CHAPTER 5

PAVEMENT DRAINAGE

5.1 Pavement Design Acceptance, Consideration of Drainage, Memorandum, T. D. Larson, February 6, 1992.
- Technical Guide Paper, 90-01, Subsurface Pavement Drainage, 1990.

5.2 Longitudinal Edgedrains, Concrete Pavement Drainage Rehabilitation, State of Practice Report, Experimental Project No. 12, April 1989.

5.3 Permeable Base Design and Construction, January 1989.

5.4 Case Study, Pavement Edgedrain, TA 5040.14, June 8, 1989.

5.5 Subsurface Drainage of Portland Cement Concrete Pavements; Where Are We? December 1991.

5.6 Western States Pavement Subdrainage Conference, August 10, 1994.

5.7 Drainable Pavement Systems, Demonstration Project 87, April 06, 1992.

5.8 Effectiveness of Highway Edgedrains, Concrete Pavement Drainage Rehabilitation, State of Practice Report, Experimental Project No. 12, April 14, 1993.

5.9 Maintenance of Pavement Edgedrain Systems, March 21, 1995.

5.10 Pavement Subsurface Drainage Activities, December 16, 1994.

U.S. Department
of Transportation

Federal Highway
Administration

Memorandum

Subject Pavement Design Acceptance
Consideration of Drainage

Date February 6, 1992

From Administrator

Reply to
Attn of HNG-42

To Regional Federal Highway Administrators
Federal Lands Highway Program Administrator

Consideration of drainage is recognized as one of the important factors in pavement design. However, inadequate subsurface drainage continues to be identified as a major cause of pavement distress. During the last 10 years, significant strides have been made in the development of positive drainage systems for new and reconstructed pavements. In addition, there has been major product development of materials which can be used for retrofit longitudinal edgedrains. The attached Technical Guide Paper 90-01 provides state-of-the-practice guidance on the design, construction, and maintenance of subsurface drainage systems.

The developments in technology for permeable bases and longitudinal edgedrains make the provision of positive drainage of the pavement section possible and affordable. Accordingly, to be acceptable to the Federal Highway Administration, each State's pavement design procedure must include a drainage analysis for each new or reconstructed pavement section. Where the drainage analysis or past performance indicates the potential for reduced service life due to saturated structural layers or pumping, the design must include positive measures to minimize that potential.

Each division office is to evaluate the State's current design procedures to determine if pavement drainage is being adequately addressed. Where deficiencies are noted, the division will work with the State to accomplish needed changes by August 1, 1992.

The Pavement Division is available to provide technical support and guidance to achieve these actions. I have directed the Pavement Division to report to me monthly on progress. This will require a report from each Region to the Pavement Division (HNG-40) on the first of each month, until acceptable design procedures that consider pavement drainage are in operation in each State. I ask that each of you lend your personal support to this important initiative to improve pavements.

T. D. Larson

Attachment

TECHNICAL PAPER 90-01

TECHNICAL GUIDE PAPER

ON

SUBSURFACE PAVEMENT DRAINAGE

FEDERAL HIGHWAY ADMINISTRATION

OFFICE OF ENGINEERING

PAVEMENT DIVISION

OCTOBER 1990

INTRODUCTION

Water in the pavement structure is a recognized cause of pavement distress, particularly in portland cement concrete (PCC) pavements. Many highway agencies are retrofitting drainage on existing pavements and including free draining bases on new or reconstructed pavements.

This paper is based on the observation of many pavement structure drainage installations and a review of current research. It represents the current state-of-the-practice in design practices for draining the pavement structure. Design and construction of permeable bases and retrofit longitudinal edgedrains are discussed.

This paper was originally developed as a Technical Advisory (TA) on subsurface pavement drainage. However, because of the large amount of experimentation and research underway in pavement structure drainage, it was decided to delay issuance of the TA. The purpose of this paper is to provide interim guidance until the TA is issued. If there are any questions concerning this paper, or if you wish to offer any information relating to permeable bases or retrofit longitudinal edgedrains, please send them to the Pavement Division (HNG-40) or contact John Hallin at (202) 366-1323.

Technical Guide Paper October 25, 1990

Subsurface Pavement Drainage

1. PURPOSE. To provide guidance for the design, construction, and maintenance of subsurface drainage systems for the removal of surface water that infiltrates the pavement structure. The procedures and practices outlined below are directed primarily towards high-type portland cement concrete (PCC) pavements; however, the principles and procedures may be applicable to high-type asphalt concrete (AC) pavements as well.

2. DEFINITIONS

a. Permeability - the capacity of a material to conduct or discharge water under a given hydraulic gradient.

b. Coefficient of permeability (K) - a measure of the rate at which water passes through a unit area of material in a given amount of time under a unit hydraulic gradient.

c. Permeable Base - a base that is designed and constructed with the intent to rapidly drain moisture that infiltrates the overlying pavement structure.

3. BACKGROUND

a. The pavement structural section is a costly element of the highway system, and its premature failure is of major concern. Among the reasons cited for pavement failures, inadequate base drainage has been identified as a nationwide problem, particularly for PCC pavements. The *AASHTO Guide for Design of Pavement Structures (1986)* includes drainage as an essential element of pavement design.

b. One of the primary distress mechanisms observed on PCC pavements is pumping. The conditions which cause pumping are free water, voids in the pavement section, repeated heavy wheel loads, and an erodible base. Unfortunately, these four conditions are present on the vast majority of PCC pavements designed and constructed to date.

c. The primary source of free water is infiltration through cracks and joints in the pavement. A major source of infiltrated moisture is the longitudinal pavement/shoulder joint, particularly when AC shoulders are used. Water also enters the pavement section from shallow ditches and medians.

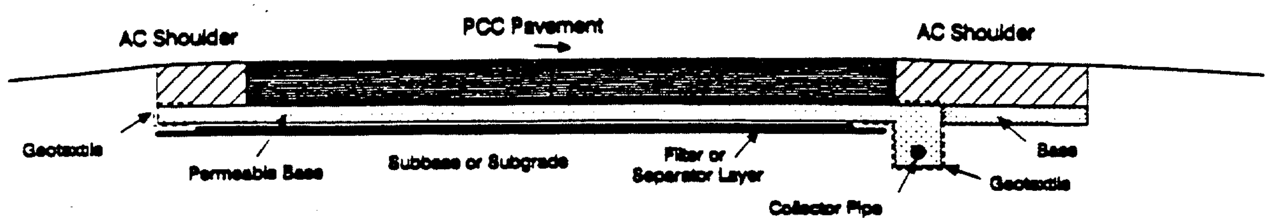
d. To reduce moisture infiltration into the pavement structure, two approaches are recommended. First, all pavement joints and cracks should be sealed to reduce infiltration. While a pavement cannot be completely sealed, properly sealed joints can significantly reduce the amount of water entering the pavement structure. Second, pavement structure drainage systems should be used to remove free water as quickly as possible.

e. Adequate pavement and shoulder cross-slope are important drainage features. In addition, proper joint design (including tiebars and joint sealing) and adequate roadside ditch depth are important. Tiebars help prevent joints from separating and allowing water to infiltrate. The use of tied PCC shoulders provides a tighter and easier to seal joint which can reduce the amount of infiltration.

