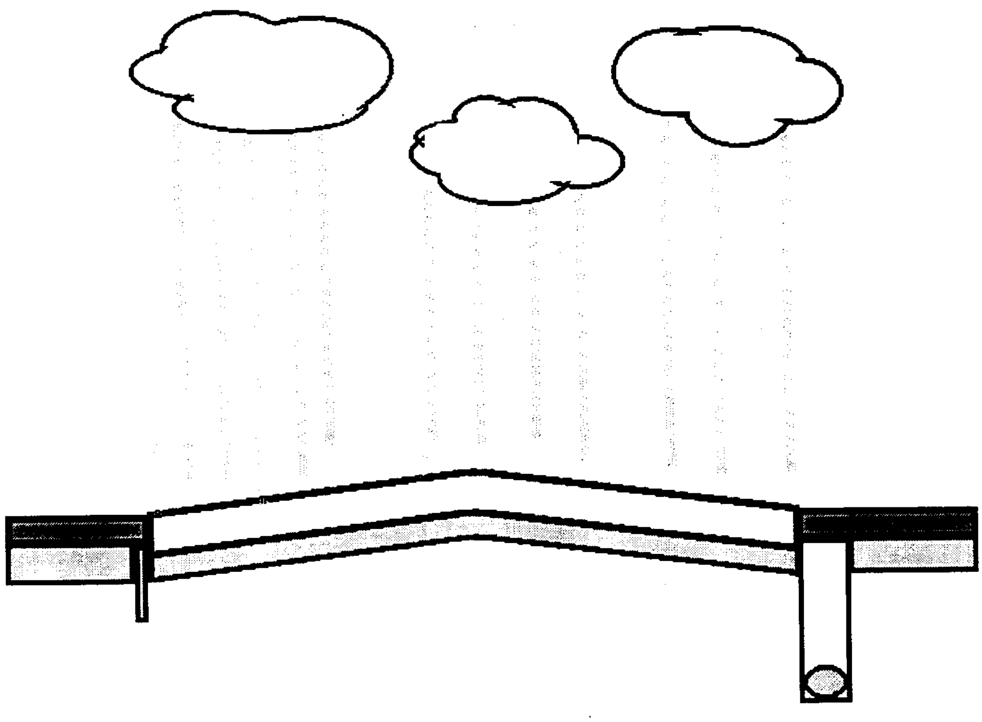
An Evaluation of IDOT's Current Underdrain Systems

Physical Research Report No. 120
December 1995



Illinois Department of Transportation
Bureau of Materials and Physical Research

Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
IL PRR-120		

4. Title and Subtitle AN EVALUATION OF IDOT'S CURRENT UNDERDRAIN SYSTEMS	5. Report Date DECEMBER 1995 6. Performing Organization Code
7. Author(s) JAMES B. DuBOSE, P.E.	8. Performing Organization Report No. Physical Research No. 120
9. Performing Organization Name and Address Illinois Department of Transportation Bureau of Materials and Physical Research 126 East Ash Street Springfield, Illinois 62704-4766	10. Work Unit (TRAIS) 11. Contract or Grant No. IHR-104
12. Sponsoring Agency Name and Address Illinois Department of Transportation Bureau of Materials and Physical Research 126 East Ash Street Springfield, Illinois 62704-4766	13. Type of Report and Period Covered FINAL REPORT Sept. 1994 - Dec. 1995 14. Sponsoring Agency Code

15. Supplementary Notes

STUDY TITLE: IHR-104 -UNDERDRAIN INVESTIGATION. This is a non-federal participating study.

16. Abstract

The use of pavement underdrains became common practice in Illinois following the issuance of a Department underdrain policy in December 1970. Since that time, a variety of materials have been incorporated as underdrains. As these materials evolved, IDOT's standards and specifications were modified and unacceptable products were rejected from further use. This evolution, along with cost considerations, has led to the dominance of geocomposite drainage mats and perforated, corrugated, polyethylene (PE) tubing in the marketplace. However, within the past few years, there have been increasing concerns within the Department regarding the effectiveness of IDOT's underdrain systems, particularly those incorporating geocomposite drainage mats. These concerns were raised in part by the discovery of considerable deposits of silt in drainage mat samples recovered during the reconstruction of I-80 near Morris in 1993. In addition, some districts had strong reservations regarding drainage mats. It was eventually decided in September 1994 that the best approach would be to conduct a research study to determine the relative field performance of the major underdrain types approved at that time. This report outlines the findings of that study.

17. Key Words	18. Distribution Statement
underdrains, geocomposite drainage mats, 4" PE, ADS, Contech, Monsanto, Springfield Plastics, J-ing	No restrictions. This document is available to the public through the National Technical Information Service, Springfield, Virginia 22161.

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	42	

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State of Illinois

DEPARTMENT OF TRANSPORTATION

Division of Highways

Bureau of Materials and Physical Research

AN EVALUATION

OF

IDOT'S CURRENT UNDERDRAIN SYSTEMS

FINAL REPORT

by

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Development Studies Engineer

December 1995

ACKNOWLEDGMENT

This study was conducted at the request and with the approval of Deputy Director Miller. The author would like to express his gratitude to the many district personnel who participated in this study. Special thanks are due to the District Bureaus of Operations for providing equipment, traffic control, and manpower throughout the field phase of this study. In addition, District Materials and Construction personnel played a vital role in the selection of field sites and coordination of project activities and their efforts are greatly appreciated.

DISCLAIMER

The contents of this report reflect the views of the author, who is responsible for the accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the Illinois Department of Transportation. This report does not constitute a standard, specification, or regulation.

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I. INTRODUCTION

The use of pavement underdrains became common practice in Illinois following the issuance of a Department underdrain policy in December 1970. Since that time, a variety of materials have been incorporated as underdrains. As these materials evolved, IDOT's standards and specifications were modified and unacceptable products were rejected from further use. This evolution, along with cost considerations, has led to the dominance of geocomposite drainage mats and perforated, corrugated, polyethylene (PE) tubing in the marketplace. However, within the past few years, there have been increasing concerns within the Department regarding the effectiveness of IDOT's underdrain systems, particularly those incorporating geocomposite drainage mats. These concerns were raised in part by the discovery of considerable deposits of silt in drainage mat samples recovered during the reconstruction of I-80 near Morris in 1993. In addition, some districts had strong reservations regarding drainage mats. It was eventually decided in September 1994 that the best approach would be to conduct a research study to determine the relative field performance of the major underdrain types approved at that time. This report outlines the findings of that study.

II. PLAN OF STUDY

The original plan was to have the districts suggest sections for evaluation with the stipulation that no more than four sections would be evaluated per district. The field evaluation was to consist of a borescope evaluation, the probing and flushing of an outlet, and the removal of a small section of shoulder to facilitate a visual inspection of the underdrain. This plan was reconsidered and modified prior to the initiation of the field phase of the study. The Bureau of Design and Environment suggested that about half of the sections should be selected by the Central Office rather than the districts. Also, an analysis of previous borescope investigations revealed that photographs taken using IDOT's borescope were of poor quality and were difficult to interpret. Therefore, it was decided to eliminate the borescope phase of the study and replace it with an additional outlet probe and shoulder removal section.

During January 1995, memorandums were sent to the districts informing them of the study and requesting their participation and cooperation. Each district was given at least one section suggested by the Central Office to consider for evaluation. In turn, the districts were asked to verify the accuracy of the information pertaining to the suggested section(s) and supplement the list by adding sections of their own, as needed, to increase the total to at least four sections per district. In selecting sections for evaluation, the districts were asked to consider projects constructed between 1987 and 1993 and to include both 4" PE pipe and 12" mat underdrains. Within each category, an attempt was made to obtain a cross section of manufacturers. Both new construction and rehabilitation contracts were considered and priority was given to interstate projects. It was requested that the districts complete their response by March 1, 1995.

During March and April 1995, the candidate sites were field reviewed and their suitability was assessed. Contracts that were deemed acceptable were marked at the two selected outlet probe areas. The markings consisted of the contract number and either "T-1" or "T-2" painted on the shoulder (see Figure 1). It was attempted to locate

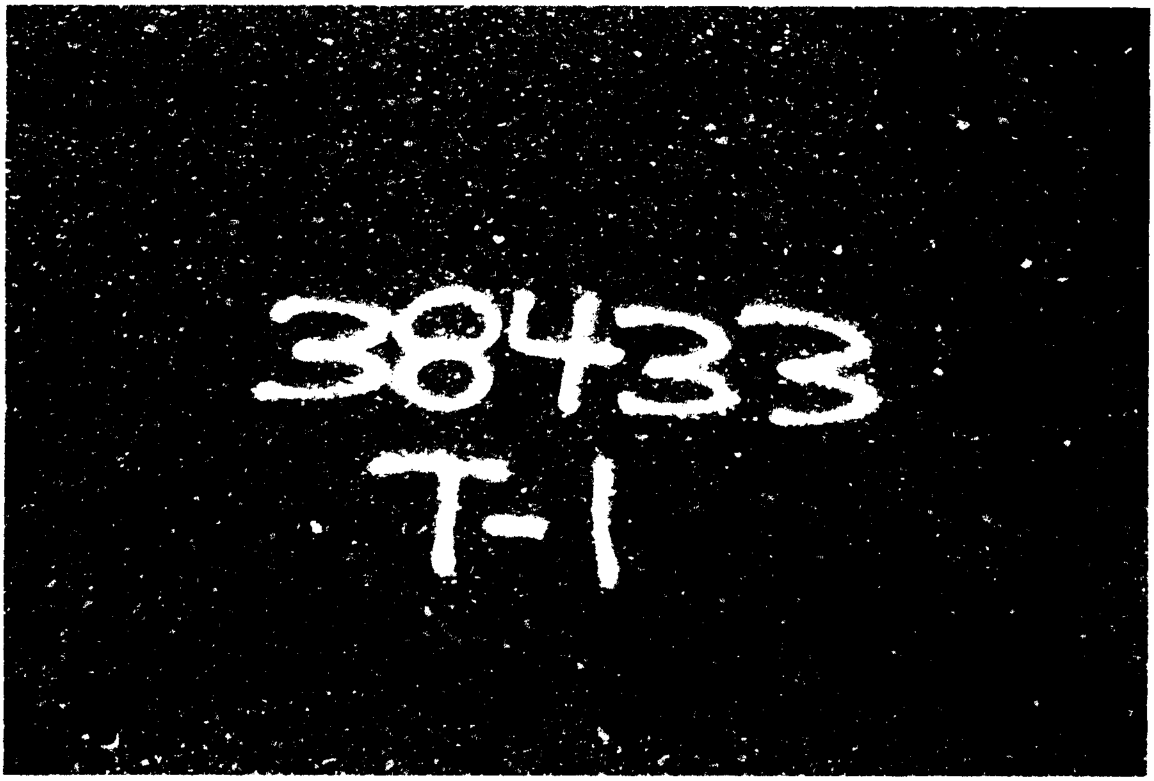

Figure 1. Sample of markings used to identify test sections.

the shoulder removal areas in representative portions of each contract rather than looking for problem areas. Ultimately, the overriding factor in selecting test locations became safety considerations. Since the field work would require a lane closure, long tangent sections were selected to provide excellent traffic visibility and maximum safety. Fortunately, using safety considerations as the primary test site selection input did result in the desired variation in drainage conditions.

During April 1995, the districts were sent a memorandum containing a reduced project list consisting of 54 test sites within 27 construction contracts. This list reflected two slight modifications that were made in the selection criteria. Those changes were the inclusion of 14" drainage mats in the study and the addition of projects constructed in 1985 and 1986. The 14" drainage mats were included because they were more commonly used on full depth asphalt projects than 12" mats. The additional two construction years were added to increase the pool of projects from which to select test sites. Since both 12" mat and 4" PE pipe underdrains were available during those years, it was not considered harmful to the balance of the study to include the added two years. Also in the April 1995 memorandum, the districts were informed of their exact responsibilities during the field phase and were requested to contact the principal investigator to reserve a week for field testing. Field testing was commenced during May 1995 and completed during August 1995. This was followed by a laboratory analysis which was completed during November 1995.

