Evaluation of Prefabricated Edge Drains in Ohio

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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 all fifty states and Ohio Department of Transportation 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.

This paper summarizes results and conclusions from the survey and the field inspections on PED in Ohio. Specifications for installing PED vary considerably. The primary problems that have occurred are deformation of the PED, compression of the filter into the core, clogging of the filter, sedimentation of the core and blockage of drainage outlets. The deformations occur during installation of the PED. Some clogging of the filter and sedimentation of the core are expected since the materials immediately surrounding the PED consist of native fine-grained soils and granular backfill with some fines. The problems result in reduced drainage capacity. However, the PED are effective in providing drainage provided the drainage outlets are not blocked. Recommendations are provided for construction specifications to ensure adequate drainage capabilities and for highway maintenance personnel for inspecting and maintaining PED.

Key Words: Prefabricated edge drains; construction specifications; video borescope; permittivity testing.

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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 for more than ten years. PED consist of a thin support core wrapped in a geosynthetic fabric wrap. American Society for Testing and Materials (ASTM) specifications were developed for PED compressive strength (1), core flow capacity (2) and fabric permittivity (3). However, there is concern that deformation and siltation of the drains render them ineffective for drainage.

Specifications for installing prefabricated edge drains vary among the states using them. Specifications can be summarized as those concerned with 1) the type, orientation and location of the PED in the trench; 2) the backfill materials and compaction procedures; and 3) location and construction of drainage outlets and outlet structures. This paper summarizes responses from the survey sent to all state DOT and from ODOT construction personnel on questions concerning construction procedures and performance of PED.

The research included 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 that a hydraulic gradient could be applied to the pavement side of 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.

RESEARCH OBJECTIVE AND APPROACH

The objective of the research was to evaluate installation procedures for PED and to investigate the condition of PED installed in Ohio. Specifications for installing PED by state DOT were to be determined. PED was to be excavated and inspected at several locations in Ohio. The research approach included the following:

- Literature review of previous experience with PED installation and performance;
- Survey of state DOT on installation, and performance of PED and pavements constructed with PED;
- Survey of ODOT construction personnel on experience with PED installation;
- Visual inspection of PED installed in Ohio;

- Permittivity testing of PED samples; and
- Recommendations for installation and maintenance of PED.

OVERVIEW OF RESEARCH ON PED

Results from several studies on PED have been reported. Goddard (4) reported information on the design of prefabricated edge drains. Highlands et al. (5) and Koerner and Hwu (6) reported information on both the design of prefabricated edge drains and the costs of construction. Laboratory testing to evaluate the structural capacity of vertical edge drains has been reported (7). A report by Elsharief (8) 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 et al. (9). Dempsey (10) reported results of flow tests conducted both in the laboratory and the field. A project in Ohio that included the measurement of flow from edge drains was reported by Hinshaw (11). Bodocsi et al. (12) developed methods for testing the field permeability of pavement bases. Field investigations in which video systems were used to evaluate pavement edge drains were conducted in several states (13-16). Other DOT field investigations were conducted to evaluate the condition of PED (17,18).

ODOT PED PROJECTS

PED were specified for construction on over 72 ODOT projects between 1989 and 1993. The total length of PED specified for installation was over 6 million linear feet. The total cost was $14.05 million dollars for an average of $2.12 per linear foot. Plans and specifications for installation of PED dated 3/20/91 called for the placement of shallow edge drains below the pavement edge joints in contact with the pavement and base materials. The first layer of backfill was to be placed simultaneously with the trenching operation to hold the edge drain in place. The specifications allowed the use of the excavated materials for the PED backfill. Excavated materials were required to be backfilled in 3 lifts minimum with each lift of uncompacted material not exceeding 8 inches in thickness. The material properties of acceptable PED were described referring to ASTM standards (1, 2). Acceptable PED were listed by name and manufacturer. Specifications for splicing, fittings and outlet pipe were included. Current ODOT specifications dated 1/1/97 state that the PED is to be placed on the outside of a 4 inches wide by 24 inches deep trench. Trenches are backfilled with No. 8 natural aggregate using at least one backfill layer. Drainage outlet must be installed every 1000 feet.

SURVEY OF INSTALLATION AND PERFORMANCE OF PED

Engineers from state departments of transportation and the ODOT were querried to investigate current practices for installation of edge drains and to evaluate the performance of edge drains. A summary of the survey results follows.

