt. It was not possible to advance the probe near the bottom of the PED at five of the sections because of J'ing of the core. In some cases the probe was advanced until it reached refusal with silt blocking the lens so it was not possible to view the PED. There was compression of the core near the top of the PED at three locations that prevented the probe from being advanced. A classification system was developed to describe the condition of the PED as shown in Table 5.1 based on the borescope videos obtained during the inspections. The PED shown in the pictures in Chapter 4 were evaluated using the descriptions in Table

5.1 as shown in Table 5.2. The video pictures are only examples of the condition of the PED. Therefore Table 5.2 cannot be used to evaluate the condition of the PED in a quantitative sense without evaluating the VCR videos.

Table 5.1 - Video Borescope Evaluation of PED Condition

Fabric/core siltation	**Fabric Compression**	**Core Compression**
Clean, very little soil on filter and core	Insignificant, none or little penetration into core	None, no bending of cusps
Dirty, soil on fabric filter and core	Minor, some penetration into core	Some, J'ing of core and bending of cusps
Silted, siltation of core	Major, significant penetration into core	Collapse, buckling of cusps

Table 5.2 - Evaluation of Video Borescope Pictures

Figure/Picture	Fabric/core Siltation	Fabric Compression	Core Compression
4.3 / HAN Run 0	Outlet structure, good condition		
4.3 / HAN Run 1	Clean	Major	Some
4.3 / HAN Run 1	Dirty	Minor	None
4.3 / HAN Run 2	Clean	Minor	None
4.3 / HAN Run 2	Clean	Minor	None
4.3 / HAN Run 3	Clean	Major	Some
4.6 / OTT(1) Run 1	Dirty	Insignificant	Some
4.6 / OTT(1) Run 1	Dirty	Minor	Collapse
4.6 / OTT(1) Run 2	Clean	Insignificant	Collapse
4.6 / OTT(1) Run 2	Clean	Insignificant	Collapse
4.6 / OTT(1) Run 3	Clean	Major	Collapse
4.6 / OTT(1) Run 3	Clean	Major	Collapse
4.6 / OTT(1) Run 4	Clean	Minor	Collapse
4.6 / OTT(1) Run 4	Clean	Minor	Collapse
4.6 / OTT(1) Run 4	Clean	Minor	Some
4.6 / OTT(1) Run 4	Clean	Minor	None
4.6 / OTT(1) Run 4	Clean	Minor	Nome
4.6 / OTT(1) Run 4	Clean	Minor	Some
4.6 / OTT(1) Run 5	Dirty	Major	Collapse
4.6 / OTT(1) Run 5	Dirty	Minor	Some
4.6 / OTT(1) Run 4	PED outlet, good condition		
4.6 / OTT(1) Run 4	PED outlet, good condition		
4.6 / OTT(2) Run 2	Clean	Minor	Some
4.6 / OTT(2) Run 3	Dirty	Major	Collapse
4.6 / OTT(2) Run 3	Dirty	Minor	Some
4.6 / OTT(2) Run 4	Dirty	Minor	Some
4.6 / OTT(2) Run 4	Clean	Minor	None
4.6 / OTT(2) Run 5	Clean	Minor	None
4.6 / OTT(2) Run 5	Clean	Minor	Collapse
4.6 / OTT(2) Run 5	Clean	Minor	Collapse
4.9 / WAR Run 1	Dirty	Minor	Some
4.9 / WAR Run 1	Dirty	Minor	Collapse
4.9 / WAR Run 3	Dirty	Minor	Some
4.9 / WAR Run 3	Dirty	Minor	Some
4.9 / WAR Run 4	Clean	Minor	Some
4.9 / WAR Run 4	Clean	Minor	Some
4.9 / WAR Run 5	Clean	Minor	Some
4.9 / WAR Run 5	Clean	Minor	Some
4.9 / WAR Run 6	Dirty	Minor	Some

Table 5.2 - Evaluation of Video Borescope Pictures (Concluded)