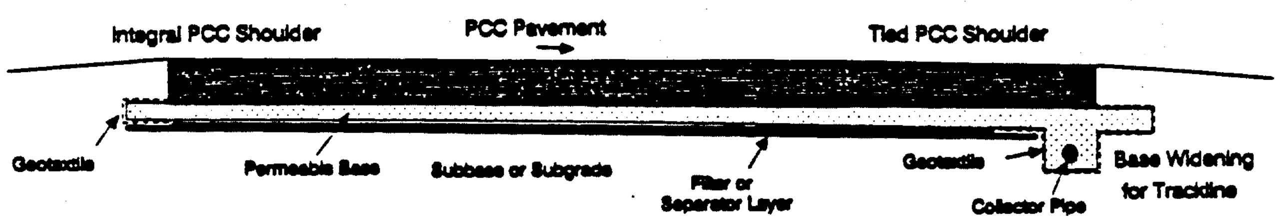
4. DESIGN OVERVIEW

a. Drainage Policy. The FHPM on *Pavement Management and Design Policy (6-2-4-1)* states FHWA's position on pavement structure drainage. State highway agencies (SHA's) are encouraged to perform a drainage analysis for each new, rehabilitated, or reconstructed pavement design. Designs should include methods to minimize the potential for reduced service life due to saturated structural layers.

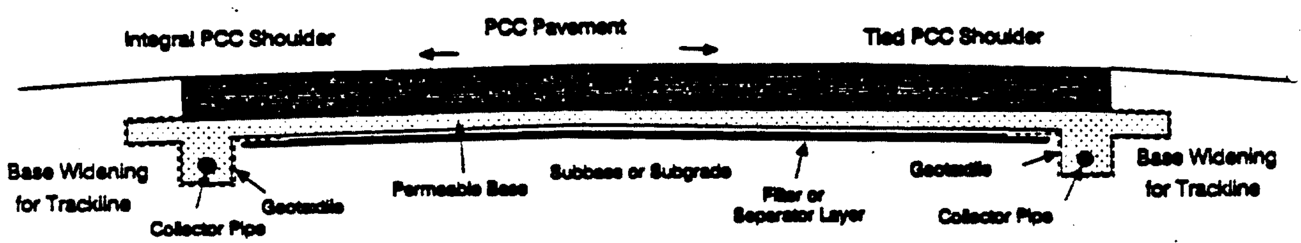
b. Positive Drainage for New and Reconstructed Pavements. For new construction and reconstruction of PCC pavements, positive drainage is strongly recommended. Positive drainage consists of three elements: 1) a permeable base to provide rapid drainage of free water that may enter the pavement structure; 2) a longitudinal edgedrain collector system to convey accumulated water from the permeable base; and 3) a filter-separator layer to prevent migration of fines (minus 200 material) into the permeable base from the subgrade, subbase, or shoulder base material. Filter material should not be placed between the pavement and the permeable base, nor between the permeable base and the edgedrain. Unrestricted flow to the permeable base and the edgedrain must be ensured. The filter-separator layer, whether aggregate or geotextile, must be properly designed to prevent migration of fines and possible base contamination. These elements are shown in Figure 1.



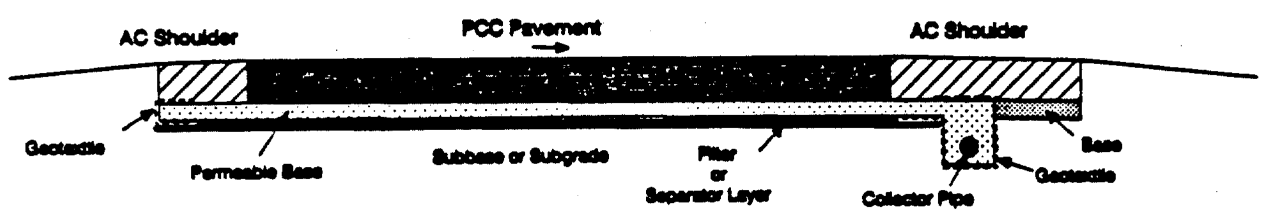
PCC Pavement (Widened Lanes)/AC Shoulder Section



PCC Pavement/Tied PCC Shoulder Section



Crowned PCC Pavement/Tied PCC Shoulder Section



PCC Pavement (Widened Lanes)/AC Shoulder Section
(Edgedrain Installed After PCC Paving)

Figure 1. Permeable Base Sections

c. Positive Drainage for Rehabilitated Pavements. Since most existing PCC pavements have been designed and constructed with impermeable bases, rapid lateral drainage of infiltrated water from the base is not practical. However, retrofit longitudinal edgedrains can rapidly drain water that has infiltrated the pavement structure and migrated to the slab/base interface particularly when AC shoulders are used. Edgedrains placed adjacent to the pavement/shoulder joint can intercept this moisture and significantly shorten the time that free water is present in the interface, thereby minimizing the potential for pumping.

d. AASHTO Drainage Coefficient

(1) The *AASHTO Guide for Design of Pavement Structures (1986)* attempts to recognize the effects of drainage on pavement design. The guide uses a drainage coefficient to model the effect of drainage in determining the thickness of PCC pavement. Of all the parameters in pavement thickness design, pavement thickness is most sensitive to changes in the drainage coefficient. **However, it must be emphasized that a thicker pavement will not compensate for poor drainage.**

(2) A positive drainage system, including a permeable base, a filter layer, and longitudinal edgedrains, should be provided to ensure good drainage. Once adequate drainage has been provided, pavement thickness can be determined using a drainage coefficient of 1.0 or greater.

e. Drainage Analysis

There are generally two types of pavement subsurface design criteria used in design. They are: 1) criterion for the time of drainage of the base beginning with the saturated condition and continuing to an established acceptable level, and 2) an inflow-outflow criterion, by which drainage occurs at a rate greater than or equal to the inflow rate, thus avoiding saturation. It should be noted that the drainage layer design is based only on the infiltration of water from the surface. Normally, other sources of water to the drainage layer would be minor and normally are not a consideration in the design of the permeable base. Should ground water be present in any substantial quantities, special provisions should be made to intercept and drain the water before it reaches the permeable base. The permeable base is expected to aid in the drainage of water in the subbase and subgrade caused by frost action, but this volume of water is generally not considered in computing the design water inflow.

(1) (a) One method of drainage analysis is to examine the gradation of the base material. Estimates of permeability and filter-separator criteria can be made by analyzing the gradations of the base and subgrade material. By comparing the gradation of the sample material to the gradation of a material whose permeability has been determined, the permeability of the sample material can be estimated.

(b) Material permeability can also be determined in the laboratory by the constant head permeability test or the falling head permeability test. The tests should be performed in accordance with *AASHTO T 215, Permeability of Granular Soils (Constant Head)* and the *U.S. Army Corps of Engineers, Engineer Manual (EM 1110-2-1906), Laboratory Soils Testing, Appendix VII, Permeability Tests (Falling Head)*.

(c) A method of determining the in-situ permeability of a base material is to use the field permeability testing device (FPTD) as described in the report, ***Determination of the In Situ Permeability of Base and Subbase Courses***. This device determines the in-situ permeability of a material by measuring the velocity of flow between two points. The FPTD's upper and lower limits are 28,000 feet per day (10 centimeters per second) and 0.28 feet per day (10^{-4} centimeters per second), respectively. Average coefficients of permeability determined in field testing of the FPTD have shown good correlation with average laboratory permeabilities.