III. TEST LOCATIONS

During the field phase, one contract was rejected when a drainage material other than what was expected was encountered. This resulted in a revised total of 52 test sites within 26 construction contracts. Of these 26 contracts, 11 were selected by the Central Office and 15 were selected by the districts. Fourteen(14) contracts contained 12" mat underdrains, three contracts contained 14" mat underdrains, and nine contracts contained 4" PE pipe underdrains. Fifteen(15) contracts were rehabilitation projects and 11 contracts were new construction projects. Three(3) different drainage mat manufacturers were selected as well as three different pipe manufacturers. Table 1 contains a listing of the test locations in order by district.

DIST	CONTR	ROUTE	TEST#	DIR	STATION	LOCATION	UNDERDRAIN TYPE
1	80208	I-55	T-1	N	502+93	Between MP 239-240	12" Mat-Monsanto
1	80208	I-55	T-2	N	742+00	Between MP 245-246	12" Mat-Monsanto
1	80209	I-55	T-1	S	716+00	Between MP 243-244	12" Mat-Monsanto
1	80209	I-55	T-2	S	469+92	Between MP 239-240	12" Mat-Monsanto
1	80633	I-80	T-1	W	1827+00	Between MP 123-124	12" Mat-Monsanto
1	80633	I-80	T-2	E	1847+00	Between MP 124-125	12" Mat-Monsanto
2	84384	IL 75	T-1	W	53+04	W. of Willowbrook Sign	12" Mat-Contech
2	84384	IL 75	T-2	W	30+97	0.35 mi E. of IL 251	12" Mat-Contech
3	42281	US 51	T-1	N	235+00	0.5 mi S. of US 136	12" Mat-Monsanto
3	42281	US 51	T-2	N	341+00	1 mi N. of US 136	12" Mat-Monsanto
3	42754	I-74	T-1	E		255' W. of MP 144	4" PE-ADS
3	42754	I-74	T-2	E	1233+95	Between MP 145-146	4" PE-ADS
4	38433	US34	T-1	E	343+95	W. of MP 14.00	12" Mat-Monsanto
4	38433	US34	T-2	E	492+00	1 mi W. of Cameron Rd.	12" Mat-Monsanto
4	38996	US34	T-1	E	633+00	Between MP 19-20	4" PE-Hancor
4	38996	US34	T-2	E	838+50	Between MP 0-1	4" PE-Hancor
4	42583	I-74	T-1	E	142+10	Between MP 72-73	12" Mat-Monsanto
4	42583	I-74	T-2	E	528+00	395' W. of MP 80	12" Mat-Monsanto
4	88050	I-155	T-1	N	930+25	Between MP 14-15	14" Mat-Monsanto
4	88050	I-155	T-2	N	828+00	Between MP 16-17	14" Mat-Monsanto
5	40913	I-70	T-1	E	595+00	Between MP 126-127	4" PE-ADS
5	40913	I-70	T-2	E	680+00	E. of MP 128	4" PE-ADS
5	42234	I-70	T-1	W	430+00	Between MP 113-114	4" PE-ADS
5	42234	I-70	T-2	W	305+50	Between MP 111-112	4" PE-ADS
5	90128	I-57	T-1	S	300+97	Between MP 223-224	12" Mat-Monsanto
5	90128	I-57	T-2	S	275+00	Between MP 222-223	12" Mat-Monsanto
6	92110	I-72	T-1	W	168+95	Between MP 37-38	4" PE-Spfld Plastics
6	92110	I-72	T-2	E	287+00	Between MP 39-40	4" PE-Spfld Plastics
6	92177	I-72	T-1	E	1511+00	Between MP 13-14	14" Mat-Monsanto
6	92177	I-72	T-2	E	925+00	Between MP 17-18	14" Mat-Monsanto
6	92232	I-72	T-1	W	94+55	Between MP 32-33	14" Mat-Monsanto
6	92232	I-72	T-2	E	542+40	Between MP 29-30	14" Mat-Monsanto
6	92400	I-55	T-1	N	30+50	Between MP 55-56	12" Mat-ADS
6	92400	I-55	T-2	N	1559+97	S. of MP 62	12" Mat-ADS
7	40230	I-57	T-1	N	4255+00	Between MP 143-144	12" Mat-Monsanto
7	40230	I-57	T-2	N	4429+43	S. of MP 147	12" Mat-Monsanto
7	40673	I-57	T-1	N	1118+00	Between MP 101-102	12" Mat-Monsanto
7	40673	I-57	T-2	N	1362+05	Between MP 105-106	12" Mat-Monsanto
7	42908	I-57	T-1	N	2646+07	S. of MP 130	12" Mat-Monsanto
7	42908	I-57	T-2	N	2847+77	Between MP 133-134	12" Mat-Monsanto
7	94027	I-57	T-1	N	2130+03	Between MP 120-121	12" Mat-Monsanto
7	94027	I-57	T-2	N	2243+93	Between MP 122-123	12" Mat-Monsanto
8	38343	I-255	T-1	S	1132+00	Between MP 21-22	4" PE-ADS
8	38343	I-255	T-2	N	1128+00	Between MP 21-22	4" PE-ADS
8	42263	I-255	T-1	S	1553+00	Between MP 29-30	4" PE-ADS
8	42263	I-255	T-2	N	1568+00	Between MP 29-30	4" PE-ADS
8	42363	I-255	T-1	S	1404+50	Between MP 26-27	4" PE-Spfld Plastics
8	42363	I-255	T-2	N	1419+50	Between MP 27-28	4" PE-Spfld Plastics
9	40406	I-57	T-1	N	567+50	Between MP 11-12	4" PE-Hancor
9	40406	I-57	T-2	S	592+50	Between MP 10-11	4" PE-Hancor
9	42073	IL 13	T-1	W	688+50	E. of Ryder Rent-All	12" Mat-Monsanto
9	42073	IL 13	T-2	E	698+00	Adj. to Garden Center	12" Mat-Monsanto

Table 1. Listing of field test sites.

IV. FIELD EVALUATION

The shoulder removal areas were all located adjacent to a preselected outlet. In general, the shoulder removal areas were offset 10-15 feet upstream from the outlet.. This set up was chosen to allow a correlation to be made between the condition of the outlet pipe and the underdrains. It was felt that the offset would be great enough to prevent any material loss in the underdrain during the backflushing of the outlet, yet close enough to provide a meaningful comparison between the underdrain condition and the outlet condition. Backflushing of the outlet was accomplished using a high pressure jet rodder unit ranging in size from a trailer to a large, self-contained, truck rig - depending on the district. The jet rodder hose was inserted in the outlet pipe until the pavement edge was reached and withdrawn 3-4 times until the majority of the accumulated debris was removed. This operation was videotaped to document any excess or unusual material flushed from the outlet.

An area approximately 40 inches x 40 inches was removed from the shoulder to permit the collection of each underdrain sample. Various techniques were employed to remove the asphalt surface and base. The asphalt material was either broken up by jackhammering or sawed full depth. Excavation was either done by hand or with a backhoe. In all cases, only hand digging was allowed adjacent to the underdrain to minimize the risk of damaging the sample. After the underdrain was exposed, approximately 14 inches was removed and replaced by new underdrain of the same type. The splice was then wrapped using an oversized piece of new geotextile. Photographs were taken prior to sample removal and a picture was also taken of the interior of the removed sample. Additional photographs were taken as needed and each sample was bagged, labeled, and brought back to Springfield for analysis. Throughout the entire operation, notes were recorded documenting all observations considered to be of potential interest. The following is a discussion of some of the more important categories of observations made.

<u>Outlets</u>

In general, the outlet pipes contained only small amounts of debris that were congregated in the corrugations of the pipe. Several headwalls contained silt and/or plant matter, but this did not appear to extend past the headwall. Two outlets contained a large quantity of calcite deposits that had formed in the pipe corrugations (see Figure 2).

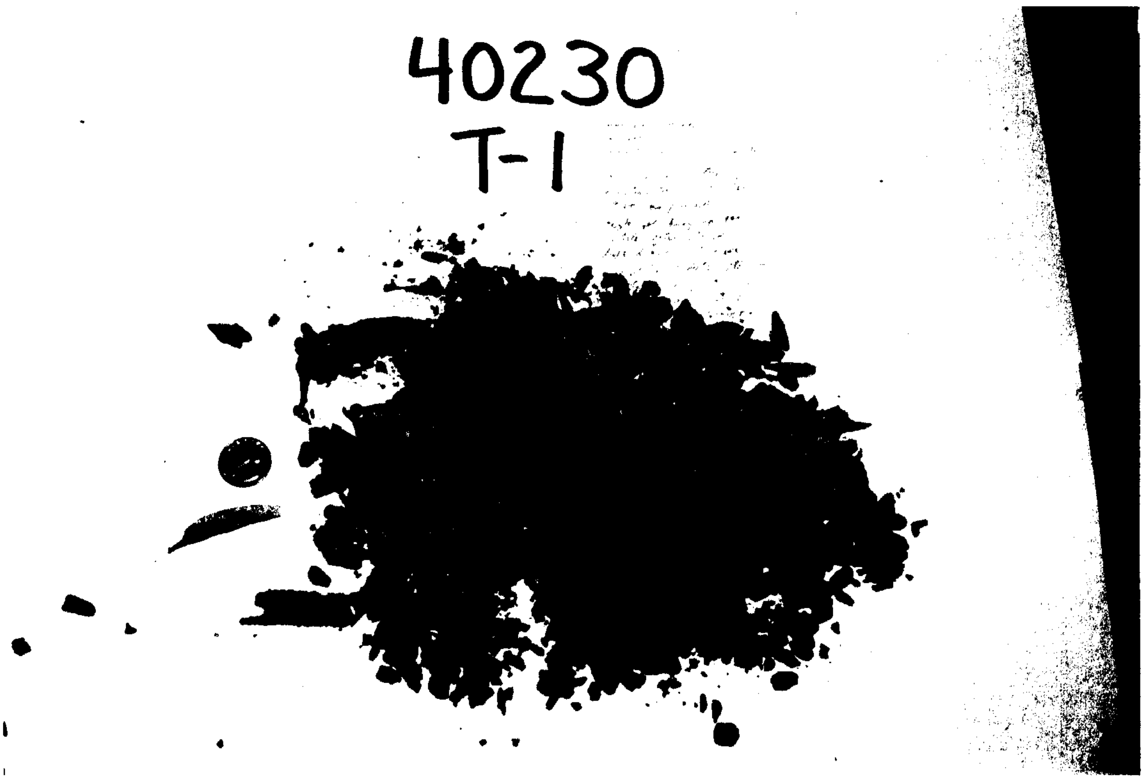

Figure 2. Calcite deposits formed in outlet pipe.

Animal activity was evident in a few outlets that contained fibrous material similar to a mouse nest and one outlet which contained a large quantity of tan snake eggs. It should be noted that these outlets either were missing their rodent screen or had wider openings in their screens than is currently allowed in IDOT's standards. A few outlets originally appeared to be full, but were found on closer examination to only have some stone from the shoulder base mounded against the rodent screen. This stone probably was trapped in the outlet during construction.

Many outlets were constructed using perforated rather than solid pipes. One outlet was found to be collapsed at a joint a few feet upstream from the headwall (see Figure 3). The type of pipe coupler used was short and dependent on the connecting pipes for structural strength. As the headwall moved and pulled away from the coupler, the strength of the joint was lost and the entire joint collapsed. In addition, one outlet

Figure 3. Outlet pipe collapsed at joint.

pipe was partially collapsed due to improper construction.