Figure/Picture	Fabric/core Siltation	Fabric Compression	Core Compression
4.9 / WAR Run 6	Dirty	Minor	Collapse
4.9 / WAR Run 6	Clean	Minor	Some
4.9 / WAR Run 6	Clean	Minor	Collapse
4.12 / ATH Run 1	Clean	Minor	Some
4.12 / ATH Run 3	Clean	Minor	Some
4.12 / ATH Run	Clean	Minor	Some
4.12 / ATH Run	Dirty	Minor	Collapse
4.12 / ATH Run	Clean	Minor	Collapse
4.12 / ATH Run	Dirty	Minor	Collapse
4.12 / ATH Run	Clean	Minor	Some
4.12 / ATH Run	Clean	Minor	None
4.12 / ATH Run	Clean	Minor	Collapse
4.12 / ATH Run	Clean	Minor	None
4.12 / ATH Run	Clean	Minor	Some
4.12 / ATH Run	Dirty	Minor	Collapse
4.15 / JAC Run 1	Clean	Minor	Some
4.15 / JAC Run 3	Clean	Minor	Collapse
4.15 / JAC Run	Clean	Minor	Some
4.15 / JAC Run	Clean	Minor	Some
4.15 / JAC Run	Clean	Major	Some
4.15 / JAC Run	Clean	Minor	Collapse
4.15 / JAC Run	Dirty	Minor	Collapse
4.15 / JAC Run	Outlet pipe, good condition		
4.18 / LIC Run 1	Dirty	Minor	Some
4.18 / LIC Run 1	Dirty	Minor	Some
4.18 / LIC Run 2	Clean	Minor	Some
4.18 / LIC Run 2	PED outlet, good condition		
4.18 / LIC Run 3	Clean	Minor	Some
4.18 / LIC Run 3	Clean	Minor	Some
4.18 / LIC Run 4	Clean	Minor	Some
4.18 / LIC Run 4	PED outlet, good condition		
4.18 / LIC Run 5	Dirty	Minor	None
4.18 / LIC Run 5	Dirty	Minor	None
4.18 / LIC Run 6	Clean	Minor	Some
4.18 / LIC Run 6	Clean	Minor	None
4.18 / LIC Run 7	Clean	Minor	Collapse
4.18 / LIC Run 7	Clean	Minor	Collapse
4.18 / LIC Run 8	Clean	Minor	Collapse
4.18 / LIC Run 8	Clean	Minor	Collapse

5.25 Permittivity Testing

An apparatus was designed and built at the University of Toledo to test samples of PED for the permittivity of the fabric material. The apparatus is described in Chapter 4. The tests were conducted in the field. The test procedure required establishing a head difference, h, across the fabric material and measuring the discharge rate. Permittivity is computed using Equation 4.1 by dividing the discharge rate, Q/t, by the area of flow and the head difference, Q/(Ath). Each sample was tested at three or four different head differences using five trial measurements and the results of the five trials were averaged. A plot of average permittivity versus average head difference is shown in Figure 5.1 for all of the tests similarly to the figures in Chapter 4. The figure also shows results of testing conducted at the University of Toledo on samples of PED obtained from the manufacturers. The average flow rates were computed from the testing by dividing the discharge rate by the area of flow, Q/At. The average flow rates are plotted in Figure 5.2 versus the average head difference. For laminar flow conditions, the variation of flow rate should be linear.

Permittivity was used for this research to test the effects of clogging of the fabric material. It was possible to establish a large head difference across the fabric for the dirty samples from Jackson, Ottawa and Warren Counties. For these three counties the permittivity decreased as the head difference increased. The PED samples from Hancock, Licking and Athens Counties do not follow this same trend. The sample from Hancock County was clean so results are very similar to the tests on the samples provided by the manufacturers. The PED from Licking County is much older and dirtier than Hancock County but the results are similar. The fabric material of the PED from Licking County may have been more permeable. The variation of flow rate is approximately linear so near laminar conditions existed during the testing. Based on the results of the testing, it is concluded that the permittivity of the fabric material is not significantly reduced by the soil.