(d) Field percolation tests are another method for evaluating the ability of the existing base material to drain. In a percolation test, a hole is cored down to the base and filled with water. Observation of the water level in the hole over time will give an indication of the base material's ability to drain. Caution must be exercised with this method to ensure that percolating moisture is confined to the particular layer being tested. If moisture is allowed to escape along an interface, through voids, or through an adjacent material, the percolation test can give a false indication. In addition, it is important to ensure that the top of base is not clogged during coring.

(2) Edgedrain Hydraulic Capacity. In any drainage analysis, the hydraulic capacity of the edgedrain should be determined to establish the outlet pipe spacing.

(a) Permeable Base Edgedrain. The hydraulic capacity of a longitudinal edgedrain to drain a permeable base should be based on draining free water within the pavement structure within 2 hours of rain cessation. In most cases, a conventional partially geotextile wrapped trench with a 4-inch diameter pipe and backfilled with permeable material will provide excess hydraulic capacity.

(b) Non-Drainable Base and Retrofit Edgedrain. Determining the hydraulic capacity of the edgedrain is not as critical with longitudinal edgedrains on pavements with non-draining or very slow draining bases. Drains should be sized to remove the volume of water occupying the voids in the pavement section once rain has stopped. The purpose of a longitudinal edgedrain in these cases should be to drain free water in the slab/base interface within 2 hours of rain cessation. The capacity should be calculated to satisfy this criteria and flow rates across geotextiles should permit this. Because of the potential for blinding (soil particles blocking the geotextile openings) or clogging (soil particles are trapped within the pore openings, thus reducing the permeability of the geotextile) it is extremely important to properly size the geotextile for the particular soil type and percentage of fines.

f. Outflow Design. To ensure rapid drainage of accumulations of water within a permeable base structural section and to protect the component parts of a drainage system, the outflow capacities of the system should increase in the direction of flow, starting at points of entry and progressing through the base drainage layer, collector pipes, and outflow pipes. In essence, when progressing along possible paths of flow in drainage systems, the water removing capabilities should increase, never decrease, in the direction of flow. This is particularly important with respect to pipe drains and the backfill surrounding them.

g. Filter Design.

(1) The function of any filter is to provide both drainage and filtration. The filter must allow water to pass (drainage) with minimal head loss while retaining soil particles (filtration). It must also enable the creation of a natural filter in the neighboring soil to prevent piping (loss of finer soil particles through the filter leaving larger soil voids behind). For a geotextile to effectively perform as a

filter in a geotextile drainage system, it must remain free-draining by having opening characteristics compatible with the surrounding soil. In some cases, the geotextile is required to prevent migration of fine grained soils without clogging. In complete clogging, the fabric's permeability is reduced to less than that of the soil. In other cases, some fine-grained soils may be required to pass through the geotextile to prevent blinding. In blinding, particles coat the surface of the geotextile such that the permeability is substantially reduced. In any case, some loss of soil particles through the filter during its early life takes place. As fine soil moves through the geotextile, larger particles may combine to bridge the appertures of the geotextile. Immediately behind this bridging zone is another zone (soil filter zone) consisting of soil particles whose permeability decreases with distance from the geotextile. Thus, the choice of a correct geotextile is critical to formation of a stable and effective soil filter. Geotextiles, like graded filters, require engineering design. Unless proper fabric piping resistance, clogging resistance, and constructability strength requirements are specified, it is doubtful that the desired results will be obtained. Construction installation and monitoring must also be provided to ensure that the materials have been installed correctly.

(2) The major criteria considered for a geotextile drainage/filtration application include: 1) soil retention (piping resistance), 2) permeability, 3) clogging potential, 4) chemical composition requirements/considerations, and 5) constructability and survivability requirements.

(3) As with other elements of highway design, geotextiles must be engineered. The geotextile should have a permeability at least several times greater than the aggregate base/subbase so that water can drain freely from it. Geotextiles must also retain the upstream soil. The apparent opening size (AOS) (or equivalent opening size (EOS)) -- AOS and EOS are equivalent terms -- is defined as the U.S. standard sieve number that has openings closest in size to the openings in the geotextile. If given as the equivalent sieve size opening in millimeters, it is referred to as the 95 percent opening size or O_{95}. The AOS of the geotextile should be selected to prevent fines from piping through the filter and clogging the permeable material and leaving voids behind. The appropriate geotextile AOS can be determined by the following criteria adopted by Task Force 25 (refer to Appendix B, Table 1).

1. For a soil with 50 percent or less particles by weight passing the No. 200 sieve, the AOS of the geotextile should be equal to or greater than the No. 30 sieve (i.e., $O_{95} \leq 0.60$ mm).

2. For a soil with more than 50 percent particles by weight passing the No. 200 sieve, the AOS of the geotextile should be equal to or greater than the No. 50 sieve (i.e., $O_{95} \leq 0.30$ mm).

(4) It should be noted that there is no way to prevent a filter adjacent to a material with a high percentage of fines from eventually clogging. If there are no voids or if the voids are small, the filter won't clog up as rapidly and the filter will function for a longer period of time. If, however, voids are present between the material to be drained and the filter, soil particles are provided an opportunity to go into suspension and will eventually clog the filter. Likewise, geotextiles need intimate contact with the material to be drained. A filter placed along a pavement with voids between the slab and the base or between the geotextile and the pavement base would be comparable to this situation.

(5) Generally, nonwoven needle-punched geotextiles are better for pavement drainage applications than heat-bonded geotextiles. Woven or slit-film geotextiles should not be used.

5. PERMEABLE BASES

a. Permeable Base Design. Most existing design methods have relied on the practice of building pavements strong enough to resist the combined effects of load and water. However, they do not always account for the potential destructive effects of water within the pavement structure. As a result, increased emphasis is needed to exclude water from the pavement and provide rapid drainage of any moisture that infiltrates the pavement surface. Permeable bases provide rapid drainage of this moisture. In theory, a properly designed and constructed permeable base will rapidly drain water that infiltrates the pavement surface and not allow destructive high pressures to build up beneath the pavement.

(1) To overcome moisture related distresses in PCC pavements, many SHA's are now using permeable bases. There are two types of permeable bases; unstabilized and stabilized.

(2) The combination of base thickness and permeability should be capable of rapidly draining the design flows and preventing saturation of the base. The time period that free water is present within the pavement structure should

be as short as possible, desirably less than 2 hours following the cessation of precipitation.

(3) A longitudinal edgedrain collector system with outlet pipes should be provided to ensure positive drainage. The outlets must be discharged into gutters or drainage ditches or connected to culverts or drainage structures. Daylighting the permeable base layer is not effective in draining the base since it is subject to clogging from roadway debris and vegetation. In addition, daylighted layers may allow silty material or storm water from ditches to enter the pavement structure.

b. Base Material. Both unstabilized and stabilized permeable base material should consist of a hard, durable, crushed, angular aggregate with essentially no fines (minus No. 200 sieve material). A permeable base consisting of crushed aggregate meeting the gradation requirements noted in this Technical Guide Paper will provide sufficient stability on which construction equipment such as dump trucks, transit trucks, and tracked pavers can operate, as well as provide good slab support. The permeable base material gradation should have good aggregate interlock. To prevent the aggregate from degrading and generating fines during construction, the material for the permeable base should also be hard and durable. Also, consideration should be given to construction of a test section to ensure the material will be stable under construction traffic. Recommended gradations of the base material vary depending on whether the material is stabilized or unstabilized. A coefficient of permeability greater than 1000 feet per day is recommended.