A number of problems were noted regarding headwalls. Many headwalls were overgrown with weeds and grass as a result of the Department's adherence to a policy of not mowing beyond 15 feet from the pavement edge. Another common problem was headwalls located in the ditchline due to difficulties in obtaining outfall slope from a 30 inch deep pipe underdrain trench to a shallow ditch. This condition allows water to back up into the system during periods of wet weather. Finally, many headwalls were found to have deficient slopes and some were found to be sloped backwards.

Overall, it appeared that the periodic outlet cleaning performed by district maintenance personnel was sufficient. Rigid pipe is now required for all outlet pipes and this modification should alleviate some of the previously noted problems. Table 2 gives a summary of the headwall and outlet conditions.

Placement and Grade Control

Numerous measurements were taken to determine how closely placement of the drains in the field compared to design standards. Four(4) of the 12" mat underdrain samples were found to be away from the pavement edge. Three(3) of these were within three inches of the pavement edge. The fourth sample was 30 inches from the pavement edge. The reason this sample was out so far was that it was a new construction contract with the underdrains placed at the edge of the subbase. One installation (42281 T-2) was found to have a large error in the depth of placement with the mat installed 12 inches too low. Sags in the drains were manifested by water

DIST	CONTR	TEST#	HEADWALL	OUTLET PIPE
1	80208	T-1	Slightly tilted back	Clean
1	80208	T-2	Screen missing	Clean
1	80209	T-1		Muddy water
1	80209	T-2		Clean
1	80633	T-1		Muddy water
1	80633	T-2		Muddy water
2	84384	T-1		Muddy water
2	84384	T-2		Clean
3	42281	T-1	Wide opening screen.	Some dirt. Lots of eggs.
3	42281	T-2	Screen missing	Muddy water
3	42754	T-1	Sloped backwards-standing water and muck	Clean
3	42754	T-2	Small amount of muck	Clean
4	38433	T-1		Clean
4	38433	T-2		Muddy water
4	38996	T-1	Screen missing	Muddy water
4	38996	T-2	Wide opening screen	Muddy water
4	42583	T-1		Muddy water
4	42583	T-2		Clean
4	88050	T-1	Submerged in water. Tall grass.	
4	88050	T-2		Collapsed at coupler.
5	40913	T-1	Water standing.	3/4 full at end. Rest clean
5	40913	T-2	Older, more open, lift out screen.	Some dirt and rocks at end
5	42234	T-1	Wide opening screen. Good slope. Grass.	Clean
5	42234	T-2	Older, more open, lift out screen	Some mud and stone
5	90128	T-1		Muddy water
5	90128	T-2		Very muddy water, fibery material.
6	92110	T-1	Spiral screen	Mouse nest. Otherwise clean.
6	92110	T-2	Into ditch line. Deficient slope.	Brown water.
6	92177	T-1		Clean
6	92177	T-2	Heavily overgrown with tall grass.	Clean
6	92232	T-1	Into ditch line. Filled with dirt.	Clean
6	92232	T-2	Heavily overgrown with grass and weeds.	Clump of fibery material
6	92400	T-1		Clean
6	92400	T-2	Grass growing in headwall. Standing water.	Black and dark brown water
7	40230	T-1	Water standing (rained previous night).	Large amount of tan concretions
7	40230	T-2	Wide opening screen	Some tan concretions
7	40673	T-1		0.25" silt in bottom
7	40673	T-2	Cattails growing inside.	Muddy water
7	42908	T-1	Two screens- lift out and push in.	Muddy water
7	42908	T-2	Two screens- lift out and push in.	Muddy water
7	94027	T-1	Sloped backward. Green slime inside.	Muddy water
7	94027	T-2	Cattails and water inside.	Muddy water
8	38343	T-1	Rodent screen missing	Mouse nest
8	38343	T-2		Clean
8	42263	T-1		Clean
8	42263	T-2	Green slime inside.	Rust colored water
8	42363	T-1	Cattails growing inside.	Organic material
8	42363	T-2		Clean
9	40406	T-1	Wide opening screen. Overgrown.	Clean
9	40406	T-2	Wide opening screen. Green slime.	Clean
9	42073	T-1		Some mud and stones
9	42073	T-2	Flimsy screen. Grass and muck inside.	Clean

Table 2. Summary of outlet and headwall condition.

ponding in the excavated area and not draining away. Improper slope was felt to be a contributing factor in the large silt deposits found in two samples (42583 T-1, 40673 T-1). However, grade control was not a common problem with the 12" mats, as only three of 28 samples demonstrated ponding.

Five of the six 14" mat underdrain samples were eight inches or more from the pavement edge. These drains were only used on full depth asphalt pavement. The wide drain placement was attributed to the trapezoidal shape of the pavement which narrows from bottom to top. In other words, the drain may have been in contact at the base of the pavement, but the tapering of the edge resulted in the top being 8-18 inches away. A major downside of this detail is that it was common for low permeability material to be backfilled in the triangular-shaped area adjacent to the 14" mat underdrain (see figure 4). No sagging or depth control problems were noted for the 14" mat underdrains.

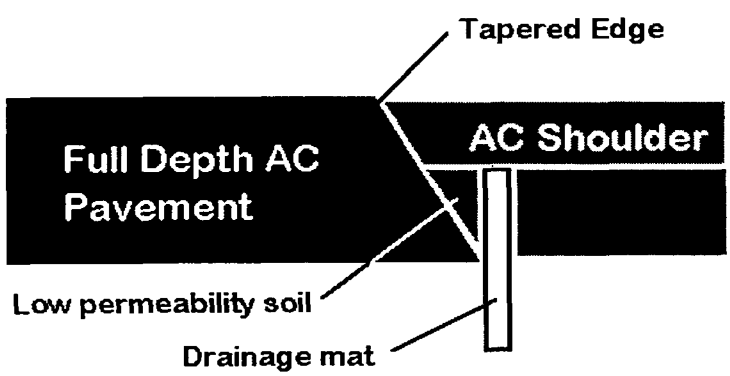

Figure 4. Observed 14" mat installation adjacent to full depth asphalt pavement.

Most of the 4" PE pipe underdrains were located well away from the pavement edge due to the fact they were constructed under an old standard that specified that the underdrains be placed at the subbase edge rather than the pavement edge. However, many drains were placed well beyond the subbase edge at over 30 inches from the pavement edge. It was found that many of these contracts had a low permeability, silty clay column between the subbase and the sand trench. The result was, while the pipe underdrain looked fine, no water was getting to it. A classic example is Contract 42263 T-2 which has water constantly weeping from the longitudinal joint because it can't get to the underdrain trench (see Figure 5).

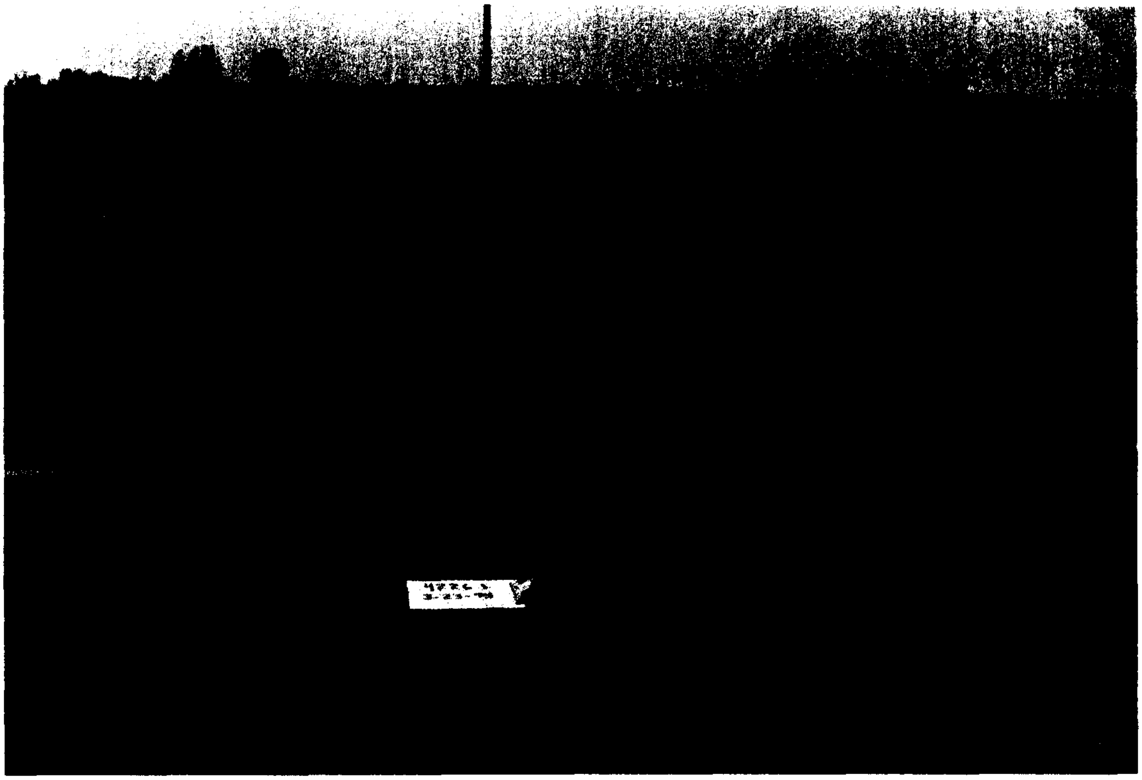

Figure 5. Water weeping from longitudinal joint. Contract 42263, test # T-2.

The depth of placement was found to be highly variable. It is readily apparent that field personnel are having to decrease the trench depth and raise the underdrains in order to provide a proper outlet slope without burying the headwalls in the ditchline. Sags were found to be common, with 11 of 18 pipe underdrain excavations showing some water ponding. Although this is not an ideal condition, the majority of the water should still drain away, while the remainder should pose little threat due to its distance below the pavement structure. A qualitative assessment of the adequacy of longitudinal slope of the various underdrain types is illustrated in Figure 6.

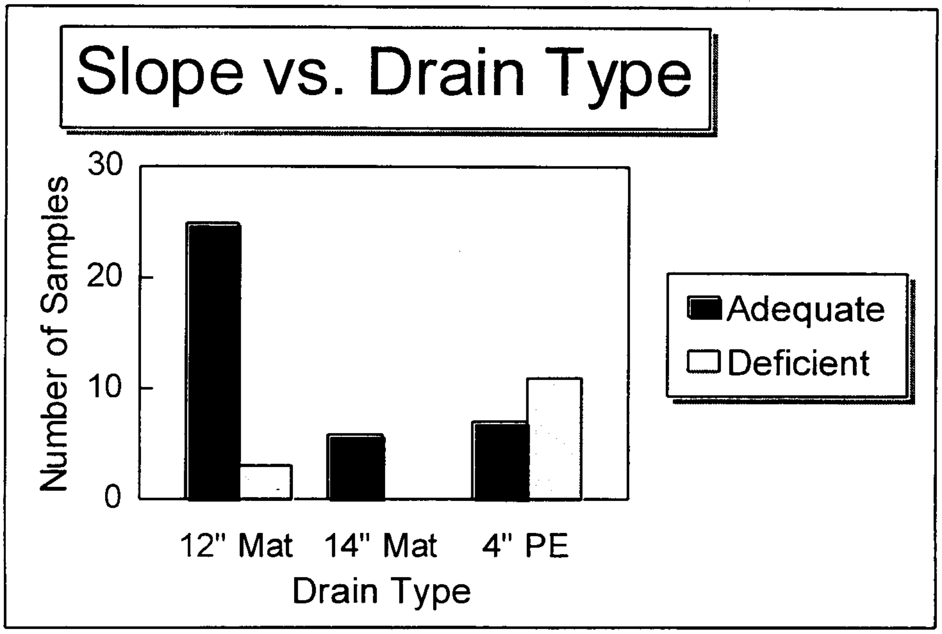

Figure 6. Qualitative assessment of underdrain longitudinal slope.