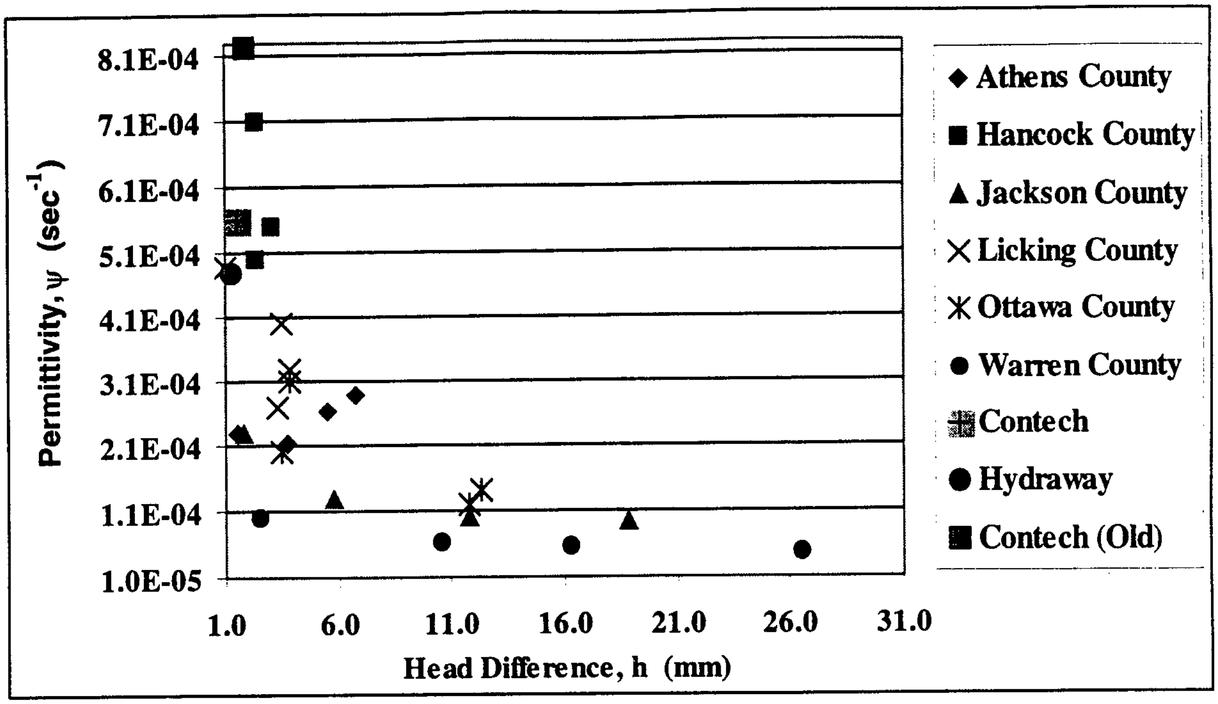


Figure 5.1 - Average Permittivity, All Tests

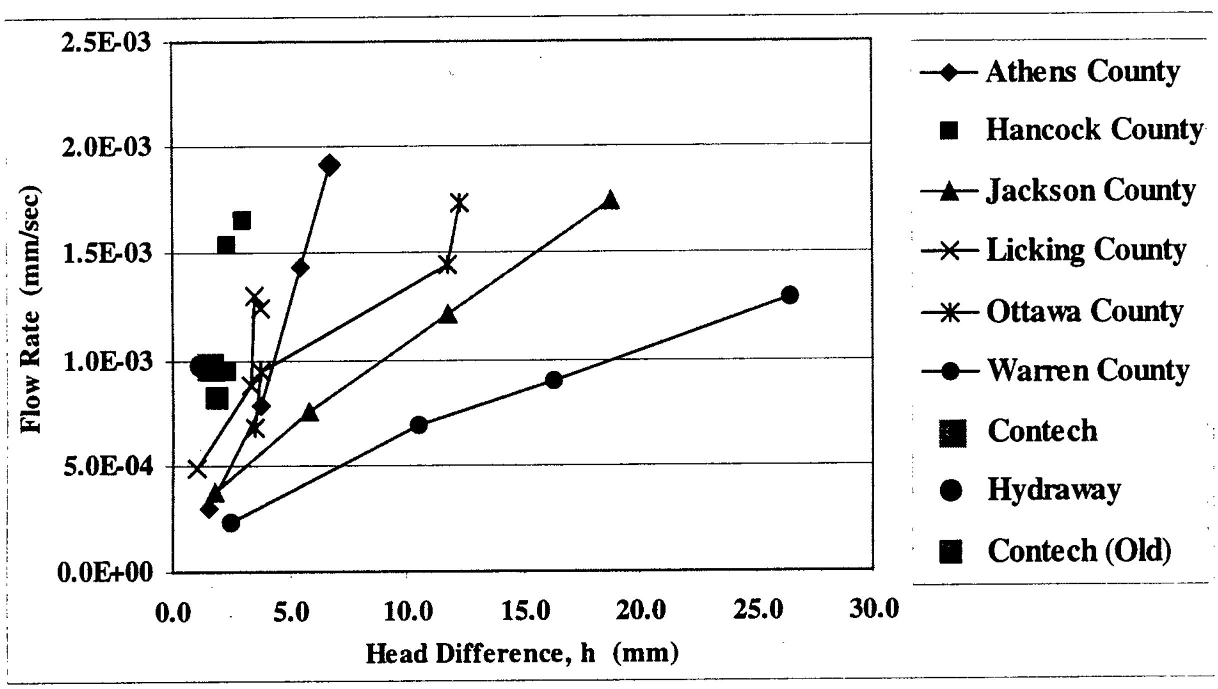


Figure 5.2 - Flow Rates, All Tests

5.3 Conclusions and Recommendations

The following conclusions and recommendations are based on the results of the survey of DOT personnel and the field evaluations.