(1) Unstabilized Permeable Base

(a) Unstabilized permeable bases utilize an open-graded aggregate material. Most SHA's that use unstabilized permeable bases have developed a gradation that represents a careful trade-off of constructability, stability, and permeability. Unstabilized permeable base materials contain more smaller size aggregate to provide stability through aggregate interlock. The use of more smaller sized aggregate results in lower permeability. To provide good stability for paving equipment, unstabilized permeable base aggregate should be composed of 100 percent crushed stone. Where 100 percent crushed stone with an LA abrasion index of 30 or less is not available, consideration should be given to stabilizing the aggregate with asphalt cement or portland cement. If a material other than a crushed stone is used, other gradations and/or stabilization will need to be investigated.

(b) Below is a gradation for unstabilized permeable material which provides satisfactory permeability (greater than 1000 feet per day) and excellent stability to carry construction equipment. The following is an example of a gradation that has worked:

Sieve Size	Percentage Passing
1 1/2"	100
1"	95-100
1/2"	60-80
No. 4	40-55
No. 8	5-25
No. 16	0-8
No. 50	0-5

(Note: Wet-washed, dry-sieved)

(2) Stabilized Permeable Base

(a) Stabilized permeable bases utilize open-graded aggregate that has been stabilized with asphalt cement or portland cement. Many SHA's require 90 to 100 percent two-crushed faces with a maximum LA Abrasion wear of 40 to 45 percent. Material passing the No. 8 sieve has been virtually eliminated, and the resulting coefficient of permeability is usually much greater than 3,000 feet per day. Stabilizing the permeable base provides a stable working platform without appreciably affecting the permeability of the material. Stabilization is accomplished by using only enough asphalt or cement paste to coat the aggregate. Therefore, its the gradation of the permeable base material that will determine how much stabilizer to use. Its very important that the voids are not filled by excess stabilizer.

1. The stabilization material predominantly used is asphalt cement (AC-20) at 2 to 2 1/2 percent (by weight) for the very open-graded materials such as the AASHTO No. 57 stone. Higher asphalt cement percentages are required when a less open-graded material is used. For example, New Jersey's asphalt cement stabilized permeable base gradation shown below requires 3 percent asphalt cement to coat the aggregates. For additional asphalt stabilized permeable base stability, a stiffer asphalt cement, such as an AC-40, should be used. It should be noted that if AC-40 is used the aggregate should be heated to 275 to 325 degrees Fahrenheit to stiffen the asphalt cement.

2. Portland cement at 1 1/2 to 3 bags per cubic yard has also been used. As with asphalt cement stabilized permeable base, the amount of portland cement per cubic yard will depend on the voids and surface area of the aggregate in the permeable material. For example, California uses not less than 282 pounds of portland cement per cubic yard with a water-cement ratio of 0.37. The permeability of this material is approximately 4,000 feet per day. Whereas Wisconsin with a more open material (permeability approximately 10,000 feet per day) has found that 200 pounds of portland cement per cubic yard and a water-cement ratio of 0.37 provides adequate strength, durability, and stability.

(b) Several SHA's use the AASHTO No. 57 gradation for their stabilized permeable base. This gradation and four other stabilized permeable gradations are as follows:

	Percentage Passing				
	No. 57	California		Wis.	New Jersey
Sieve Size	AC/PC Stab.	AC Stab.	PC Stab.	PC Stab.	AC Stab.
1 1/2"	100	-	100	-	-
1"	95-100	100	86-100	-	100
3/4"	-	90-100	X±22	90-100	95-100
1/2"	25-60	35-65	-	-	85-100
3/8"	-	20-45	X±22	20-55	60-90
No. 4	0-10	0-10	0-18	0-10	15-25
No. 8	0-5	0-5	0-7	0-5	2-10
No. 10	-	-	-	0-5	-
No. 16	-	-	-	-	2-5
No. 200	0-2	0-2	-	-	*
Est. "K" (feet per day)	20,000	15,000	4,000	10,000	1,000

("X" is the gradation which the contractor proposes to furnish for the specific sieve size).

(* Add 2 percent (by weight of total mix) mineral filler).

Its important to note that California uses different gradations for their stabilized permeable bases. The AC stabilized gradation is more open (30 percent voids) and has a high crushed content requirement, whereas the PC stabilized gradation is less open (14 percent voids) and has no crushed content requirement.

c. <u>Base Thickness and Width</u>. A minimum permeable base thickness of 4 inches is suggested when the above gradations are used. This thickness should be adequate to overcome any construction variances and provide an adequate hydraulic conduit to transmit the water to the edgedrain collector system. The permeable base should be placed 1 to 3 feet outside the edge of the pavement to provide a stable trackline for the paver (see Figure 1).

d. <u>Filter-Separator Layer</u>

(1) A filter-separator layer must be provided between the permeable base and the subbase/subgrade to prevent subgrade fines from infiltrating and contaminating the permeable base, to provide a working platform for construction equipment, and to provide support for the permeable base and pavement. Generally, a minimum of 4 inches of dense-graded aggregate base is used. Because very little upward flow of water is expected from the subgrade, the permeability criteria for filter layer design does not apply. Either aggregate or a geotextile can be used. However, a filter-separator layer over stabilized subbases/subgrades may not be needed provided the stabilized material is not subject to saturation or high pressures for an extended period of time. An asphalt prime coat placed on the stabilized subbase/subgrade would provide additional protection. Although, a geotextile is generally more costly than 4 inches of dense-graded aggregate base, there may be instances where sufficient aggregate is not available and a geotextile may be cost-effective.

(2) The following are recommended criteria for the design gradation of the filter-separator layer. Both the filter-separator layer/subgrade and the permeable base/filter-separator layer interfaces must be considered. The gradation of the filter-separator must meet the requirements for the filter-separator layer/subgrade interface as listed below:

<u>EQ. 1</u> D_{15} (Filter-Separator) $\leq$ 5 D_{85} (Subgrade)
[Separation requirement]

<u>EQ. 2</u> D_{50} (Filter-Separator) $\leq$ 25 D_{50} (Subgrade)
[Uniformity criteria for piping resistance]

where the D_x is the size at which "X" percent of the particles, by weight, are smaller than that size.

Similarly, the filter-separator layer must meet the requirements for the permeable base/filter-separator layer interface as listed below:

EQ. 3 D_{15} (Base) $\leq$ 5 D_{85} (Filter-Separator)
[Separation requirement]

EQ. 4 D_{50} (Base) $\leq$ 25 D_{50} (Filter-Separator)
[Uniformity criteria for piping resistance]

Plotting the results of these equations on a gradation chart eases the determination of the gradation of the filter-separator layer. An example problem illustrating the design is provided in Appendix A.

Also, it is recommended that the filter-separator layer have a maximum of 12 percent passing the No. 200 sieve to ensure a dense-graded material without excess fines increasing the potential for loss of support or contamination of the permeable base.

In addition, to ensure that the filter-separator layer is stable the following requirement is also recommended:

$$20 \leq \text{Coefficient of Uniformity} \leq 40$$

$$\text{where Coefficient of Uniformity} = \frac{D_{60}\ (\text{Filter})}{D_{10}\ (\text{Filter})}$$

The term coefficient of uniformity (CU) is an indication of the grading of a material. For example, a uniform (one-size) material will have a small CU because the the size of the D_{60} material is very similar in size to that of the D_{10}. Because it consists primarily of one-size material, it contains insufficient fines to fill the voids between the larger particles and consequently it will have an open, more porous structure despite compaction. As a result it will be more easily displaced under load and have less supporting power. The most uniform granular material commonly encountered in engineering is standard Ottawa sand, which has a CU of approximately 1.1. Conversely, a well-graded material will have a large CU because the D_{60} will be much larger than the D_{10}. A well-graded dense aggregate base material plotted on the maximum density line will have CU of between 50 and 60. A well-graded material is relatively stable, can readily be compacted to a very dense condition, and will develop high shear resistance and bearing capacity.