Survey of State DOT

A two-page survey was sent to departments of transportation in all states including questions about PED construction specifications (Section A), performance of PED (Section B) and performance of pavements with PED (Section C). Responses were returned from 30 states. The responses from the survey are tabulated with the number of responses to each question shown in parentheses.

Section A - Prefabricated Edge Drain Construction

The reponses on PED constrution are shown in Table 1. Of the 30 responses, only eight states currently use PED frequently and the other states are evenly divided between seldom or never using PED. There is considerable variation among the state DOT specifications for constructing with PED. Some of the states have modified their specifications and reported information on previous (P) and current (C) specifications, as requested in the survey. 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. Some states use both PED under the pavement edge joints as well as longitudinal pipe underdrains (PU). All states that use PED have specifications for construction and payment for PED.

States have specified and continue to specify products that are acceptable products. PED from at least nine different manufacturers have been installed in the states that responded to the survey. 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. Two states reported fabric clogging due to a clayey soil and to cement from deteriorated concrete (17, 18). Michigan reported no problems with filter clogging from soil or cement (16).

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 area, but is weaker, open-face (weak) side. Most states specify that the weak side should face towards the pavement or base materials to provide better drainage for the pavement drainage layers. 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 4-inch wide trenches. Most states now place the PED adjacent to the pavement and base materials with the backfill on the outside of the PED. 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. A few states place the PED adjacent to the outside of the trench with the backfill between the pavement and base materials.

Outlet pipes are connected to the PED at a specified spacing to remove the water from the PED. The spacing varies from 200 feet to 1000 feet. The outlet spacing should depend on the pavement grade. Most states, however, just specify an outlet spacing of from 250 to 500 feet. 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. Some states expressed concern about maintenance of the outlets. Michigan DOT requires permanent markers to reduce damage to the outlets and so that they can be maintained more easily.

Section B - Field Performance of PED

Several of the responding states performed field evaluation studies of PED as described in Table 2. PED are inspected during installation and sections of PED have been excavated for visual inspections during construction. PED were investigated after construction by pavement condition assessments or visual inspections. Twelve states conducted field investigations that included either excavating the PED or examining PED with a borescope or both. The hydraulic capacity of the cores is reduced when PED structural problems occur. Major problems occur with twisting, J'ing, core compression and fabric penetration of the core, but most problems are considered minor or insignificant. In evaluating the PED for structural problems, two failures and several major problems were reported. 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. Failures and major problems were reported because of fabric caking, fabric clogging, edge drain siltation and outlet blockage. 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 were more often considered minor or insignificant. Several states reported having no pavement problems associated with PED.

Section C - Pavement Performance With PED

The major objective for using PED is to increase pavement performance by removing water from below the pavement edges. Information from investigations on the performance of pavements with PED is shown in Table 3. The responses to a question on pavement performance were mixed with a slight edge to improved performance. A few respondents indicated that bad pavement performance was caused by specific construction problems. 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 (19) concluded that pavement performance can be improved and pavement life can be significantly increased for most cases if the PED are installed properly.

Space was provided on the survey for recommendations from the results of pavement performance studies. Many of the respondents provided very useful comments on their experience with PED. 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.

Survey of ODOT Personnel

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.

EVALUATION OF PED IN OHIO

Visual and Video Borescope Inspections

Visual inspections were conducted to investigate the condition of the PED by excavating a small trench through the pavement shoulder at six construction projects (Table 4). 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 of the PED. All PED experienced some amount of J'ing near the bottom varying from just the bottom row of cusps to 5 or 6 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. Water ran out of the PED after it was excavated at four of the sections. The outlet drain was blocked or damaged at two of the sections and it was not possible to locate the outlets at the other two sections.

A video borescope probe with a 25-foot fibreoptic cable was used for the investigation. The probe was advanced the full 25 feet wherever possible. Example video pictures showing either no problems or major problems with fabric siltation, fabric compression into the core and compression of the core are provided in Figures 1 through 6. 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 but silt blocked 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.

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 (Figure 7). 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 1.

$$\psi = Q R_t / h A t \qquad (1)$$

Where ψ = permittivity (S^{-1});

Q = quantity of flow (L^3);

h = head difference of water across the fabric 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).

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 8. The figure also shows results of testing conducted at the University of Toledo on samples of PED obtained from the manufacturers. 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 from Hancock, Licking and Athens Counties does 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.