1) There was some silt observed in all of the PED investigated. The silt inside the PED and the soil outside the PED was moist. There was above average rainfall during the period that the PED were investigated but the material probably remains moist during most of the year. This moisture can affect the base materials below the edge joint decreasing the pavement life.

2) There was a significant amount of soil on the outside and inside of the PED constructed using the excavated material for backfill. Use of a select granular backfill will increase the time and cost required for construction of the PED. However, some type of granular backfill should be used. The ODOT should consider alternatives to No. 8 granular backfill such as dense graded aggregates and puddled sand.

3) Placement of the PED on the outside of the trench with a select backfill on the inside of the PED will reduce clogging and siltation of the PED.

4) The permittivity of the filter material is not reduced significantly by clogging. Therefore, PED can be used effectively for drainage, particularly if a select granular material is used for the backfill.

5) The permittivity apparatus designed and built for this research performed adequately. An improved apparatus would enable ODOT personnel to conduct permittivity tests as a part of regular inspections.

6) There was compression of fabric into the core and/or J'ing and/or structural damage to the core in all sections investigated. This caused a reduction of the flow capacities of the PED. In spite of this, it is likely that the PED cores have adequate drainage capacity.

7) The cause of the damage to the PED is not known for certain, but more than likely it occurred during construction. Construction of the PED should be carefully inspected to reduce damage to the PED. ODOT construction personnel should be apprised of PED construction specifications on a regular basis.

8) Video borescope inspections could be used during construction to inspect PED before acceptance.

9) Three of the PED investigated had standing water in them due to problems with the drainage outlets. It is imperative that the drainage outlets be properly constructed and maintained to ensure drainage of the PED. It is recommended that permanent markers be installed close to all drainage outlets and that a regular maintenance program be required for district personnel to inspect and clean the drainage outlets.

10) Plans should be developed for regular inspections of PED and drainage outlets using the video borescope.

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APPENDIX A

SURVEY OF DOT EXPERIENCE WITH (PED)

SURVEY OF CURRENT DOT EXPERIENCE WITH PREFABRICATED EDGE DRAINS (PED)

Scope of Research:

Prefabricated edge drains (PED) consist of a polymeric material or a core wrapped with a fabric material. They are typically placed in narrow trenches directly below the pavement edge joint. This research includes prefabricated edge drains installed for construction of new pavements and as a part of pavement rehabilitation projects. Please summarize your state DOT experience with PED using the survey below.

A. Prefabricated Edge Drain Construction

1. PED use on DOT interstate projects:

O Always   O Seldom
O Often   O Never

PED use on other projects:

O Always   O Seldom
O Often   O Never

Note: If response is never, it is not necessary to proceed but please return the survey.

2. PED use:

New construction:
O PED and longitudinal pipe drains
O PED only

Rehabilitation projects:
O PED or longitudinal pipe or aggregate drains
O PED in addition to existing longitudinal pipe or aggregate drains

3. PED specifications (List current and previous requirements if different, when and why change made):

O Sample specifications are attached
O Specifications summarized below (See questions 4 through 9 below.)

4. Types of PED accepted: Brand names (Manufactures)

____
____
____
____

O Pipe underdrains accepted alternative

5. Orientation of PED (Circle P for previous or C for current specification, if applicable):

O Open-face (weak) side towards pavement/base   (P C)
O Open-face (weak) side away from pavement/base   (P C)
O Manufacturer's recommendation   (P C)

6. Placement of PED (Circle P for previous or C for current specification, if applicable):

O Adjacent to pavement/base with backfill on outside of PED   (P C)
O Against outside of trench with backfill between PED and pavement/base   (P C)

7. Type of backfill (Circle P for previous or C for current specification, if applicable):

O Selected granular backfill as specified   (P C)
O Excavated material, if granular   (P C)
O Excavated material   (P C)

8. Compaction specifications (Circle P for previous or C for current specification, if applicable):

Number of lifts for natural material _______   Degree of compaction __________   (P C)
Number of lifts for granular material _______   Degree of compaction __________   (P C)