V. LABORATORY EVALUATION

Upon completion of the collection of all underdrain samples, a laboratory evaluation was conducted. Care was taken to keep the samples in sealed plastic bags as much as possible to prevent moisture loss and contamination. The core of each sample was exposed to facilitate visual observation. The examination of the pipe underdrain cores was simple and straightforward. The sock or fabric envelope was pulled back a few inches and the top half of the pipe was removed in this area (see Figure 7). The technique used to expose the cores of the mat underdrains varied

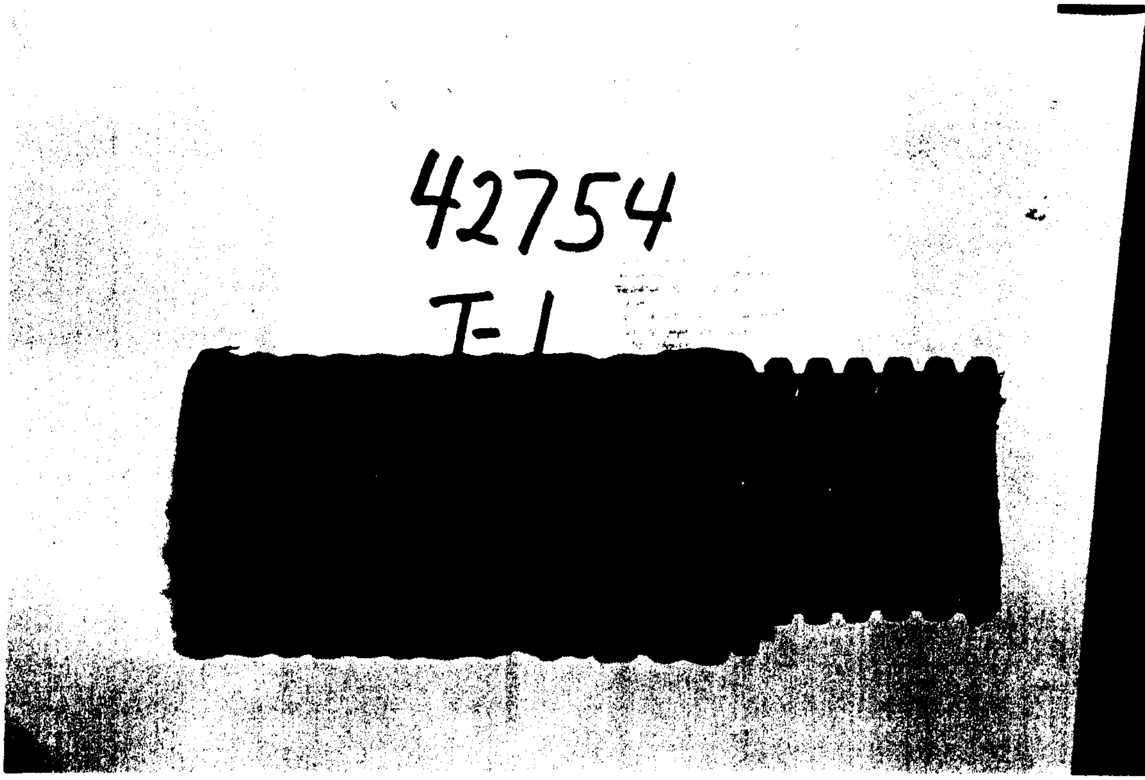

Figure 7. Exposed pipe underdrain core.

depending on the manufacturer. For the mat underdrains made by Monsanto, the geotextile on the pavement side was cut in half and the fabric was pulled away from the cylinders to which it was glued (see Figure 8). This was more difficult on the older Monsanto mats, which tended to use more glue. Examination of the cores of the Contech mat underdrains was easy. Contech's underdrains have an open core and the geotextile is not glued to it, so all one has to do is pull back the fabric envelope (see Figure 9). Like Contech, ADS does not glue their geotextile to the core. However, ADS

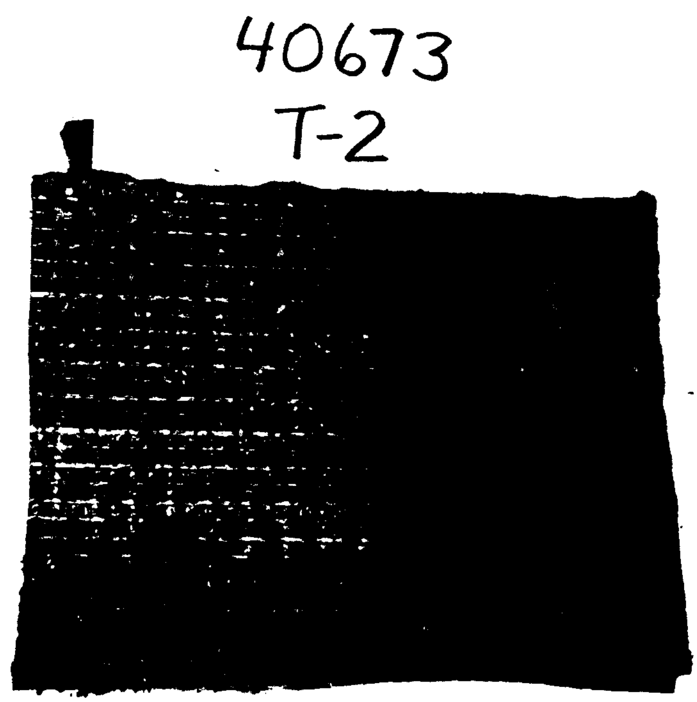

Figure 8. Exposed core of Monsanto drainage mat.

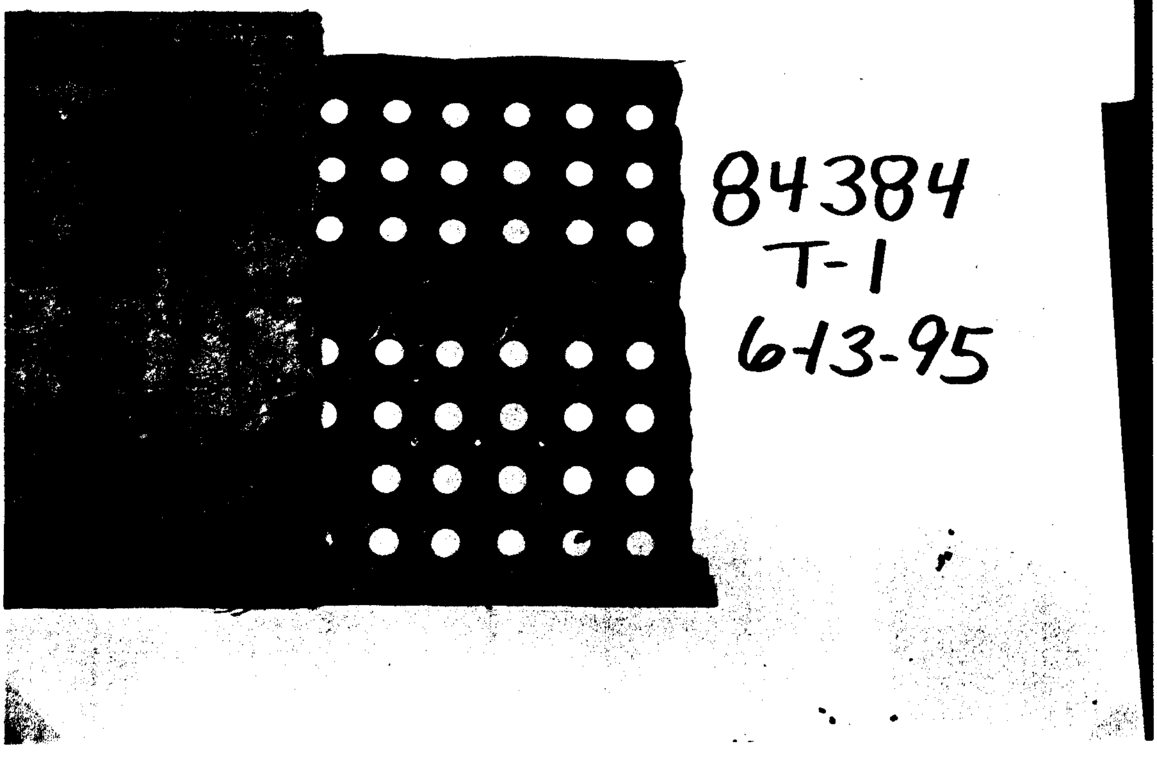

Figure 9. Exposed core of Contech drainage mat.

uses a closed core, so some cutting is required to see inside after pulling the fabric envelope back (see Figure 10). Once the core was exposed, it was possible to make a

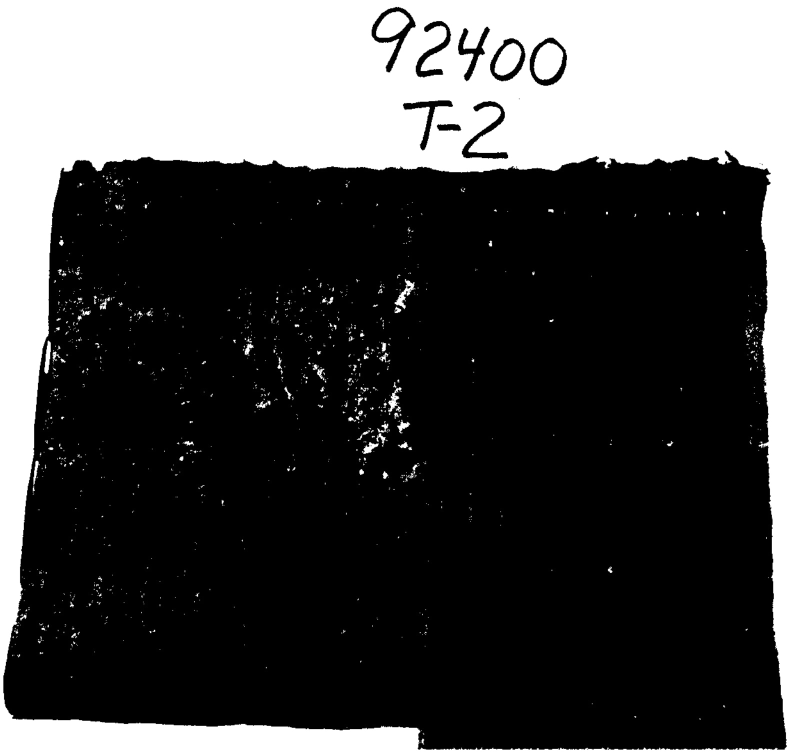

Figure 10. Exposed core of ADS drainage mat.

number of observations and perform tests on the geotextile. These observations and tests are discussed next, according to subject.