In most cases, a 4-inch dense-graded aggregate subbase will meet the filter-separator layer requirements for both the filter-separator layer/subgrade and the permeable base/filter-separator layer interfaces. In addition, 4 inches of dense-graded aggregate subbase meets the CU criteria for stability providing an excellent working platform for construction of the permeable base.

(3) Although not generally recommended, some SHA's use a geotextile instead of an aggregate filter-separator layer. The principal advantage of the geotextile is uniform installation. The geotextile should have enough strength to survive the construction phase. Care should be used in placing the geotextile so that it is not damaged during construction. Base course materials must be placed so that the geotextile is not damaged. Slit-film or most woven geotextiles should not be used as they do not prevent fines from pumping through the geotextile. Geotextiles should meet the material requirements of the AASHTO-AGC-ARTBA Task Force 25 Specification shown in Appendix B.

e. <u>Construction Considerations</u>

(1) Construction of unstabilized permeable bases requires care since these bases are subject to displacement by construction traffic. Unstabilized permeable bases are also subject to segregation of the material during placement. The addition of 2 to 3 percent water by weight of aggregate reduces the potential for segregation during hauling and placement. Care must also be exercised during construction operations to prevent contamination of the permeable base.

(2) Stabilized permeable bases have sufficient stability for paving equipment and construction traffic. However, because the material is open and must remain so to function properly, it is extremely important to prevent contamination of the permeable base from fine-grained materials. Also, the grade of the stabilized permeable base is more difficult to modify once it has been placed and compacted/consolidated.

(3) SHA's should be encouraged to restrict construction traffic from the permeable base. If the working area is restricted and construction equipment must travel on the permeable base, a stabilized permeable base should be considered.

f. <u>Compaction of Permeable Base</u>

(1) <u>General</u>. Compaction or consolidation of the permeable base material is important. The conventional approach of requiring a fixed percent of a standard or target density may not be applicable. The purpose of compacting a permeable base is to seat the aggregate. A level of consolidation should be specified which results in no appreciable displacement of the base following compaction.

(2) Unstabilized and Asphalt Stabilized. Most SHA's specify one to three passes of a 4 to 10 ton steel-wheeled roller. Over rolling can cause degradation of the material and a subsequent loss of permeability. Caution should be exercised when using vibratory rollers to compact permeable bases, as they can cause degradation, over densification, and a subsequent loss of permeability.

(3) Portland Cement Stabilized. Two methods of compacting or consolidating portland cement stabilized permeable base have been commonly used; 1) rolling consisting of 1 to 3 passes of a 4 to 10 ton steel-wheeled roller (non-vibratory) and 2) vibration using vibrating screeds or vibrating plates.

g. Curing of Portland Cement Stabilized Permeable Base. Curing is another aspect that is of concern with portland cement stabilized permeable bases. Covering the permeable base with polyethylene sheeting for 3 to 5 days is one method used by a few SHA's. A fine water mist cure applied to the portland cement stabilized permeable base several times the day after placement has been used by a few SHA's as well. The method that provides the desired strength and durability to allow for paving on the portland cement stabilized permeable base should be used. A SHA may want to construct a test strip of portland cement stabilized permeable base to determine which curing method to employ as well as which method of compaction/consolidation to use.

6. LONGITUDINAL EDGEDRAINS

a. Edgedrain Design

(1) General. Design considerations will vary for longitudinal edgedrains depending on whether they are used in a new or reconstructed case (for draining permeable base pavements) or in a retrofit case (for draining non-permeable base pavements). The amount of moisture to be drained and the presence or lack of fines and the condition of the base/subbase are important considerations in edgedrain design.

(2) Edgedrain for Permeable Bases. When a permeable base is used, all runoff that enters the pavement section should quickly drain to the edgedrain. The trench backfill material and edgedrain pipe must have adequate capacity to handle the flows. Erosion of fines should not be a problem since the base should contain very little erodible fine material. A longitudinal edgedrain collector system that is open to the permeable base should be used. A geocomposite fin drain is not recommended to drain a permeable base.

(3) Edgedrain for New Non-Permeable Base Pavement. Edgedrains installed on a new non-permeable base should function longer

than retrofit longitudinal edgedrains and are more likely to improve pavement performance. This is because the pavement and base are in excellent condition and erosion of fines should be minimal as a result of small/few voids.

(4) Retrofit Longitudinal Edgedrains

(a) For retrofit longitudinal edgedrains, a field survey should be performed on the existing pavement to determine its condition and drainage features. It is imperative that the existing pavement structure be no more than moderately distressed (i.e., less than 5 percent of the right lane requiring full depth replacement). Studies have shown that if the pavement is severely cracked or has broken slabs, retrofit edgedrains may not be an appropriate rehabilitation technique unless combined with a technique which also increases the structural capacity of the pavement such as an overlay.

(b) In any design analysis of retrofit longitudinal edgedrains, there are two steps that must be followed to determine if the proposed design will accomplish its goal of pavement drainage; 1) identify the source of moisture, and 2) evaluate the erodibility of base material.

1. The first step is to identify the source of moisture that the edgedrains will drain. Retrofit longitudinal edgedrains will drain water that enters the pavement/shoulder joint and any water that infiltrates the PCC pavement slab and collects in voids along the slab/base interface or the base/subgrade interface. This is free water that follows the path of least resistance and is strongly influenced by the effects of gravity. Any water that enters and ultimately saturates the dense graded base may take days or weeks to be drained by the retrofit longitudinal edgedrain.

2. The second step is to evaluate the erodibility of the base material. If the base tends to have 15 to 20 percent or more fines (minus 200 sieve material), it will probably be highly erodible. A geotextile around the drain will not prevent fines from being eroded from the base material. The geotextile controls what happens to the fines after they migrate to the edgedrain. The AOS of the geotextile determines the size of the soil particles that will be retained and those that will pass through the geotextile. The

selection of the AOS for soils with a high percentage of fines becomes a trade-off between allowing the fines to pass through the geotextile and clogging the drain and preventing the fines from passing and clogging and/or blinding the geotextile. If an excessive amount of fines are eroding from the base, retrofit longitudinal edgedrains will not be effective in extending the pavement life and may actually be detrimental by carrying eroded fines away.

(5) Adequate Relief. For both the permeable base and retrofit cases, the cross section of the highway surface must have sufficient relief to provide positive drainage to the roadside ditches. Subsurface and surface drainage must be coordinated. If sufficient relief does not exist, lateral outlet pipes carried out to the ditch may not be feasible and an enclosed drain pipe system may have to be constructed. In addition, shallow ditches result in the water being closer to the pavement structure than with deep ditches.