9. Drainage outlets (Circle P for previous or C for current specification, if applicable):

Spacing of outlet pipes ____________________   (P C)

Outlet to:
O Existing longitudinal pipe underdrain   (P C)
O Precast concrete outlet   (P C)
O Catch basin or manhole   (P C)

B. Field Performance of PED (Please complete this section for each brand name or manufacturer)

1. Method of evaluation:

O Construction inspection
O Pavement condition assessment
O Excavation and visual inspection of PED
O Video borescope

2. PED structural problems: (F = failure PED to drain; M = major problems, drainage significantly reduced; M = minor problems, moderate drainage reduction; I = Insignificant drainage reduction)

	F	M	M	I
O Twisting	___	___	___	___
O J'ing	___	___	___	___
O Core Compression	___	___	___	___
O Fabric penetration of core	___	___	___	___

O No problems observed

3. PED material problems: (F = failure of PED to drain; M = major problems, drainage significantly reduced; M = minor problems, moderate drainage reduction; I = Insignificant, slight drainage reduction)

	F	M	M	I
O Fabric tearing	___	___	___	___
O Splicing	___	___	___	___
O Outlet connection	___	___	___	___
O Outlet conduit	___	___	___	___

O No problems observed

4. PED drainage problems: (F = failure of PED to drain; M = major problems, drainage significantly reduced; M = minor problems, moderate drainage reduction; I = Insignificant, slight drainage reduction)

	F	M	M	I
O Fabric caking	___	___	___	___
O Fabric clogging	___	___	___	___
O Edge drain siltation	___	___	___	___
O Outlet blockage	___	___	___	___

O No problems observed

5. Pavement problems associated with PED: (F = failure of pavement; M = major pavement damage; M = minor pavement damage; I = Insignificant pavement damage)

	F	M	M	I
O Edge joint vertical movement	___	___	___	___
O Edge joint opening	___	___	___	___
O Piping of fines from edge joints	___	___	___	___
O Pavement cracking	___	___	___	___

O No problems observed

C. Pavement Performance With PED

1. Pavement performance with PED

O Significantly better than those without PED
O Slightly better
O About the same
O Worse
O Some are better, some are worse
O No studies have been done

2. Recommendations from pavement performance studies

____
____
____
____
____
____
____

Table A-1 - Survey of DOT Experience with PED, Question A.1 - A.3

State	A.1. PED Constr.		A.2. PED Use		A.3. PED Specs.
	Interstate	Other	New Constr.	Rehabilitation Proj.	
AL	Often	Often	PED only	PED or PU or AD	Sample specs. attach.
AR	Seldom	Seldom		PED or PU only	Sample specs. attach.
CO	Never	Never			
DE	Never	Never			
GA	Seldom	Never	NA	PED or PU or AG	See questions 4-9
HA	Never	Never			
IL	Often prev.	Not now	PED & PU	PED or PU or AG	NA
IN	Seldom	Seldom	NA	PED in addition to existing PU or AG	NA
IA	Never	Seldom	PED only	Not given	Sample specs. attach.
KS	Never	Seldom	NA	PED or PU or AG	See questions 4-9
KY	Often	Often	PED & PU	PED or PU or AG	
LA	Always	Seldom	PED only	PED or PU or AG	Sample specs. attach.
ME	Seldom (1)	Never	NA	PED or PU or AG (once)	Sample specs. attach.
MD	Seldom	Seldom	PED or PU	PED or PU or AG	Sample specs. attach.
MI	Often	Often	PED & PU	PED or in addition to existing PU or AG	Sample specs. attach.
MO	Seldom	Seldom	PED or PU	PED or PU or AG	Sample specs. attach.
NE	Never	Never			
NV	Never	Never			
NJ	Seldom	Seldom	PED or PU	NA	None
NM	Seldom	NA	NA	PED or PU or AG	NA
NY	Often	Seldom	PU only	PED or PU or AG	Note different sample specifications
NC	Seldom	Seldom	PED &PU	PED or PU or AD	See questions 4-9
OH	Often	Seldom	PED &PU		Sample specs. attach.
OK	Often	Seldom	PED & PU	NA	See questions 4-9
SC	Seldom	Seldom	NA	PED or PU or AD	Sample specs. attach.
SD	Seldom	Never	PED only	PED or PU or AD	
TN	Never	Never			
TX	Never	Never			
VT	Never	Never			
WY	Never	Never			