<u>Solids</u>

The examination of solids trapped in the underdrains yielded some interesting results. The majority of the drains had little or no solids filling their interior. Surprisingly, the solids found weren't limited to the anticipated accumulations of silt. Calcite deposits similar to those found during the backflushing of the outlets were also found. In addition, a few underdrains contained a very sticky, brown silty clay. Other solids found in small amounts included sand and root-like material. Deposits found in the bottom of the drain only told half the story. It was common for fines to coat the walls of the mat underdrains, well above the level of solids. Depending on the composition of these fines, they could have a very detrimental effect on the underdrain performance. Low permeability fines, such as clay, can almost completely cut off the inflow of water (see Figure 11). The pipe underdrains showed less of a tendency to collect solids than

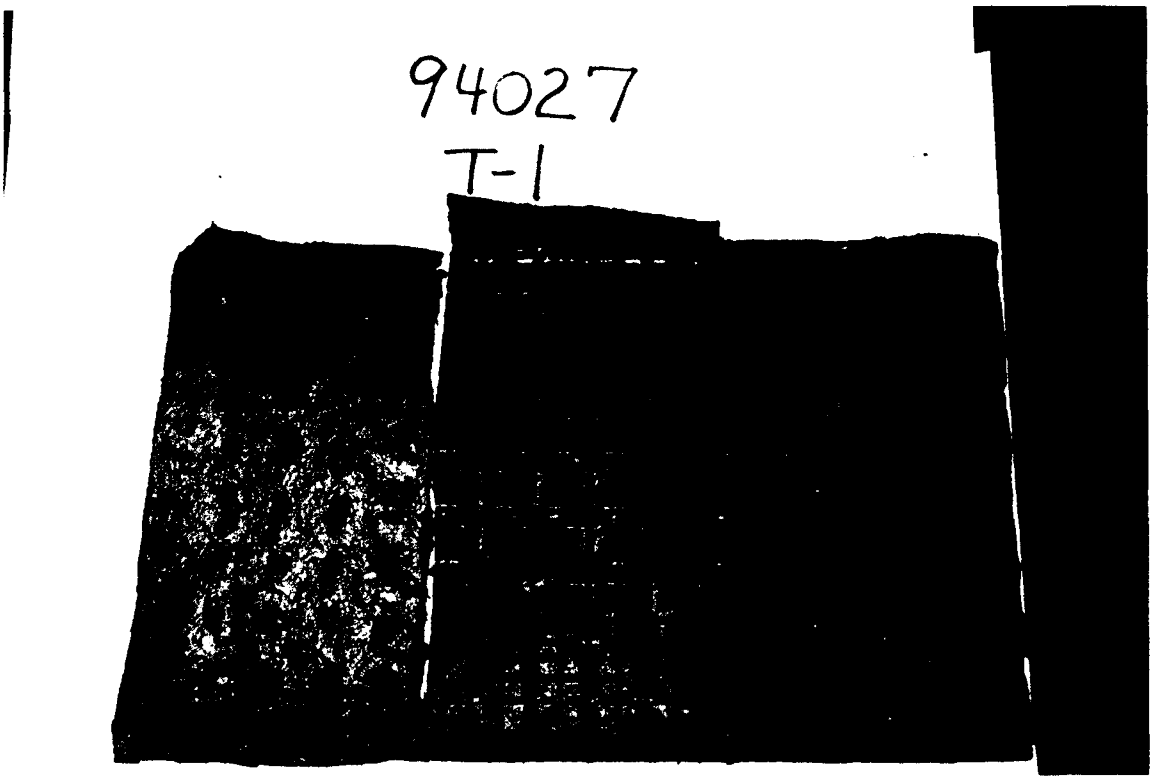

Figure 11. Mat underdrain geotextile coated with clay.

the mat underdrains (see Figure 12). This appears to be a result of the beneficial

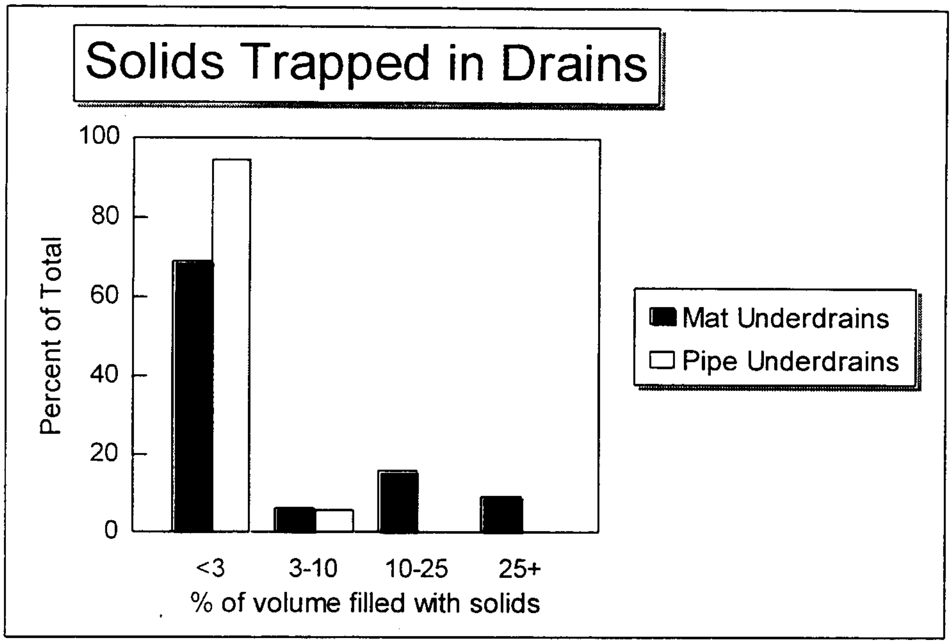

Figure 12. Distribution of percent solids vs. drain type.

filtering properties of the granular backfill used for pipe underdrains and not for mat underdrains, which were all backfilled with in situ material. Table 3 summarizes the type and amount of solids found in the underdrain field samples.

Structural Evaluation

The pipe underdrains did not exhibit any brittle characteristics and no fractures were found. However, some permanent deformation was measured in all samples. An estimate of the amount of vertical deflection in each sample was calculated based on measurements of maximum and minimum diameter. The deflections ranged in magnitude from a low of 0.01 inch to a high of 0.19 inch. These values represent relative percent deflections of 0.3 percent and 4.7 percent respectively. IDOT routinely

DIST	CONTR	TEST#	DRAIN TYPE	MANUFACTURER	SOLIDS INSIDE	WALL COATING
1	80208	T-1	12" mat	Monsanto -New		
1	80208	T-2	12" mat	Monsanto -New	Small amount	8.5" Dirt
1	80209	T-1	12" mat	Monsanto -New		
1	80209	T-2	12" mat	Monsanto -Old		
1	80633	T-1	12" mat	Monsanto -New	Small amount	1.5" Silt
1	80633	T-2	12" mat	Monsanto -New		3" Silt
2	84384	T-1	12" mat	Contech	Small amount	1.25" Silt
2	84384	T-2	12" mat	Contech	Small amount	3" Silt
3	42281	T-1	12" mat	Monsanto -Old	2" Calcite	
3	42281	T-2	12" mat	Monsanto -Old	1.5" Calcite	7.5" Dirt
3	42754	T-1	4" PE	ADS	Calcite	
3	42754	T-2	4" PE	ADS		
4	38433	T-1	12" mat	Monsanto -Old		
4	38433	T-2	12" mat	Monsanto -Old		
4	38996	T-1	4" PE	Hancor		
4	38996	T-2	4" PE	Hancor		
4	42583	T-1	12" mat	Monsanto -Old	6" silt	
4	42583	T-2	12" mat	Monsanto -Old		
4	88050	T-1	14" mat	Monsanto -New		
4	88050	T-2	14" mat	Monsanto -New		7" Silt
5	40913	T-1	4" PE	ADS		
5	40913	T-2	4" PE	ADS	Calcite flakes	
5	42234	T-1	4" PE	ADS	Sand and calcite	
5	42234	T-2	4" PE	ADS	0.5" silt	
5	90128	T-1	12" mat	Monsanto -New	0.5" silt	5" Silt
5	90128	T-2	12" mat	Monsanto -New	2" silty clay	7" Silty Clay
6	92110	T-1	4" PE	Springfield Plastics		
6	92110	T-2	4" PE	Springfield Plastics		
6	92177	T-1	14" mat	Monsanto -New		
6	92177	T-2	14" mat	Monsanto -New		
6	92232	T-1	14" mat	Monsanto -New		
6	92232	T-2	14" mat	Monsanto -New		
6	92400	T-1	12" mat	ADS	Calcite flakes	
6	92400	T-2	12" mat	ADS		4" Silt & Calcite
7	40230	T-1	12" mat	Monsanto -Old	2" calcite	
7	40230	T-2	12" mat	Monsanto -Old	1.5" silt	
7	40673	T-1	12" mat	Monsanto -Old	9" silt	
7	40673	T-2	12" mat	Monsanto -Old	1.5" silt and calcite	
7	42908	T-1	12" mat	Monsanto -Old	3" silt	
7	42908	T-2	12" mat	Monsanto -Old		8" Silt
7	94027	T-1	12" mat	Monsanto -New	0.5" silt	
7	94027	T-2	12" mat	Monsanto -New	1.75" silt	7" Silt
8	38343	T-1	4" PE	ADS	Small amount	
8	38343	T-2	4" PE	ADS	Small amount	
8	42263	T-1	4" PE	ADS	Small amount	
8	42263	T-2	4" PE	ADS		
8	42363	T-1	4" PE	Springfield Plastics	Some sand	
8	42363	T-2	4" PE	Springfield Plastics	Small amount	
9	40406	T-1	4" PE	Hancor		
9	40406	T-2	4" PE	Hancor		
9	42073	T-1	12" Mat	Monsanto -Old		
9	42073	T-2	12" Mat	Monsanto -Old	Rootlike material	

Table 3. Summary of solids found in underdrain samples.

tests new pipe underdrains for their load carrying capability at 5 percent deflection; so the measured field values appear to be well within the normally expected range. A summary of the pipe deflection measurements is contained in Table 4.

DIST	CONTR	MANUFACTURER	TEST#	DEPTH TO TOP (in.)	DIST FROM EDGE OF PAVT (in)	DEFLECTION (in.)	DEFLECTION (%)
3	42754	ADS	T-1	24	0	0.08	1.9
3	42754	ADS	T-2	24	0	0.07	1.8
4	38996	Hancor	T-1	25	34	0.16	3.9
4	38996	Hancor	T-2	25	35	0.19	4.6
5	40913	ADS	T-1	21	0	0.01	0.3
5	40913	ADS	T-2		0	0.01	0.3
5	42234	ADS	T-1		0	0.06	1.4
5	42234	ADS	T-2	19.5	0	0.05	1.3
6	92110	Springfield Plastics	T-1	24.5	12	0.11	2.7
6	92110	Springfield Plastics	T-2	26	18	0.07	1.6
8	38343	ADS	T-1	32	28	0.11	2.7
8	38343	ADS	T-2		30	0.10	2.5
8	42263	ADS	T-1	29	31	0.05	1.1
8	42263	ADS	T-2	22	38	0.12	2.9
8	42363	Springfield Plastics	T-1	27.5	34	0.06	1.5
8	42363	Springfield Plastics	T-2		38	0.12	3.0
9	40406	Hancor	T-1	23	8	0.19	4.7
9	40406	Hancor	T-2	26	13	0.08	2.0

Table 4. Summary of pipe underdrain measurements.

Most of the pipe depths were measured in the field. Using these depth values along with the estimated vertical deflections, a comparison can be made between the two variables. The purpose of the comparison is to determine if decreasing the underdrain trench depth will have an adverse effect on pipe deflection. If not, a feasible solution to the problem of outlets located too close to the ditchline would be to raise the underdrain elevation. A plot of pipe deflection vs. depth (Figure 13) reveals there is no correlation between trench depth and deflection. It appears that deflection is determined by some other factor such as installation procedure. Therefore, decreasing the trench depth from 30 inches to 24 inches should be a viable option.