CONCLUSIONS AND RECOMMENDATIONS

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

1) Structural damage to the PED core occurs during installation if the PED is not in intimate contact with the side of the trench before any backfilling of the trench occurs. Backfill placed adjacent to or above the PED causes J'ing near the bottom and C'ing near the top. The possible causes for the lack of contact are:
    a) The trencher is normal to the pavement during excavation. Since pavements are normally sloped, the side of the trench is not vertical. The PED is placed in the trench under tension maintaining the PED in a vertical position. If a PED is placed vertically in the trench with the top against the side of the trench, there is a gap at the bottom that can be filled by J'ing of the PED. If a PED is placed vertically in the trench with the bottom against the side of the trench, there is a gap near the top the the PED that will cause compression or C'ing near the top.
    b) Highways are contructed with horizontal curves. The tension in the PED can tend to pull the PED away from the side of the trench resulting in compression of the PED core.

c) Highways are also constructed with vertical curves. On sag vertical curves the tension in the PED wants to pull the PED out of the trench. The top of the PED will be compressed if the PED moves up in the trench. On crest vertical curves the PED is compressed into the trench causing J'ing.

Recommendations: Install PED in trenches so that contact is maintained with the side of the trench during backfilling. This may require reduction of tension on the PED from the installation equipment or hand placement of the PED in the trenches. Construction of the PED should be carefully inspected to reduce damage to the PED. DOT construction personnel should be apprised of PED construction specifications on a regular basis.

2) Trenches for drainage outlets are excavated after backfilling PED trenches, sometimes resulting in damage to the PED. This results in reduced flow to the outlet. Recommendation: Construction constrol so that PED are not damaged or excavate outlet trench before completion of PED trench backfill.

3) Four 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. Recommendations: Drainage outlets should be installed at a maximum spacing of 500 feet. Use larger outlet structures than those presently used to reduce damage and blockage of the structures. Install permanent pavement markers close to all drainage outlets. Annual pavement management personnel should rate the condition of each outlet for future mainenance needs.

4) There was 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. However, 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. Recommendation: Efforts should be made to reduce the amount of silt in PED by reducing the amount of fines in the backfill.

5) There was a significant amount of soil on the outside of the fabric for 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. Recommendations: Some type of granular backfill should be used. Alternatives to No. 8 granular backfill such as dense graded aggregates and puddled sand should be considered. 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.

6) Based on the permittivity testing, the permittivity of the filter material is not reduced significantly by clogging. Recommencation: PED can be used effectively for drainage, particularly if a select granular material is used for the backfill.

7) The permittivity apparatus designed and built for this research performed adequately. Recommendation: An improved apparatus is recommended if permittivity testing is to be performed.

8) There was compression of fabric into the core, J'ing and structural damage to the core and siltation of the core at all sections investigated. This results in a significant reduction of the flow capacities of the PED. In spite of this, it is possible that the PED have significant drainage capacity if the outlet drains perform properly. Recommendation: Continue to use PED or pipe underdrains (PU) for new and rehabilitation projects.

9) Compression of the fabric into the core occurs frequently. PED with a double-sided core are stronger than PED with single-sided cores. However, this advantage may be offset by a reduction in drainage area. Recommendation: Products designed for both core strength and drainage area should be recommended whenever they are available.

10) Visual and video borescope inspections can be used to evaluate the condition of PED, drainage outlets and other drainage systems. However, these types of investigations are not easy to carry out. Recommendations: Use video borescope equipment to inspect the ends of drainage outlets. Use permanent viewports for video boresecope inspection of PED.

11) Visual and video borescope inspections can be used, however, they are not used to correct problems. Recommendation: Design and construction personnel should do everything possible to ensure that underdrains are properly installed so that they will be effective in providing drainage.

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Table 1 - Prefabricated Edge Drain Construction

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

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

A.2. PED use:

New construction:
PED and longitudinal pipe drains **(6)**
PED only **(4)** or PU **(3)**

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

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.) **(4)**

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)**

Table 2 - 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**		**F**	**M**	**M**	**I**
Twisting	(0)	(2)	(1)	(3)	Core Compression	(0)	(3)	(4)	(1)
J'ing	(1)	(2)	(4)	(2)	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**		**F**	**M**	**M**	**I**
Fabric tearing	(0)	(0)	(2)	(3)	Outlet connection	(0)	(0)	(4)	(2)
Splicing	(0)	(0)	(2)	(3)	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**		**F**	**M**	**M**	**I**
Fabric caking	(2)	(3)	(2)	(1)	Edge drain siltation	(2)	(3)	(5)	(2)
Fabric clogging	(2)	(3)	(1)	(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)**

Table 3 - 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 September, 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	Laboratory flow/compression tests indicate 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.