Table A-2 - Survey of DOT Experience with PED, Question A.4

	A.4. Types of PED accepted
State	**Brand names and manufacturers**
AL	Hydraway, PDS-30, AdvanEdge, LD-30, Strip Drain 100, Akwadrain
AR	Not given
CO	
DE	
GA	Hydraway, Strip Drain 100
HA	
IL	Formerly allowed AdvanEdge, Contech Strip Drain and Hydraway. Contech Strip Drain and Hydraway disallowed due to structural problems w/ core. ADS due to poor draining fabric but may be reapproved w/ new geotextile.
IN	
IA	Akwadrain, Miradrain, Hydraway, AdvanEdnge, Strip Drain
KS	NA
KY	AdvanEdge, KY Trans Center recently recommended cuspated & post type edge drains not be used until tilting, rolling, J-ing, & fabric intrusion is solved
LA	Not given, pipe underdrains accepted alternative
ME	Hydraway by Monsanto for one trial
MD	NA
MI	Hydraway, PDS-20 and 30, AdvanEdge, Strip Drain, Akwadrain, Hitek 20
MO	Hydraway, Strip Drain
NE	
NV	
NJ	Project by project as designed Pipe underdrains accepted alternative
NM	NA
NY	Approved list attcd. --entry to be made
NC	AdvanEdge, Akwadrain, Hydraway, PDS 30 Highway Edgedrain
OH	Hydraway (Monsanto), Strip Drain (Contech), AdvanEdge (ADS), Prodrain, Pipe underdrains accepted alternative
OK	No PED used in the last 6 to 8 years, pipe underdrains accepted alternative
SC	NA
SD	
TN	
TX	
VT	Have a moratorium on PED due to blocking of PED in several instances and general concerns about their performance. Use conventional perforated pipe.
WY	

Table A-3 - Survey of DOT Experience with PED, Question A.5 - A.6

State	A.5. Orientation of PED		A.6. Placement of PED	
	Open-face (weak) side	P or C	Adjacent to Pavement	Against outside of Trench
AL	Towards pavement/base	C	C	
AR	NA		NA	
CO				
DE				
GA	Towards pavement/base	P	P	
HA				
IL	Towards pavement/base	P & C		C
IN				
IA	Manufacturer's recommendation	P & C	P and C	
KS	Manufacturer's recommendation	C	C	
KY	Towards pavement/base Away from pavement/base	P C	P	C
LA	Manufacturer's recommendation		C	
ME	Manufacturer's recommendation		C	
MD	Towards pavement/base		C	
MI	Manufacturer's recommendation			
MO	Towards pavement/base	C	C	
NE				
NV				
NJ	Manufacturer's recommendation		NA	
NM	Towards pavement/base		C	
NY	Towards pavement/base	C	C	
NC	Towards pavement/base		C	
OH	Towards pavement/base Away from pavement/base	P C	C	
OK	Towards pavement/base	P	P	
SC				
SD				
TN				
TX				
VT				
WY				

Table A-4 - Survey of DOT Experience with PED, Question A.7 - A.8

State	A.7. Type of Backfill			A.8. Compaction Specifications		
				Number of Lifts		
	Select Granular	Excav., if Granular	Excav. Material	Natural Material	Granular Material	Degree of compaction
AL			C (must pass 2-in. sieve)			
AR	NA			NA		
CO						
DE						
GA			P	2		5000 lb force (P)
HA						
IL	C		P	2	2	90% T-99 (P & C)
IN					1	
IA			P and C	1	1	Not specified (P & C)
KS			C			
KY	C		P	P	C	
LA	C				1	
ME		C			3 to 4	
MD	C		C		2	NA
MI	C				2	Vibrating plate compact.
MO			C	2		5000lbs (C)
NE						
NV						
NJ	P and C			NA		
NM			C	NA		
NY	C		C	3	3	
NC	C		C	Engineer		Specified by engineer
OH	C		P	3	2	
OK	C		C	NA		
SC						
SD						
TN						
TX						
VT						
WY						