(6) Transition from Edgedrain to Outlet. The transition from the edgedrain pipe to the lateral outlet pipe should be gradual to facilitate cleaning. Radii of 2 to 3 feet for pipe bends should be used. The radii should permit the use of jet rodding or cleaning equipment. Tee's should not be used on conventional trench/pipe edgedrains. Some SHA's incorporate cleanouts and/or vents into their edgedrain system to improve flow and to facilitate cleaning.

b. Longitudinal Edgedrain Types

(1) Pipe Edgedrain. Conventional pipe edgedrains have a relatively high hydraulic capacity and can be maintained. Retrofit pipe edgedrains should be used with caution when the existing base has more than 20 percent minus 200 sieve material. The edgedrain should be large enough to allow placement of and compaction around a 3 to 6 inch pipe laid in the bottom of the trench which has been partially wrapped with a geotextile and backfilled with a permeable coarse aggregate material. Figure 2 shows the suggested edgedrain configuration. An aggregate trench without a pipe conduit is not recommended because of the much smaller hydraulic capacity and inability to be cleaned. Because the geotextile serves as a filter layer, the permeability of a geotextile must meet the requirements for filter layers noted in section 6.f.(4).

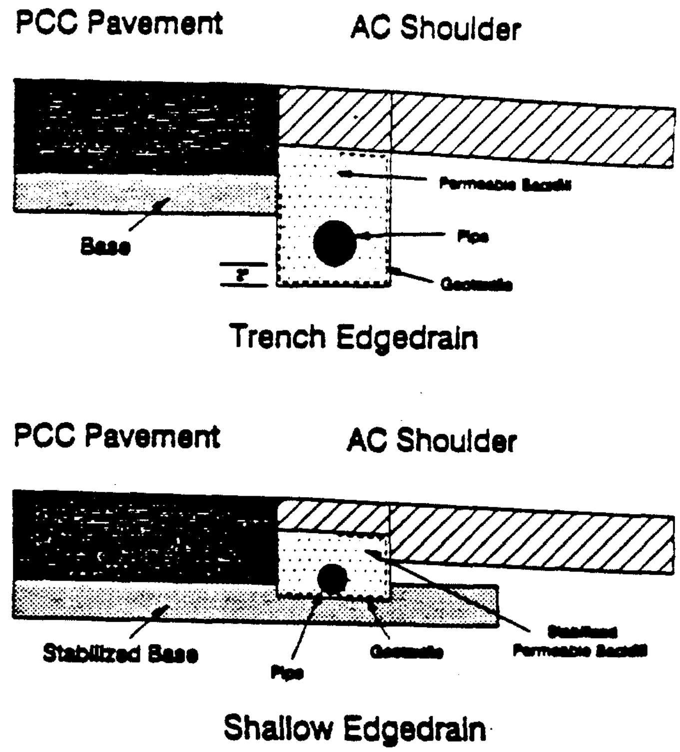


Figure 2. Retrofit Pipe Edgedrains

(2) Geocomposite Fin Drains

(a) A geocomposite fin drain consists of a plastic core, usually rectangular shaped, surrounded by a geotextile. The geotextile retains the soil particles while allowing the water to drain into the core. The plastic core provides the structural capacity and acts as a conduit for the water. Many different types of proprietary geocomposite fin drains are commercially available.

(b) The primary advantage of geocomposites is the ease of installation. Since the trench width is usually only 4 to 5 inches and excavated material is used to backfill the trench, installation costs can be reduced. However, the long-term performance of geocomposites is under evaluation. A typical geocomposite fin drain installation is shown in Figure 3. Geocomposite fin drains should be used with caution when the existing base has more than 15 percent minus 200 sieve material. There is a greater potential for plugging of the core under this condition.

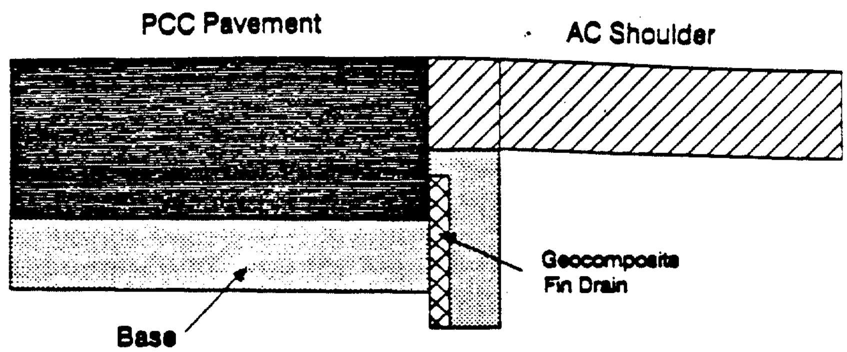


Figure 3. Retrofit Geocomposite Fin Drain

c. Edgedrain Location. For the retrofit case, the edgedrain should be located adjacent to the pavement under the shoulder so that water entering the pavement/shoulder joint can drain rapidly. In the retrofit case, the edgedrain should be placed primarily to intercept flow from the slab/base interface. Dense-graded impermeable bases, subbases, and subgrades cannot effectively be drained. With the retrofit case where tied PCC shoulders exist, the edgedrain should generally be located along the outside edge of the shoulder. For the edgedrain location on a new or reconstructed pavement with a permeable base refer to Figure 1.

d. Geotextile Design

(1) As voids develop at the slab/base interface, free water under pressure from moving heavy wheel loads will erode fines in the base material. These fines will migrate to the edgedrain. If the edgedrain is completely wrapped in a geotextile, eroded fines may collect on the surface and blind the geotextile or get trapped within the matrix and clog the geotextile. Once the geotextile has been blinded or clogged, there is no path for the water to escape and the entire pavement section will become saturated. This condition will reduce subgrade strength, accelerating pavement deterioration.

(2) Most geotextiles used for pavement drainage and filtration applications have AOS's in the 40 to 70 range. It is important that the permeability of the geotextile be greater than that of the adjacent base material. This ensures rapid removal of water that migrates to the slab/base interface, and to a much lesser extent, allows water to drain from the base while retaining the base material. The recommended permeability of a geotextile should be within a range of 4 to 10 times the permeability of the adjacent base. Most

of the geotextiles used by SHA's in pavement drainage/filtration applications have a permeability in the range of 100 to 500 feet per day. While these rates are much greater than that of most existing dense-graded base materials, they may be much less than the permeability of most permeable bases.

(3) The greater the percentage of fines in the base material, and the more free water present in the base; the more aggravated the potential clogging problem will be. Regardless of the geotextile placement, fines will be eroded from the base. The geotextile only controls what happens to the fines after erosion (i.e., retain or allow to pass through).

(4) It is recommended that the trench only be partially wrapped with a geotextile as shown in Figure 2. By eliminating the geotextile at the slab/base interface, free water entering at the pavement/shoulder joint and water flowing at the slab/base interface will be drained. This will drastically reduce the time water is available to saturate the base. Partially wrapping the trench creates the best hydraulic conditions for draining the free water present.