Table 4 - Field Investigation of PED in Ohio

Year of Constr.	ODOT District	Route	Type of PED	Outlet Location	Type of Backfill	Drainage Condition	Fabric Condition	Fabric Compression	Core Compression
1995	1	I-75	ProDrain	800' DS.	No. 8's	Good	Clean	Minor	Bottom row
1992	2	US 2	Hydraway	3' DS.	Excavated	Poor	Dirty	Minor	Bottom 5 and top 5 rows
1991	8	I-71	Hydraway	None	Excavated	Poor	Dirty	Minor	Bottom 4 and top 2 rows
1992	10	US 50	Contech	None	Excavated	Poor	Dirty	Minor	Bottom row
1991	9	US 32	ProDrain	12' DS	Excavated	Poor	Dirty	Minor	Bottom 1 and top 2 rows
1989	5	I-70	Hydraway	20' DS	Excavated	Good	Dirty	Minor	Bottom 3 and top 1 rows

Figure 1 - Video Borescope Picture Showing Clean Fabric Material

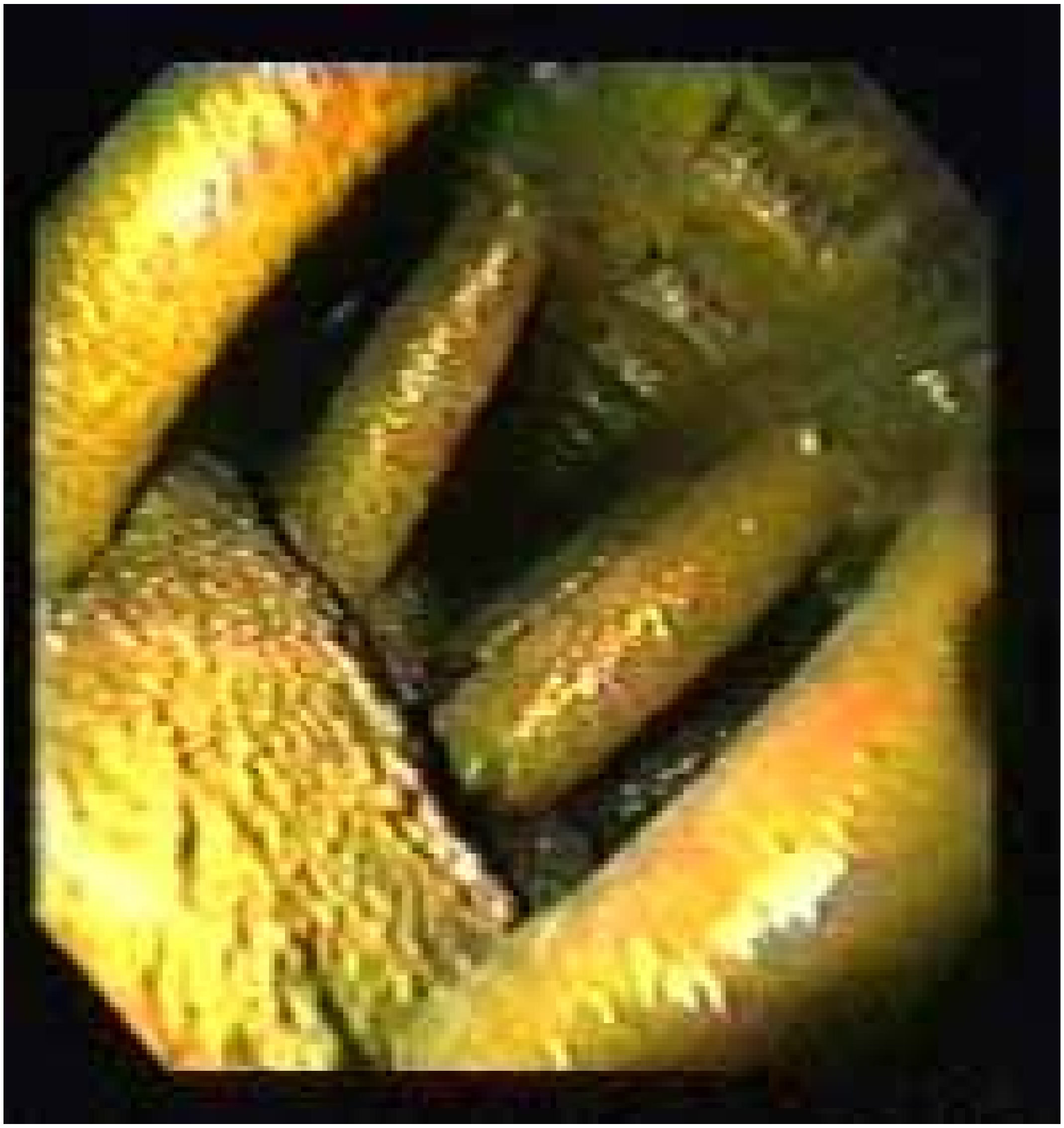

Figure 2 - Video Borescope Picture Showing Dirty Fabric Material