Table A-5 - Survey of DOT Experience with PED, Question A.9

	A.9. Drainage outlets
State	**Spacing of outlets Outlet to: Existing PU, Precast concret outlet, Catch basin**
AL	800' or 240m and precast concrete outlet (C)
AR	NA
CO	
DE	
GA	400' for grade > 0.25% and 250' for < 0.25% (P)
HA	
IL	500' (P & C) and precast concrete outlet (P & C)
IN	
IA	Spacing 500' (P& C) Outlet specifications attached
KS	Spacing 500' (C) and precast concrete outlet (C)
KY	Spacing 250' & 500', precast concrete & catch basin or manhole (C)
LA	Spacing 250' and precast concrete outlet (C)
ME	Spacing not given , outlet pipe daylighted through shoulder
MD	Spacing 200', precast concrete outlet and/or catch basin or manhole
MI	Spacing 500, catch basin or manhole
MO	Spacing - 250' (C) and catch basin or manhole (C)
NE	
NV	
NJ	NA
NM	Spacing ~ 300'
NY	Spacing 250' (+/-) C and pipe on slope daylighted
NC	Spacing 300' (+/-), precast concrete outlet &/or catch basin or drop inlet
OH	500 feet max., outlet to existing PU or precast concrete outlet
OK	Spacing approximately 300' and precast concrete outlet (P)
SC	
SD	
TN	
TX	
VT	
WY	

Table A-6 - Survey of DOT Experience with PED, Question B.1

State	B.1. Method of evaluation Construction inspection, Pavement condition assessment, Excavation and visual inspection, Video borescope
AL	
AR	
CO	
DE	NA
GA	Construction inspection, Pavement condition assessment, Excavation and visual inspection, Video borescope
HA	NA
IL	Excavation and visual inspection
IN	NA
IA	Construction inspection, Pavement condition assessment, Excavation and visual inspection, Video borescope
KS	Pavement condition assessment, Video borescope
KY	Construction inspection, Pavement condition assessment, Excavation and visual inspection, Video borescope
LA	NA
ME	Pavement condition assessment
MD	Construction inspection
MI	Construction inspection, Pavement condition assessment, Excavation and visual inspection, Video borescope
MO	Pavement condition assessment, Excavation and visual inspection
NE	NA
NV	NA
NJ	Construction inspection
NM	Pavement condition assessment, Excavation and visual inspection, Video borescope
NY	Construction inspection, Pavement condition assessment, Excavation and visual inspection
NC	Video borescope (for HYDRAWAY DRAIN)
OH	Construction inspection, Excavation and visual inspection, Video borescope
OK	Construction inspection, Video borescope
SC	Construction inspection
SD	Construction inspection
TN	NA
TX	NA
VT	NA
WY	NA

Table A-7 - Survey of DOT Experience with PED, Question B.2

State	B.2. PED Structural Problems F = failure PED to drain; M = major problems, drainage significantly reduced; M = minor problems, moderate drainage reduction; I = Insignificant drainage reduction																
	Twisting				J'ing				Core compression				Fabric Pene-tration of core				No Problems
	F	M	M	I	F	M	M	I	F	M	M	I	F	M	M	I	
AL																	
AR																	
CO																	
DE																	
GA			M								M		F				
HA																	
IL		M				M				M						I	
IN																	
IA				I			M				M				M		
KS							M									I	
KY		M				M				M				M			(Open cores)
LA																	X
ME																	
MD																	X
MI							M				M				M		
MO				I				I				I			M		
NE																	
NV																	
NJ																	(No infor.)
NM																	
NY				I			M				M				M		
NC								I									(Hydraway)
OH							M								M		
OK					F					M	M						(Improper installation)
SC																	X
SD																	X
TN																	
TX																	
VT																	
WY																	

Table A-8 - Survey of DOT Experience with PED, Question B.3

State	B.3. PED material problems F = failure of PED to drain; M = major problems, drainage significantly reduced; M = minor problems, moderate drainage reduction; I = Insignificant, slight drainage reduction																
	Fabric Tearing				Splicing				Outlet Connection				Outlet Conduit				No Problems
	F	M	M	I	F	M	M	I	F	M	M	I	F	M	M	I	
AL																	
AR																	
CO																	
DE																	
GA			M														
HA																	
IL											M				M		
IN																	
IA				I				I				I				I	
KS																	X
KY				I				I			M			M			(new pipe)
LA																	X
ME																	
MD																	X
MI			M				M				M				M		
MO							M				M				M		
NE																	
NV																	
NJ																	
NM																	X
NY				I				I				I				I	
NC																	X (Hydraway)
OH			M				M				M				M		
OK													F				
SC												I				I	
SD																	X
TN																	
TX																	
VT																	
WY																	