(5) The trench for the longitudinal edgedrain collector system for a permeable base is generally lined with a geotextile. However, the top of the trench is left open to the permeable base to allow water a direct path into the collector system. See Figure 1.

e. Collector Pipe. Most SHA's use flexible, corrugated polyethylene (CPE) or smooth rigid polyvinyl chloride (PVC) pipe. Pipe should conform to the appropriate State or AASHTO Specification. For CPE pipe, AASHTO specification M 252 Corrugated Polyethylene Drainage Tubing is suggested, while for PVC pipe, AASHTO Specification M 278, Class PC 50 Polyvinyl Chloride (PVC) Pipe, is recommended. If the pipe will be installed in trenches that are to be backfilled with asphalt stabilized permeable material (ASPM), the pipe must be capable of withstanding the temperature of the ASPM. PVC 90 degree centigrade electric plastic conduct, EPC-40 or EPC-80 conforming to the requirements of National Electrical Manufacturers Association (NEMA) Specification TC-2 is suggested when ASPM is used as a trench backfill.

f. Trench Backfill

(1) The edgedrain trench should be backfilled with a permeable material to rapidly convey water to the drainage pipe. Many SHA's use the AASHTO No. 57 stone for trench backfill. This material can be unstabilized or stabilized. Unless the unstabilized permeable backfill material is properly compacted, settlement over the edgedrain may occur. A

solution to the settlement problem is to use a stabilized permeable backfill material. Gradations similar to stabilized permeable base as discussed in paragraph 6.b. can be used for backfill. If asphalt cement stabilized backfill is used, geotextiles and pipes which will withstand the temperatures of the material must be specified.

(2) For geocomposites, the trench is usually backfilled with the previously excavated material. Care must be taken in the backfilling so that the geocomposite is not damaged. Proper compaction of the backfill is necessary to keep the geocomposite aligned, held tight against the pavement, and to prevent settlement.

g. Trench Cap. The edgedrain trench should be capped with a layer of like shoulder material. The longitudinal pavement/shoulder joint should be sealed to reduce the infiltration of surface water into the pavement structure.

h. Lateral Outlet Pipe. The installation of the outlet pipe is critical to the edgedrain system. It is recommended that a metal or rigid solid-walled pipe be used for the lateral outlet pipe to ensure the proper grade. Also they are less susceptible to crushing by mowing operations or emergency stops by heavy vehicles than flexible pipe. A 3 percent slope to the ditch as shown in Figure 4 is recommended. This will ensure that the pipe will drain if there is a slight variance of the pipe grade. A collector pipe system may have to be installed if ditches or medians are too flat to outlet the pipe. The invert of the outlet pipe should be at least 6 inches above the 10-year design flow in the ditch. Outlet pipes should be connected to existing storm drains or inlets, if possible, to provide better gradient and to reduce outlet maintenance. The trench for the outlet pipe must be backfilled with a material of low permeability, or provided with a cut-off wall or diaphragm, to prevent piping. Also, subsurface drainage design should be coordinated with surface drainage.

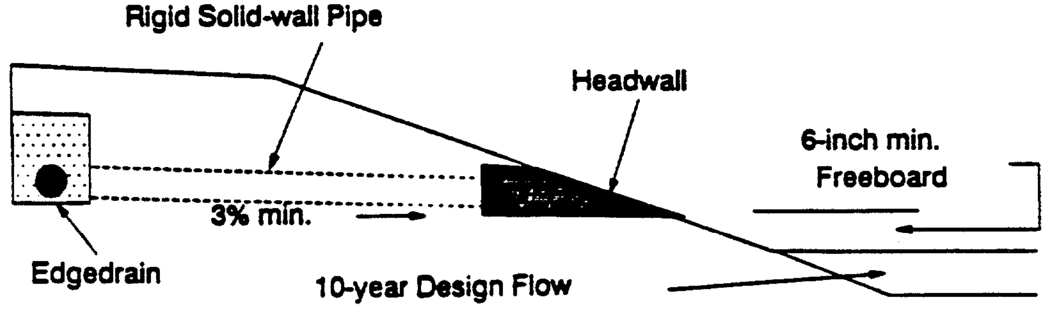


Figure 4. Outlet Pipe Design

i. Outlet Spacing. The purpose of subsurface drainage is to remove water from the pavement structure as quickly as possible; therefore, outlet spacing should be limited to 250 to 300 feet. The edgedrain should be segmented so that each section drains independently.

j. Headwalls. Headwalls are recommended because they provide the following functions: 1) protect outlet pipe from damage, 2) prevent slope erosion, and 3) facilitate the location of outlet pipes. Headwalls should be placed flush with the slope so that mowing operations are not impaired. Positive grades should be provided so that the headwall apron will drain. Both cast-in-place and precast concrete headwalls can be used. The important consideration is maintaining the outlet pipe grade. Some SHA's have used a metal pipe sleeve around plastic outlet pipes that extend 4 to 5 feet into the fill to protect the outlet pipe. A recommended design is shown in Figure 5.

k. Rodent Screens. Rodent screens are recommended as rodents have been reported to damage geocomposite fin drains and build nests in pipe edgedrains. The opening size of the rodent screen should be between 1/4 and 3/8-inch square. Erosion of base fines can build up on rodent screens and restrict the outflow. Rodent screens should be easily removable so that the screens and the outlet pipes can be cleaned (see Figure 5).

l. Reference Markers. Reference markers are recommended because they facilitate locating edgedrain outlets for maintenance or observation. Some SHA's use a simple flexible delineator post to mark the outlet, while others use a painted arrow or other marking on the shoulder.

m. Horizontal Cross Drain. In some cases, a horizontal cross drain may be required as part of a permeable base. A cross drain must be provided at the low-end terminal of permeable base projects (i.e., abutting impermeable base pavement, a bridge approach slab, a sleeper slab, a pavement end anchor or a pressure relief joint). In such cases, a rectangular trench lined with geotextile containing a collector pipe and backfilled with permeable material should be used. The trench should be a minimum of 1-foot deep, 2 feet long, and running the full width of the pavement (see Figure 6). The use of horizontal cross drains on steep grades is generally not necessary. Theoretically, these drains will only collect a small quantity of water. However, in areas such as sag vertical curves or in horizontal curve transition areas horizontal cross drains should be considered. Coordination of the cross drains with the longitudinal structural section drainage systems is important.