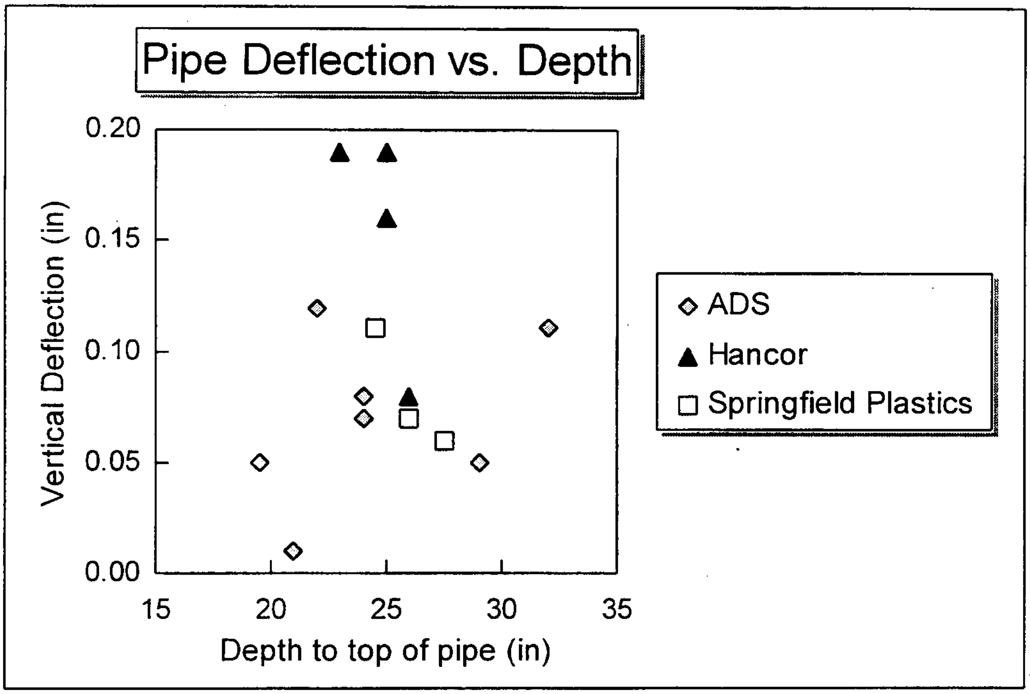

Figure 13. Plot of pipe deflection vs. depth.

Unlike the pipe underdrains, many of the mat underdrains did exhibit some brittle behavior. It was common for the mats to be deformed as a result of being compacted against an irregular pavement edge (see Figure 14). Probably the most widely known drainage mat distress is a condition called J-ing, which refers to the tendency of the bottom edge to curl towards the pavement (see Figure 15). The degree of J-ing can vary from very slight to extreme and range from a cosmetic condition to a structural problem. Another distress, which is more serious, is crushing. This refers to the physical flattening of the mat. Crushing was most common in the 14" mats which were only used adjacent to full-depth asphalt pavements. These mats had to contend with

Figure 14. Drainage mat deformed by irregular pavement edge.

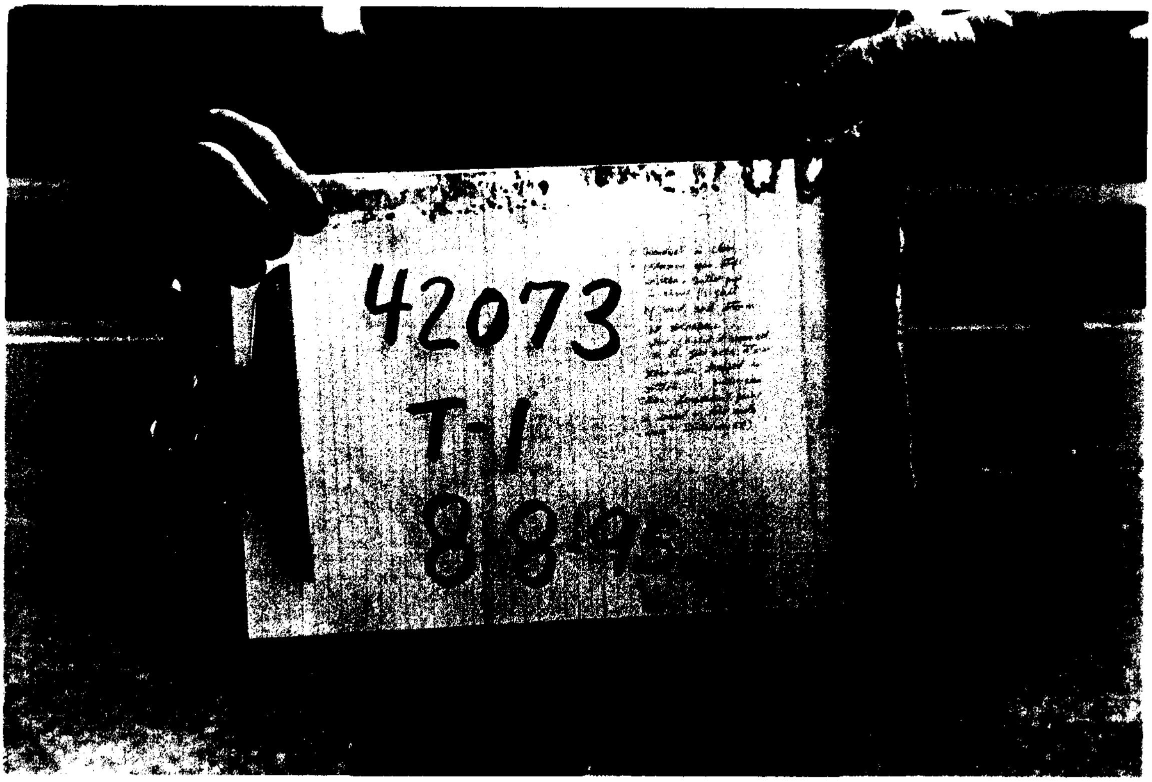

Figure 15. Example of J-ed drainage mat.

being compacted against the tapered edge of the asphalt pavement (see Figure 4) and it also appears that the contractors attempted to fit the 14" mats into 12 inch holes. A severe case of crushing is illustrated in Figure 16.

Figure 16. Example of crushing.

The structural condition of each mat sample was determined by exposing the core and checking for cracks. Each crack found was then marked by attaching a red dot at the crack location. After all cracks were marked and counted, the sample was photographed. For the purposes of discussion, it is best to consider each manufacturer separately.

ADS

The Advanedge brand drainage mat manufactured by ADS is constructed of the same material as their 4" PE pipe underdrains. In concept, the design resembles an oval-shaped pipe. No cracks or other distresses were found in the Advanedge samples (see Figure 17).

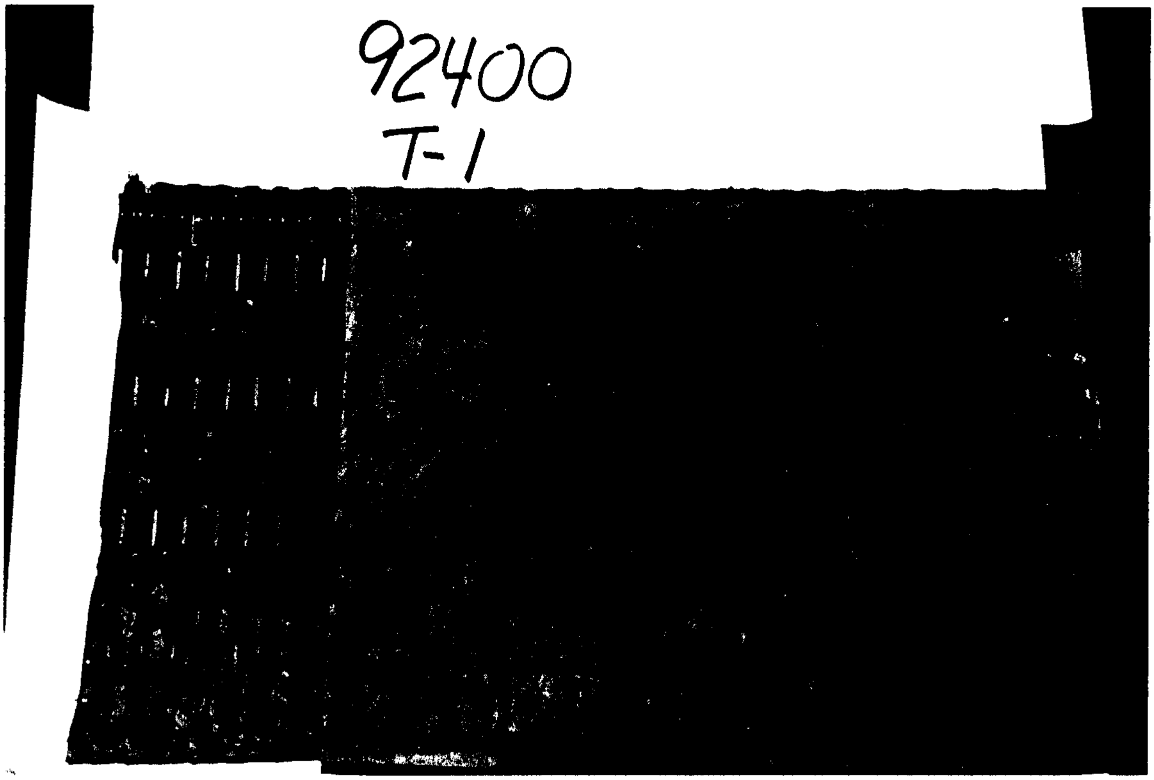

Figure 17. Intact core of Advanege drainage mat.

Contech

The core of Contech's Stripdrain consists of conical sections protruding from a flat backing with circular openings. Stripdrain was found to be very brittle and both samples contained cracking. One sample (Contract 84384 T-2) had been bent considerably in the field and was nearly broken into four sections (see Figure 18). The structural performance of Stripdrain was deemed unacceptable.

84384
T-2
6-13-95

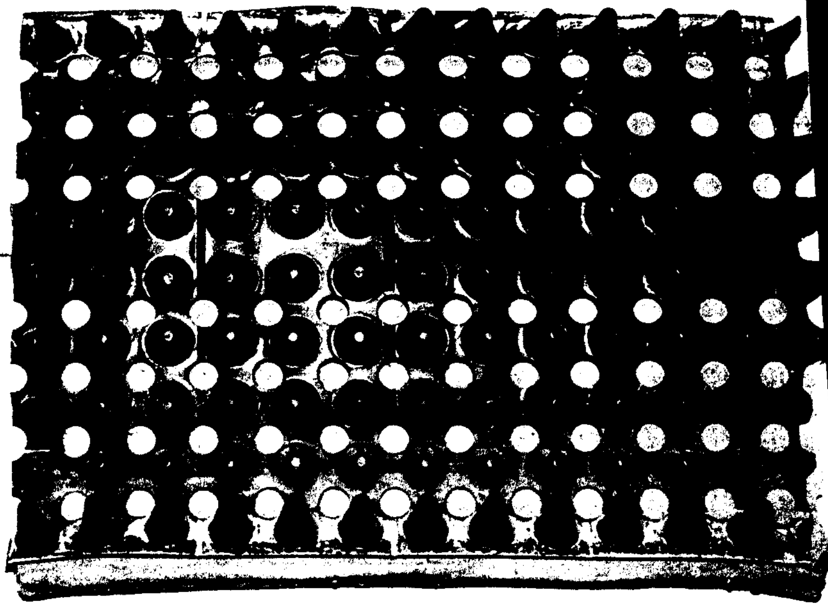

Figure 18. Highly distressed Stripdrain core.

Monsanto

The Monsanto samples consisted of two designs and two sizes. The cores of both designs contain a series of posts attached to a grid-like backing. The original design consisted of one inch long, 1/4 inch diameter posts attached to a fairly closed grid on a 3/4 inch center to center spacing. In 1989, the posts were shortened to 15/16 inch, the post diameter was increased to 3/8 inch, and the post spacing was increased to 1-1/4 inches. In addition, the backing grid was opened up considerably.