Table A-9 - Survey of DOT Experience with PED, Question B.4

State	B.4. PED drainage problems F = failure of PED to drain; M = major problems, drainage significantly reduced; M = minor problems, moderate drainage reduction; I = Insignificant, slight drainage reduction																
	Fabric caking				Fabric clogging				Edge drain siltation				Outlet blockage				No Problems
	F	M	M	I	F	M	M	I	F	M	M	I	F	M	M	I	
AL																	
AR																	
CO																	
DE																	
GA	F								F							I	
HA																	
IL		M				M				M					M		
IN																	
IA		M			F						M					I	
KS											M			M			
KY				I				I			M			M			(need maint.)
LA																	X
ME												I		M			(outlet ice)
MD																	X
MI			M				M					I		M			
MO		M				M				M				M			
NE																	
NV																	
NJ																	
NM							M							M	M		
NY			M			M					M				M		
NC								I				I					(Hydraway)
OH			M								M				M		
OK	F				F				F								
SC										M				M			
SD																	X
TN																	
TX																	
VT																	
WY																	

Table A-10 - Survey of DOT Experience with PED, Question B.5

State	B.5. Pavement problems associated with PED F = failure of pavement; M = major pavement damage; M = minor pavement damage; I = Insignificant pavement damage																
	Edge joint vertical movement				Edge joint opening				Piping of fines from edge joints				Pavement cracking				No Problems
	F	M	M	I	F	M	M	I	F	M	M	I	F	M	M	I	
AL																	
AR																	
CO																	
DE																	
GA		M									M			M			
HA																	
IL			M				M				M						
IN																	
IA																	X
KS			M				M										
KY			M				M					I				I	
LA																	X
ME														M			
MD																	X
MI																	
MO				I				I				I				I	
NE																	
NV																	
NJ																	
NM																	X
NY		M				M						I			M		
NC																	NA
OH																	X
OK													F				
SC																	X
SD																	X
TN																	
TX																	
VT																	
WY																	

Table A-11 - Survey of DOT Experience with PED, Question C.1

State	C.1. Pavement performance with PED
AL	
AR	No studies have been done
CO	
DE	
GA	Worse
HA	
IL	Some are better, some are worse.
IN	
IA	Slightly better
KS	About the same
KY	Significantly better than those without PED
LA	Significantly better than those without PED
ME	Worse
MD	No studies have been done
MI	
MO	Slightly better
NE	
NV	
NJ	No Information available
NM	Slightly better
NY	Slightly better
NC	No studies have been done
OH	
OK	**About the same
SC	No studies have been done
SD	No studies have been done
TN	
TX	
VT	
WY	

Table A-12 - Survey of DOT Experience with PED, Question C.2

State	C.2. Recommendations from pavement performance studies
AL	
AR	
CO	
DE	
GA	Not given
HA	
IL	Discontinue use of Monsanto and Contech due to structural problems. Discontinue use of heat-bonded, non-woven, polypropylene due to flow problems. Use sand backfill instead of insitu for backfill to help prevent clogging of geotextile. Evaluate conditions
IN	Indiana has stopped using PED (since Sep. 95). Instead of PED INDOT is using 4" group " K" pipe for drainage for rehabilitation projects.
IA	PED confined to granular base situations. Bedrock and Loess soils. We have had complete failure (rapid) due to fabric clogging from cement (deteriorated concrete) and from clay in high flow situations
KS	Attention to the details of outlet pipe must be made. Insure pipes are constructed to grade and plain and that outlets are above flow line of ditch.
KY	Lab, Flow/compression test indicates that significant reductions in flow can occur in open type panel drains (post or cuspated) when J'ing or fabric in tension occurs. Report KTC - 96 - 77 " Evaluation of edge drains on I64 Fayette, Scott, and Wood Counties.
LA	Not mentioned
ME	Not to use
MD	NA
MI	PED are performing well. Several specific recommendations on design and construction for PED in report.
MO	NA
NE	
NV	
NJ	No Info available
NM	NA
NY	** Some drains not working, no obvious cause may be inappropriate fabric for soil type. For C2 see attached policy.
NC	NA
OH	
OK	Cease using unless open graded drainage layer is used in pavement. Provide clean out ports. Currently ODOT does not recommend use. Now using Trench/No. 57 Stone/Fabric Wrap/ 4" diameter slotted HDPE pipe at edge of driving lane. ADS drain performing
SC	Greatly reduced usage of PED in general due to concern about future maintenance. PED are only used where severe drainage problems are noted during rehabilitation.
SD	NA
TN	
TX	
VT	
WY	Stopped using because of concerns with PED performance. Use perforated pipe.