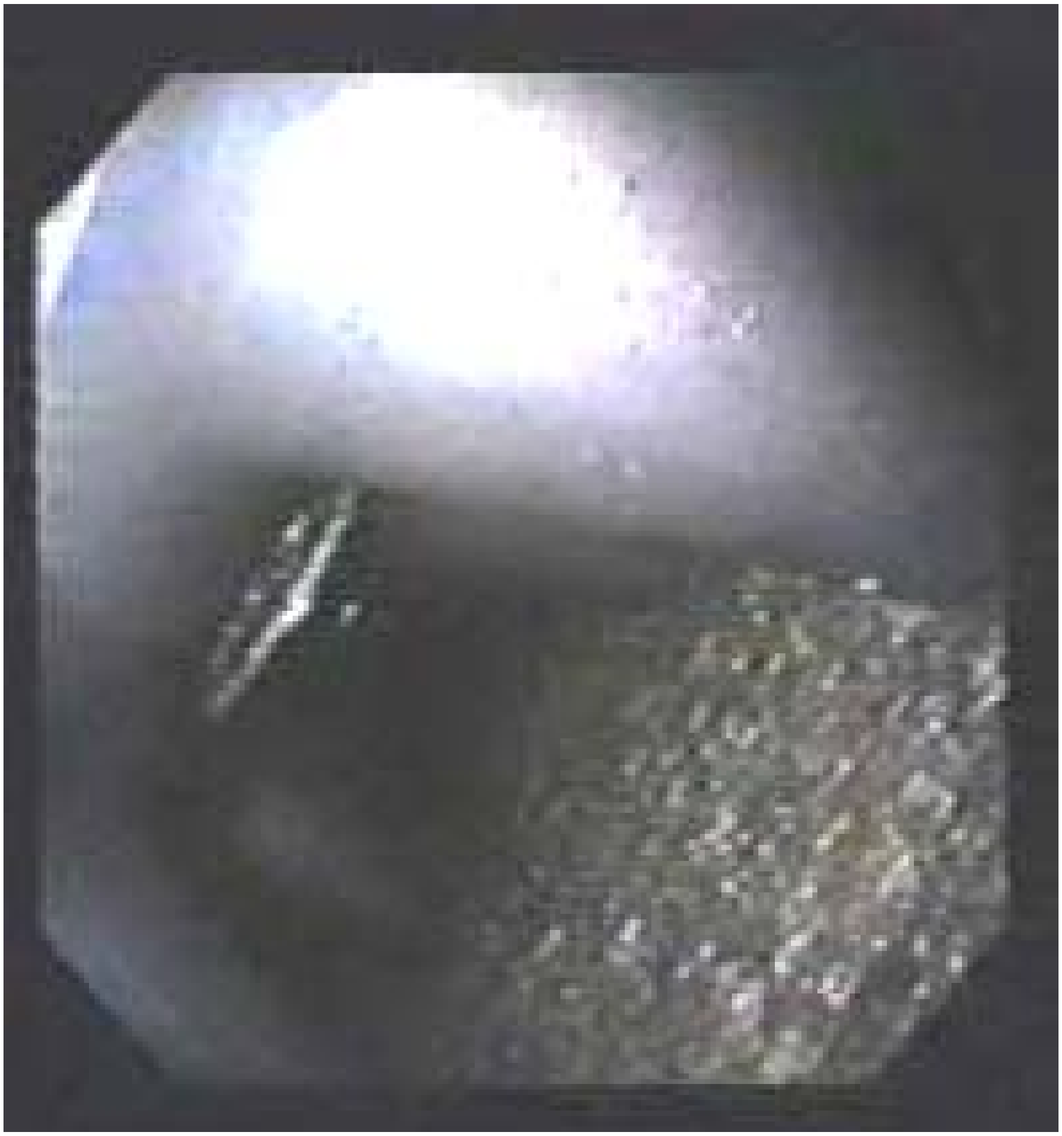

Figure 3 - Video Borescope Picture Showing No Fabric Compression

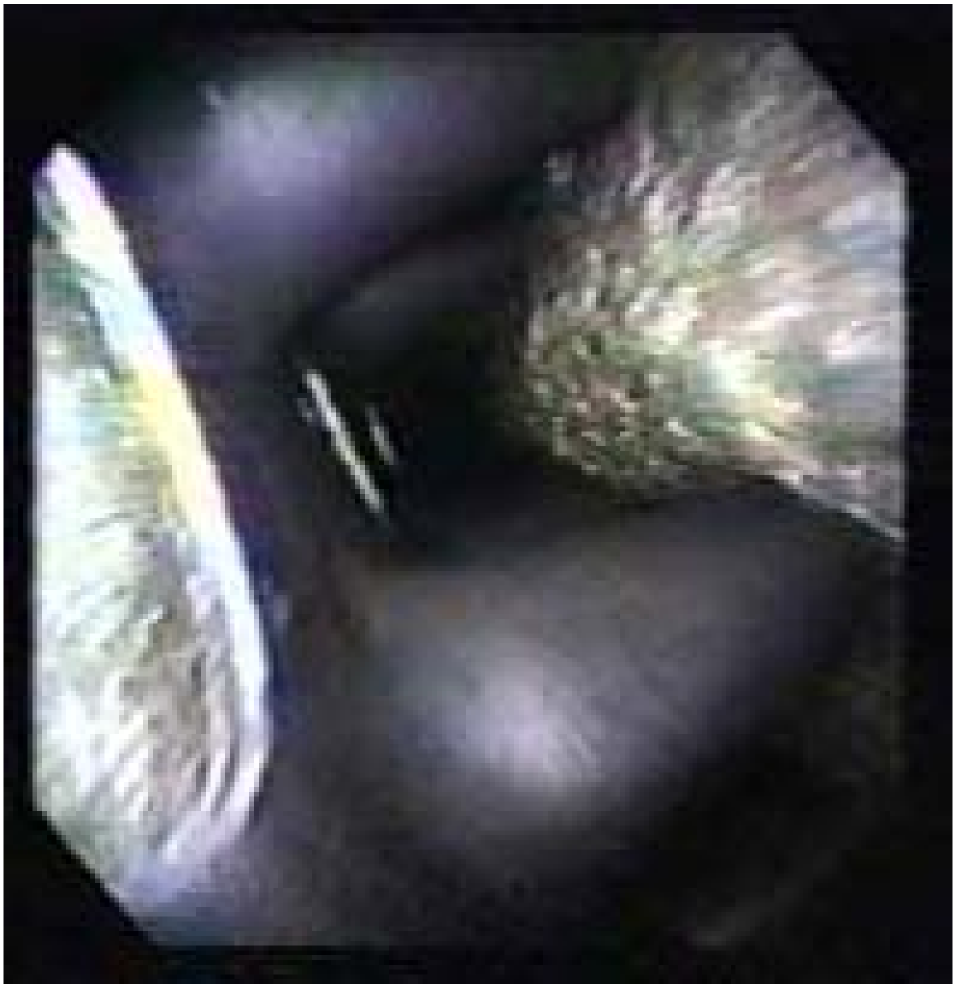

Figure 4 - Video Borescope Picture Showing Fabric Compression

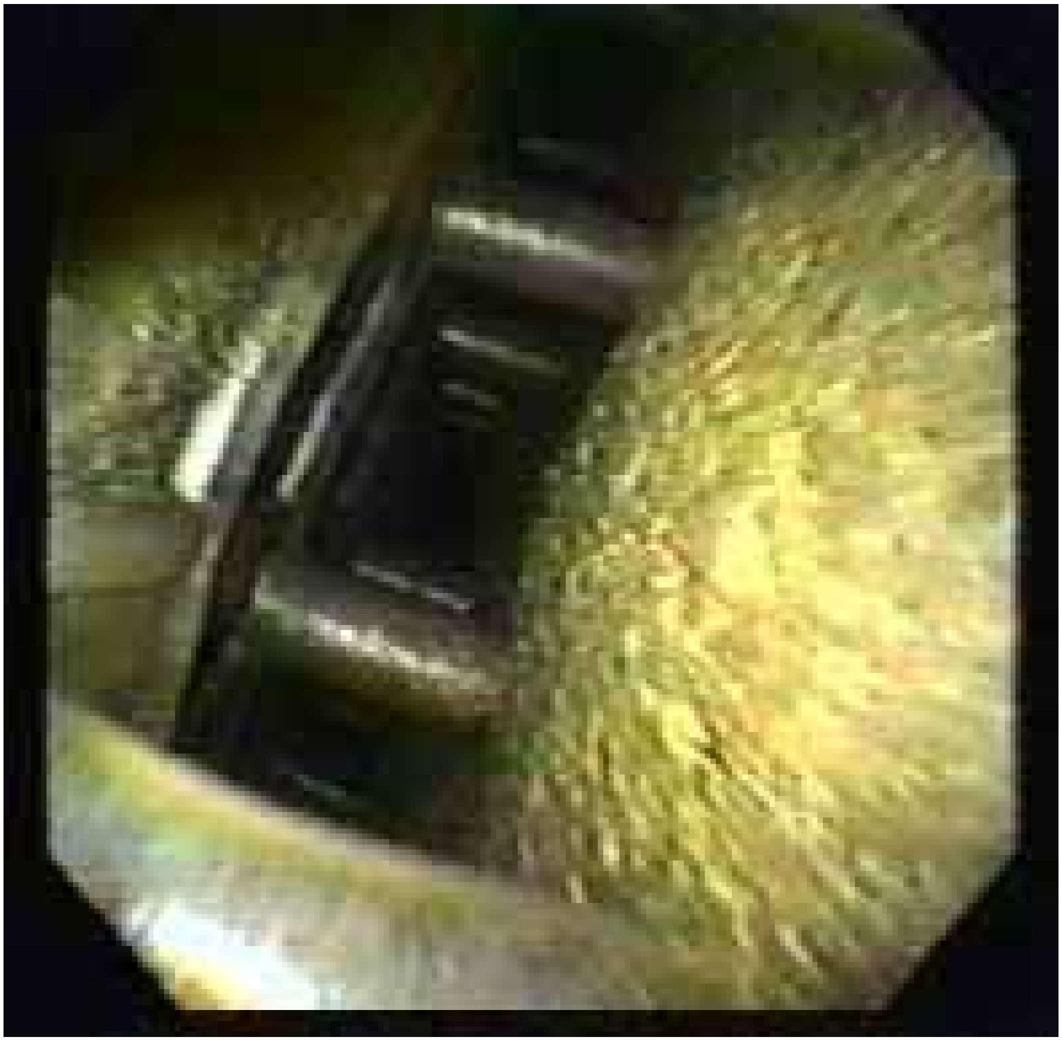