The resin used in the newer design was found to be much more brittle than the resin used in the older design (see Figure 19). Cracks were hard to see in the older mats because their cores naturally tended to have a wrinkled appearance, whereas the newer mats had a smooth texture. It was also difficult to see cracks in mats that had

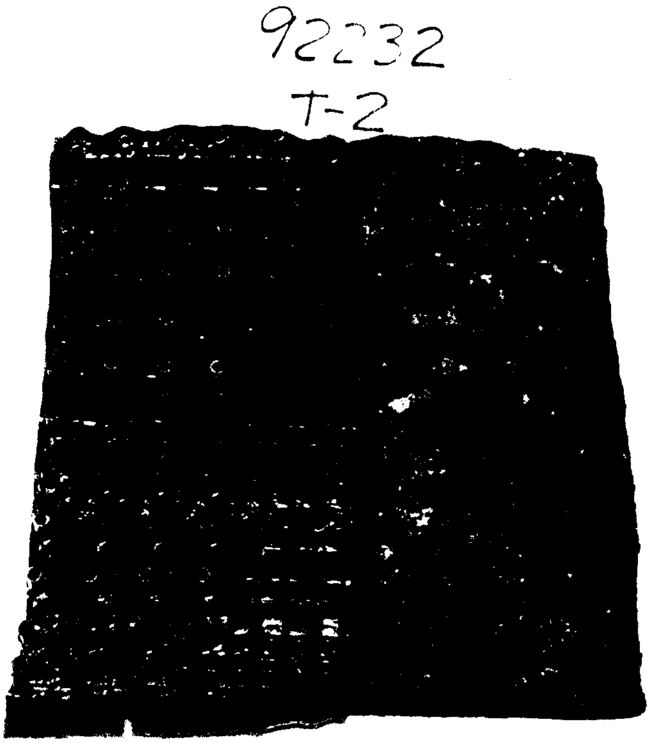

Figure 19. Brittle cracking of newer Monsanto mat. Dots indicate cracks.

appreciable silt accumulations. About half of the older design Monsanto mats appeared to contain cracks. By contrast, all of the newer design Monsanto mats contained cracks. Cracking was especially prevalent in the 14" mats. The 14" mats were all constructed using the newer design and were found to contain, on average, four times as many cracks as the 12" mats constructed with the same design. Table 5 summarizes the distresses found in the drainage mats.

Permeability

Four different types of geotextiles were used for the various underdrain types. Some of the 4" PE pipe underdrains used a knitted polyester sock. The remainder of the pipe underdrains, as well as the ADS Advanedge drainage mat, used a heat-

DIST	CONTR	TEST#	SIZE	MANUFACTURER	NO. OF CRACKS IN CORE	J-ING	CRUSHING
1	80208	T-1	12" mat	Monsanto -New	6	Some	Some
1	80208	T-2	12" mat	Monsanto -New	7		
1	80209	T-1	12" mat	Monsanto -New	30	Some	Some
1	80209	T-2	12" mat	Monsanto -Old	Hard to see		Some
1	80633	T-1	12" mat	Monsanto -New	58	Some	
1	80633	T-2	12" mat	Monsanto -New	16	Slight	
2	84384	T-1	12" mat	Contech	1	Some	
2	84384	T-2	12" mat	Contech	26	Severe	
3	42281	T-1	12" mat	Monsanto -Old	Hard to see	Slight	
3	42281	T-2	12" mat	Monsanto -Old	Hard to see	Some	
4	38433	T-1	12" mat	Monsanto -Old	Hard to see		Some
4	38433	T-2	12" mat	Monsanto -Old		Slight	
4	42583	T-1	12" mat	Monsanto -Old	Hard to see		
4	42583	T-2	12" mat	Monsanto -Old		Some	
4	88050	T-1	14" mat	Monsanto -New	108		Severe
4	88050	T-2	14" mat	Monsanto -New	32	Some	Moderate
5	90128	T-1	12" mat	Monsanto -New	2		
5	90128	T-2	12" mat	Monsanto -New	9		
6	92177	T-1	14" mat	Monsanto -New	55	Some	Some
6	92177	T-2	14" mat	Monsanto -New	62		
6	92232	T-1	14" mat	Monsanto -New	8		
6	92232	T-2	14" mat	Monsanto -New	90	Slight	Some
6	92400	T-1	12" mat	ADS			
6	92400	T-2	12" mat	ADS			
7	40230	T-1	12" mat	Monsanto -Old			
7	40230	T-2	12" mat	Monsanto -Old		Slight	
7	40673	T-1	12" mat	Monsanto -Old	Hard to see		
7	40673	T-2	12" mat	Monsanto -Old		Slight	
7	42908	T-1	12" mat	Monsanto -Old	19	Some	
7	42908	T-2	12" mat	Monsanto -Old		Some	
7	94027	T-1	12" mat	Monsanto -New	1	Slight	
7	94027	T-2	12" mat	Monsanto -New	9	Some	
9	42073	T-1	12" Mat	Monsanto -Old	23	Some	
9	42073	T-2	12" Mat	Monsanto -Old		Slight	

Table 5. Summary of drainage mat distresses.

bonded, non-woven, polypropylene fabric envelope. Finally, Contech uses a needle-punched, non-woven, polyester fabric while Monsanto uses a needle-punched, non-woven, polypropylene fabric. A fairly simple permeability test (see Figures 20 and 21) was designed to determine the relative performance of the various geotextiles. The test involved pouring 250 ml of water through a geotextile sample attached to a three inch

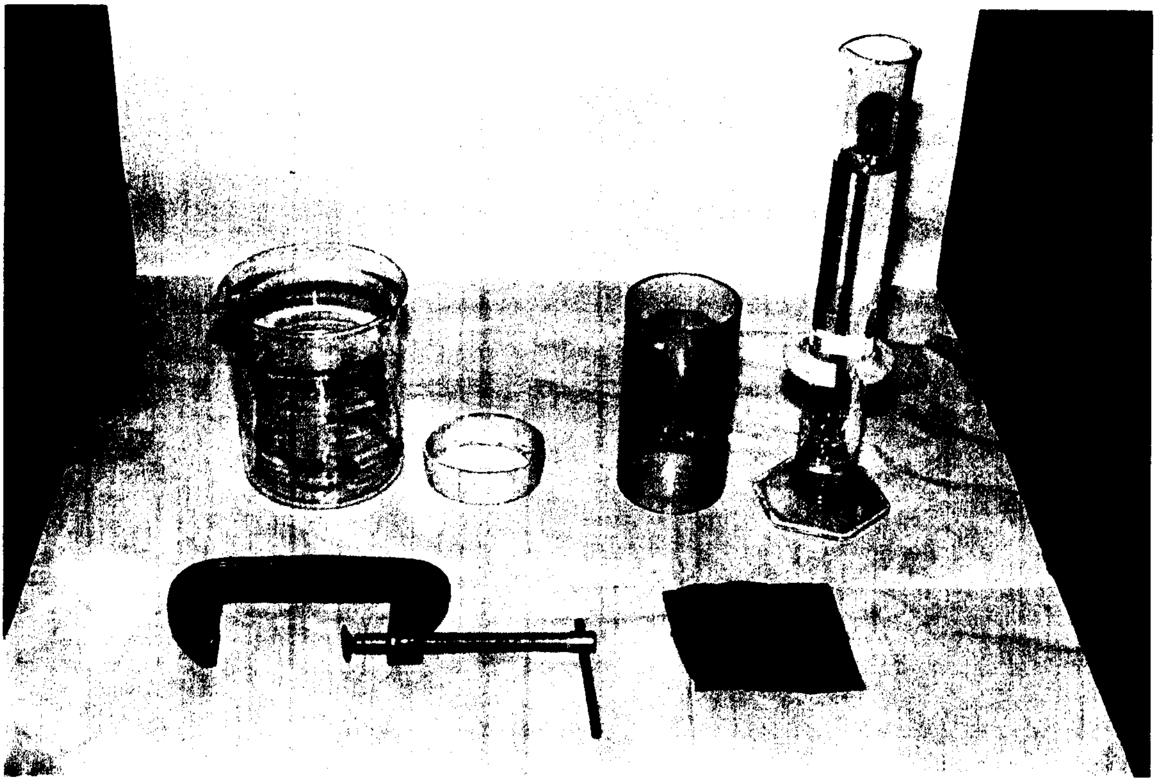

Figure 20. Components of permeability test.

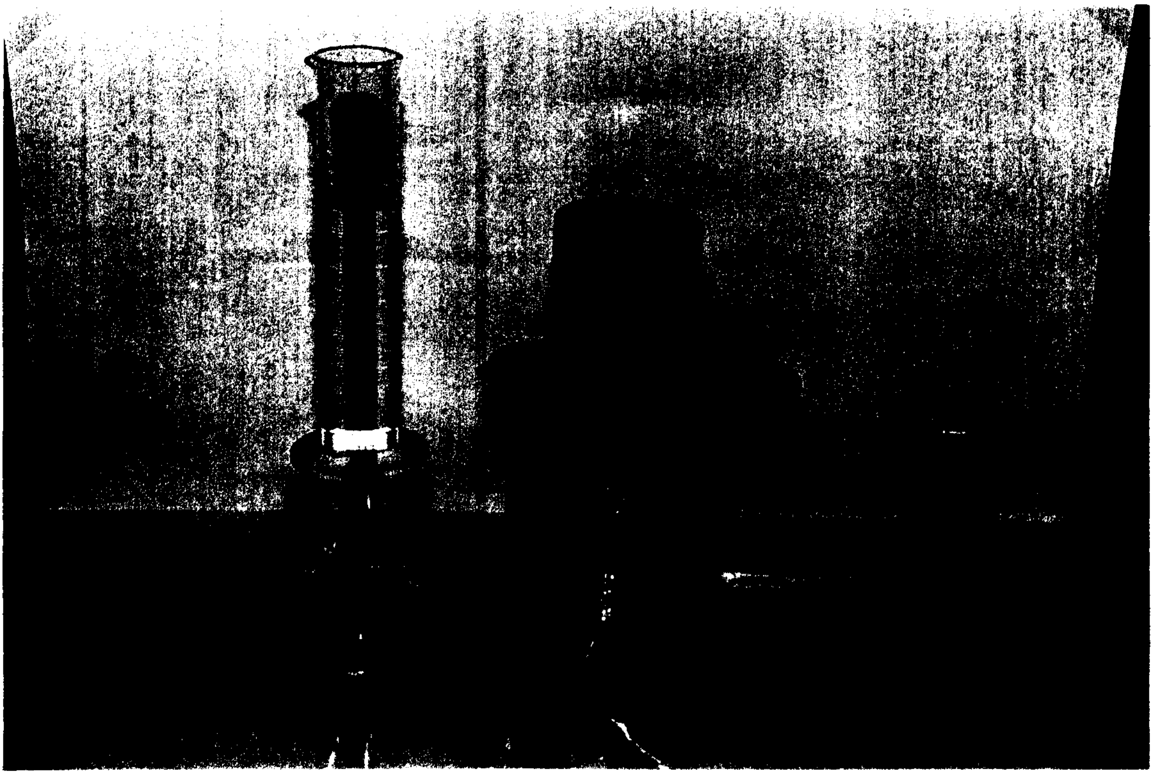

Figure 21. Sample ready for permeability test.

diameter acetate tube suspended over a 1000 ml beaker. The geotextile was oriented so that the water would flow in the same direction as in the field. The entire test was videotaped and the time for the water to pass through the fabric was recorded. In addition, the color of the filtered water was noted. The geotextile samples were taken from the bottom half of the underdrains. Although this probably represents the worst case, it was felt that, with time, the rest of the geotextile would approach the same condition. Table 6 summarizes the results of the permeability testing. From the data in Table 6, plots were prepared comparing the flow rate distribution for the various geotextiles. Since the pipe underdrains contained granular backfill and the mat underdrains did not, they were considered separately. Figure 22 contains a plot of the results of the permeability tests pertaining to the pipe underdrain samples.