Figure 5 - Video Borescope Picture Showing No Core Compression

Figure 6 - Video Borescope Picture Showing Core Compression

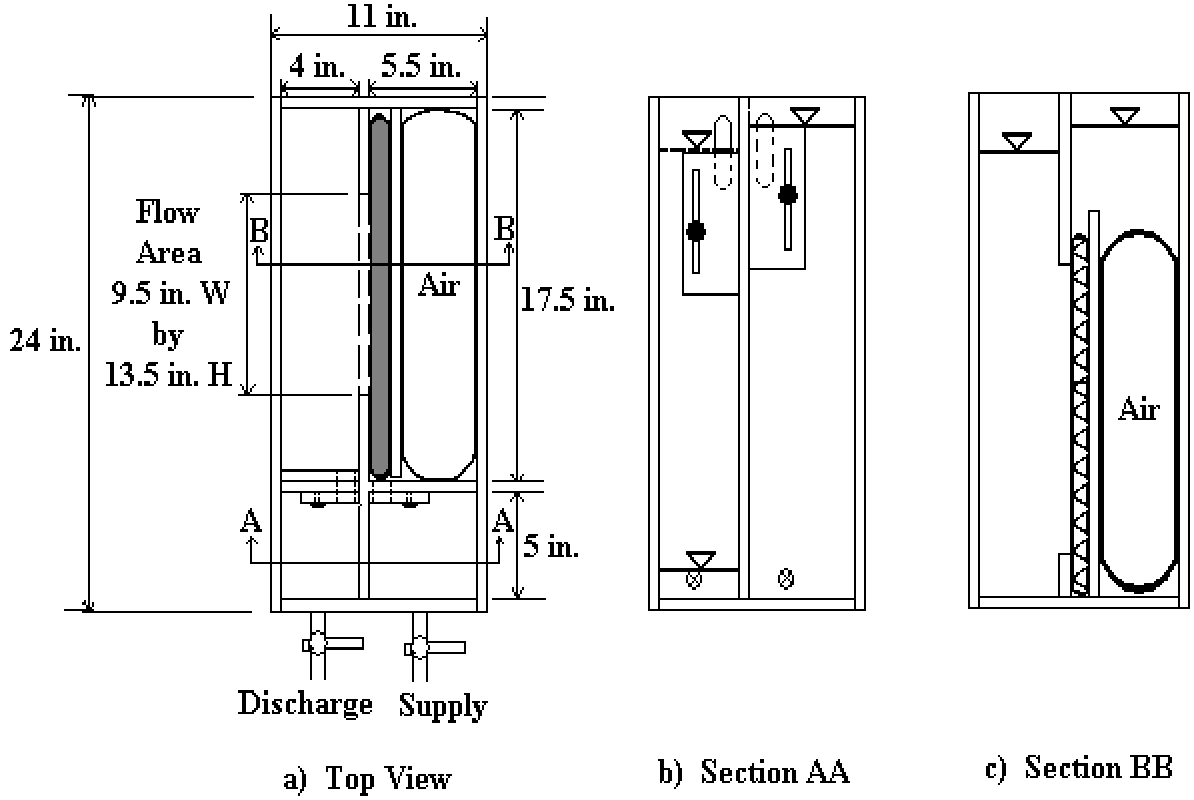

Figure 7 - Details of Permittivity Apparatus

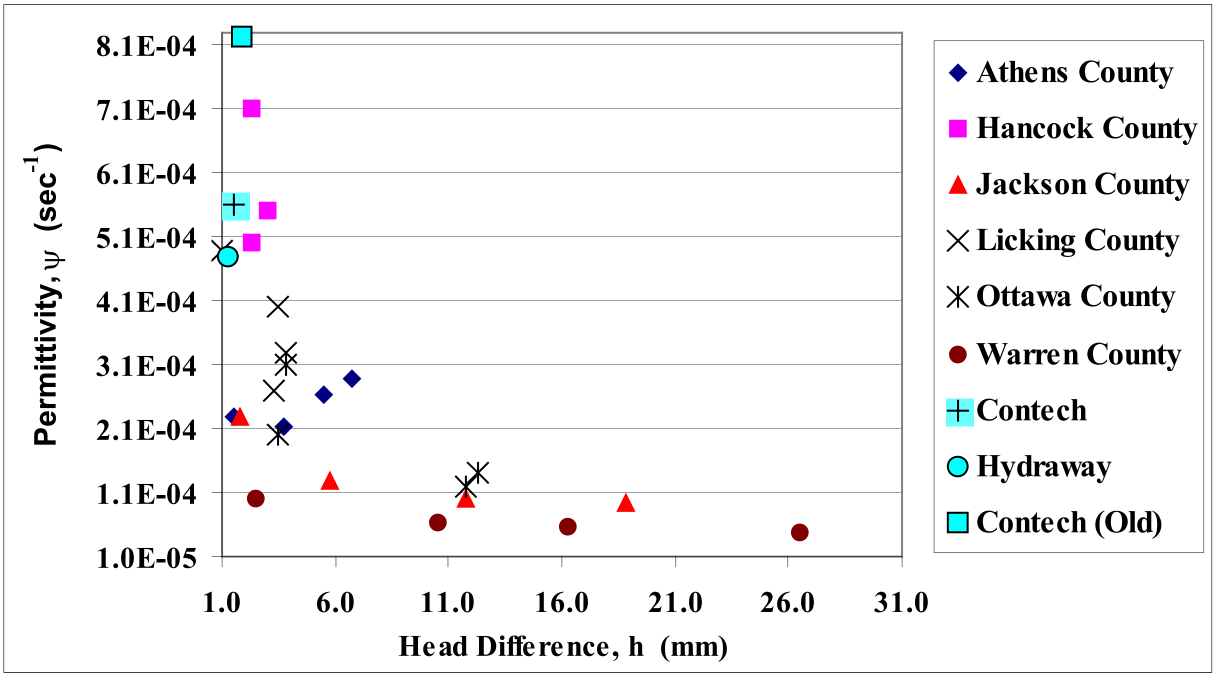

Figure 8 - Average Permittivity, All Tests