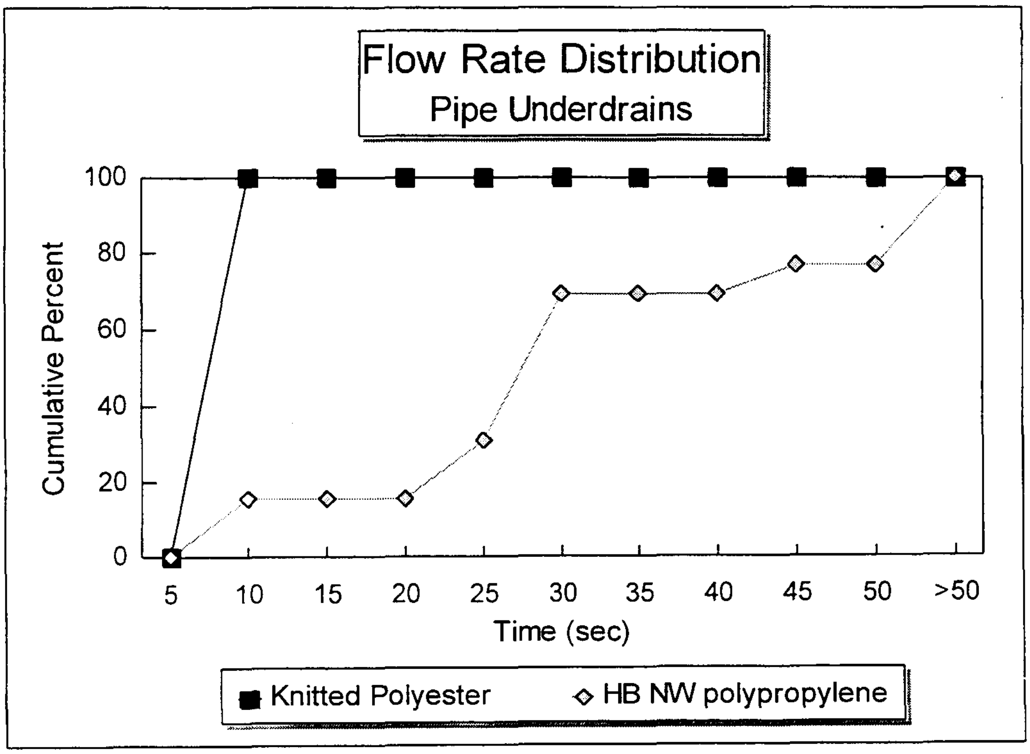

Figure 22. Flow rate distribution for pipe underdrain samples.

DIST	CONTR	TEST#	DRAIN TYPE	FABRIC TYPE	FLOW TIME	WATER COLOR
1	80208	T-1	12" mat	NP NW Polypropylene	8 sec	Tan
1	80208	T-2	12" mat	NP NW Polypropylene	8 sec	Black
1	80209	T-1	12" mat	NP NW Polypropylene	33 sec	Black
1	80209	T-2	12" mat	NP NW Polypropylene	8 sec	Black
1	80633	T-1	12" mat	NP NW Polypropylene	12 sec	Brown
1	80633	T-2	12" mat	NP NW Polypropylene	8 sec	Brown
2	84384	T-1	12" mat	NP NW Polyester	9 sec	Tan
2	84384	T-2	12" mat	NP NW Polyester	8 sec	Tan
3	42281	T-1	12" mat	NP NW Polypropylene	27 sec	Tan
3	42281	T-2	12" mat	NP NW Polypropylene	70 sec	Tan
3	42754	T-1	4" PE	Knitted Polyester	8 sec	Clear
3	42754	T-2	4" PE	Knitted Polyester	8 sec	Clear
4	38433	T-1	12" mat	NP NW Polypropylene	24 sec	Brown
4	38433	T-2	12" mat	NP NW Polypropylene	14 sec	Tan
4	38996	T-1	4" PE	HB NW Polypropylene	26 sec	Clear
4	38996	T-2	4" PE	HB NW Polypropylene	27 sec	Clear
4	42583	T-1	12" mat	NP NW Polypropylene	73 sec	Brown
4	42583	T-2	12" mat	NP NW Polypropylene	13 sec	Brown
4	88050	T-1	14" mat	NP NW Polypropylene	10 sec	Brown
4	88050	T-2	14" mat	NP NW Polypropylene	19 sec	Tan
5	40913	T-1	4" PE	HB NW Polypropylene	22 sec	Tan
5	40913	T-2	4" PE	HB NW Polypropylene	27 sec	Clear
5	42234	T-1	4" PE	HB NW Polypropylene	45 sec	Clear -particles in bottom
5	42234	T-2	4" PE	HB NW Polypropylene	73 sec	Tan
5	90128	T-1	12" mat	NP NW Polypropylene	42 sec	Tan
5	90128	T-2	12" mat	NP NW Polypropylene	1 hr +	Tan
6	92110	T-1	4" PE	HB NW Polypropylene	155 sec	Clear- particles in bottom
6	92110	T-2	4" PE	HB NW Polypropylene	27 sec	Clear
6	92177	T-1	14" mat	NP NW Polypropylene	43 sec	Black
6	92177	T-2	14" mat	NP NW Polypropylene	9 sec	Black
6	92232	T-1	14" mat	NP NW Polypropylene	28 sec	Tan
6	92232	T-2	14" mat	NP NW Polypropylene	6 sec	Tan
6	92400	T-1	12" mat	HB NW Polypropylene	110 sec	Tan
6	92400	T-2	12" mat	HB NW Polypropylene	29 sec	Clear
7	40230	T-1	12" mat	NP NW Polypropylene	11 sec	Brown
7	40230	T-2	12" mat	NP NW Polypropylene	8 sec	Brown
7	40673	T-1	12" mat	NP NW Polypropylene	42 sec	Tan
7	40673	T-2	12" mat	NP NW Polypropylene	125 sec	Tan
7	42908	T-1	12" mat	NP NW Polypropylene	44 sec	Brown
7	42908	T-2	12" mat	NP NW Polypropylene	12 sec	Brown
7	94027	T-1	12" mat	NP NW Polypropylene	320 sec +	Tan
7	94027	T-2	12" mat	NP NW Polypropylene	45 sec	Tan
8	38343	T-1	4" PE	Knitted Polyester	8 sec	Clear
8	38343	T-2	4" PE	Knitted Polyester	9 sec	Clear
8	42263	T-1	4" PE	Knitted Polyester	8 sec	Clear
8	42263	T-2	4" PE	HB NW Polypropylene	173 sec	Clear
8	42363	T-1	4" PE	HB NW Polypropylene	27 sec	Clear
8	42363	T-2	4" PE	HB NW Polypropylene	23 sec	Clear
9	40406	T-1	4" PE	HB NW Polypropylene	10 sec	Tan
9	40406	T-2	4" PE	HB NW Polypropylene	10 sec	Tan
9	42073	T-1	12" Mat	NP NW Polypropylene	9 sec	Black
9	42073	T-2	12" Mat	NP NW Polypropylene	10 sec	Black

Table 6. Summary of permeability data.

When new, most geotextiles tested let water through as fast as it could be poured (<10 seconds). However, it took approximately three times as long for the water to pass through the heat-bonded, non-woven, polypropylene when new and this material showed a greater tendency to retain fines and lose permeability. It can be seen in Figure 22 that the knitted polyester did not lose any permeability with time, whereas less than 70 percent of the heat-bonded, non-woven, polypropylene maintained its original, slower, flow rate. All of the knitted polyester samples let the water pass through in under 10 seconds whereas less than 20 percent of the heat-bonded, non-woven, polypropylene samples could make the same claim.

Figure 23 contains a plot of the permeability test results pertaining to the drainage mat samples. The needle-punched, non-woven, polyester performed the

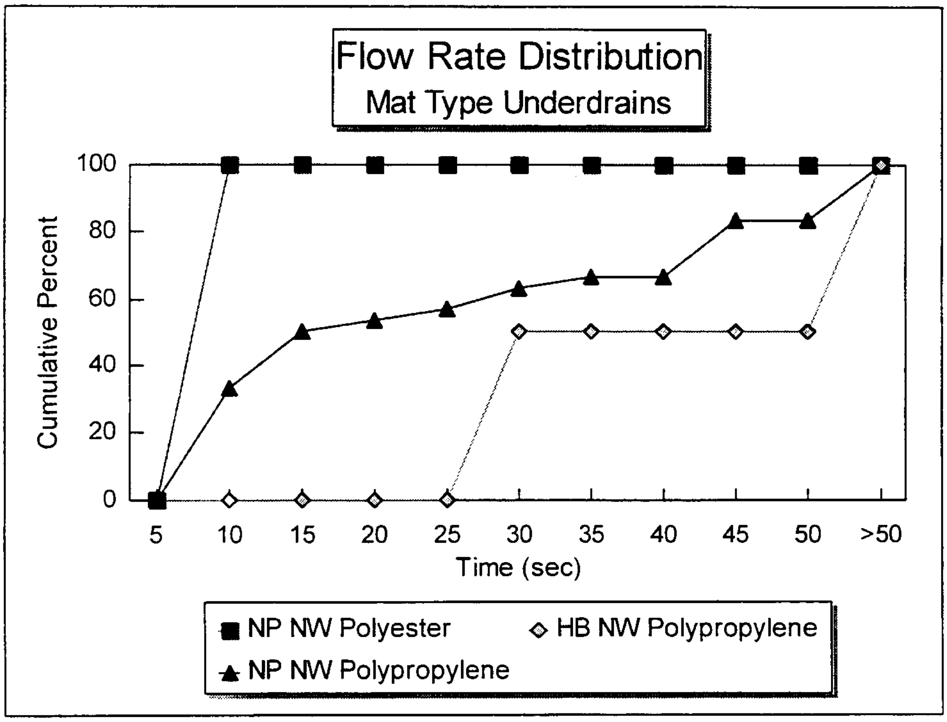

Figure 23. Flow rate distribution for mat underdrain samples.

best of the mat underdrain geotextiles. It should be noted that both samples of this material were taken from areas with a granular subgrade. Therefore, the difference may be more attributable to the cleaner subgrade than to a material superiority. The heat-bonded, non-woven, polypropylene again performed the worst of the fabrics tested. Without the aid of a granular backfill, the performance was even worse than it was for the pipe underdrains. Intermediate results were obtained from the needle-punched, non-woven, polypropylene. A wide range of values were obtained with this material ranging from under 10 seconds to over one hour. The samples with the slowest flow rates were found to contain a coating of silty clay on their interior.

VI. SUMMARY AND CONCLUSIONS

While most of the underdrains surveyed appeared to be serving their intended purpose on initial observation, closer inspection revealed some structural and flow rate problems. More solids were found in mat-type underdrains than in pipe underdrains. The difference appears to be primarily due to the lack of granular backfill in the mat underdrain installations. Past design improvements such as moving the underdrain trench from the edge of the subbase to the edge of the pavement; reducing the rodent screen opening size; requiring rigid, solid, smooth interior outlet pipes; and requiring sand backfill for mat-type underdrains were shown to be prudent changes. However, it appears that additional changes are needed to increase the performance level of IDOT's underdrains. Specific areas needing further attention are headwall maintenance, placement and grade control, drainage mat structural design, and geotextile specification. As a general note, more care needs to be taken to insure that the drainage path is not blocked by columns of low permeability soil. The following section outlines recommendations made based on the results of this investigation.

VII. RECOMMENDATIONS

- The use of the current Monsanto Hydraway and Contech Stripdrain drainage mats should be permanently discontinued due to structural and material problems. These products should not be reconsidered until design and material improvements are made.
- The use of heat-bonded, non-woven, polypropylene should be discontinued for both pipe and the Advanedge drainage mat due to its propensity to collect fines and lose permeability. The Advanedge drainage mat should be acceptable for use in Illinois once the geotextile is changed.
- New screens should be installed in all outlets found to have missing screens or screens with wider openings than the 7mm x 7mm opening size currently allowed in IDOT's standards.
- IDOT's 15 foot mowing policy should be relaxed at least enough to insure that the area around underdrain headwalls is mowed.
- The districts should continue to backflush outlets at their current frequency and should repair all bad joints found in the outlet pipe.
- The grade control of pipe underdrains should be improved to minimize sagging.
- The nominal pipe underdrain trench depth should be decreased from 30" to 24" to prevent headwalls from being located in the ditchline.
- Sand backfill should continue to be required for mat underdrains and the drains should be placed on the shoulder side of the trench.

- The condition of installed underdrains should be evaluated during the design phase of interstate rehabilitation projects. This evaluation should include removing a section of shoulder and visually inspecting the underdrains.