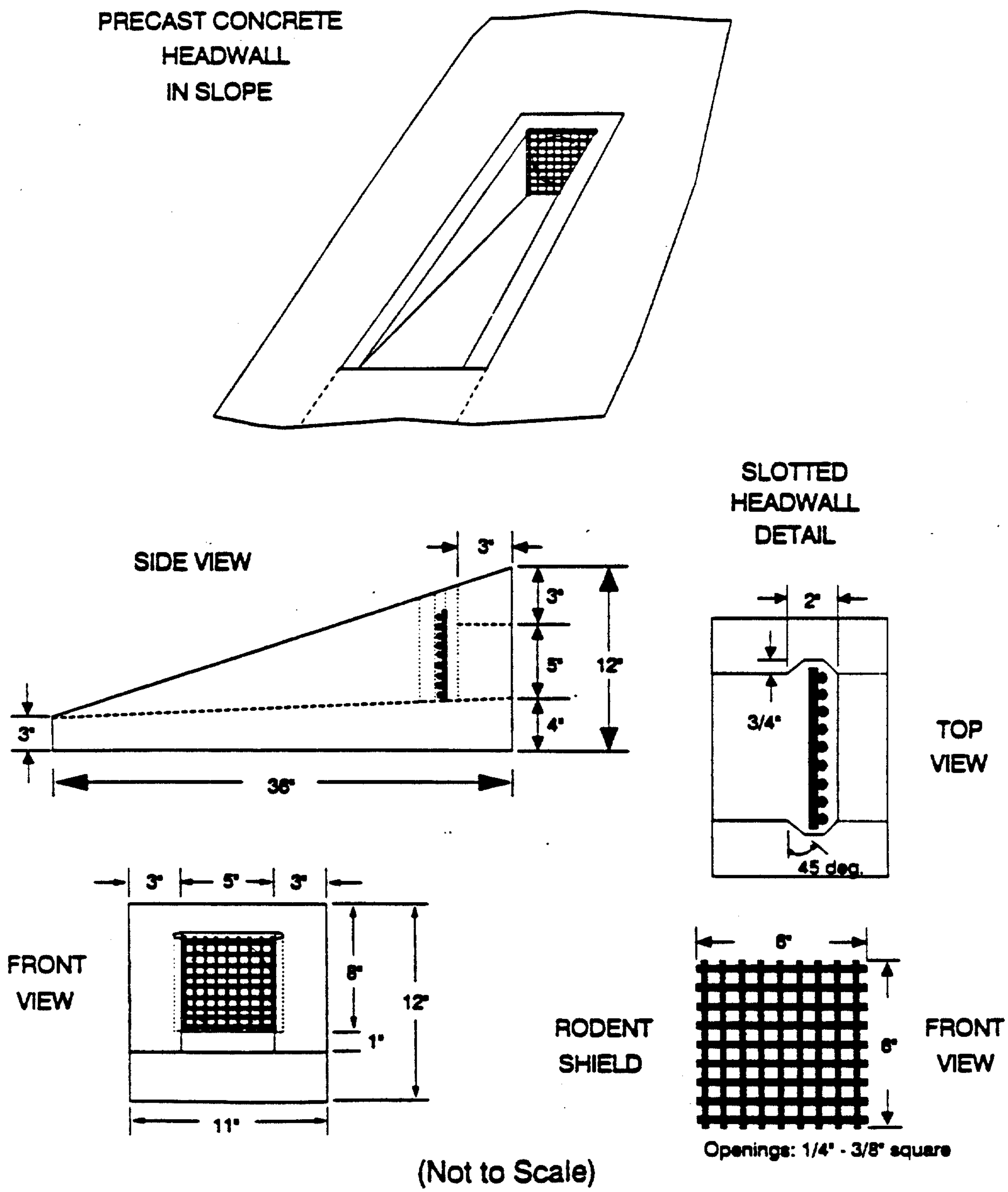


Figure 6. Precast Concrete Headwall with Removable Rodent Screen

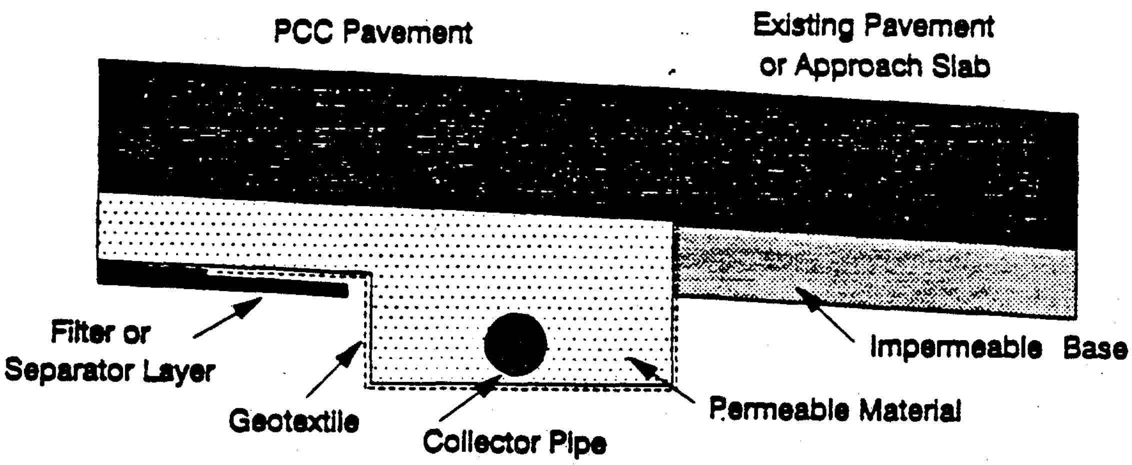


Figure 6. Horizontal Cross Drain

n. Construction Considerations

(1) Attention to details when constructing the longitudinal edgedrain collector system is critical to proper performance of the edgedrain, whether in a retrofit case or as part of a permeable base. As with any other drainage facility, correct line and grade are critical to the hydraulic function of the edgedrains. The placement of the lateral outlet pipe in the trench is very important. High or low spots in the trench must be avoided. The slope of the lateral outlet pipe should be equal to or greater than that of the longitudinal edgedrain.

(2) To prevent water entrapment, it is critical that the exposed end of the pipe is not turned upward or otherwise elevated due to poor construction procedures. There have been some problems noted where the slope of the embankment has prevented a good fit of the lateral pipe into the slope. In a few States, headwall aprons were observed with a reverse grade. Because of improper construction, placement, or settlement, the headwall apron sloped back towards the pipe. Another problem observed was the curling up of the last few feet of flexible outlet pipe resulting in a non-draining outlet. This increases the potential for pavement problems by not allowing accumulated free water adjacent to the pavement structure to drain as rapidly. The pipe curling problem was not observed in those States where rigid lateral outlet pipes were used.

(3) Proper joint seal construction can significantly reduce the amount of moisture entering the pavement.

(4) If undersealing is needed, it should precede the installation of an edgedrain system because of the potential for this operation to contaminate the geotextile and/or aggregate backfill materials.

o. <u>Maintenance</u>

(1) Maintenance is critical to the continued success of any longitudinal edgedrain system. Inadequate maintenance is a universal problem. The combination of vegetative growth, roadside slope debris, and fines discharging from the edgedrains will eventually plug the outlet pipe. Often, outlets can not be found because they are completely covered with vegetative growth and/or roadside slope debris. When outlets that could be found were unplugged, water surged from the pipes.

(2) It is obvious that if maintenance personnel cannot find the outlets no maintenance can be performed. SHA's that used concrete headwalls and/or reference markers had better success at finding outlets. The outlets could be found and maintenance provided.

(3) SHA's should be encouraged to mow around the outlets and clean the outlet pipes a minimum of twice each year.

(4) Periodic flushing or jet rodding of the edgedrain system is important to the continued performance. Therefore, it is important to have the pipe aligned with the proper radii to facilitate this maintenance operation. It is suggested that plan sheets showing alignment of drains and outlets and details on curved connectors.

(5) Maintenance policies should recognize the benefits and necessity of maintaining the joint sealant and thus preventing water from infiltrating into the base layer.

REFERENCES

1. American Association of State Highway and Transportation Officials, *AASHTO Guide for Design of Pavement Structures*, 1986, 444 North Capitol Street, N.W., Suite 225, Washington, D.C. 20001.

2. Baumgardner, R.H. and Mathis, D.M.; *Experimental Project No. 12, Concrete Pavement Drainage Rehabilitation*, State of the Practice, April 1989, Federal Highway Administration, Pavement Division and Demonstration Projects Division, Washington, D.C. 20590.

3. Bradley, M., Larsen, T.J., Temple, W., Gaines, R., Thomas, A., *Longitudinal Edgedrains in Rigid Pavement Systems*, FHWA-TS-86-208, July 1986. Available from: NTIS, Springfield, Virginia 22161.

4. Cedergren, H.R., O'Brien, K.H., Armas, J.A., *Guidelines for the Design of Subsurface Drainage System for Highway Structural Section*, FHWA-RD-72-30, June 1972, Federal Highway Administration. Available from: NTIS, Springfield, Virginia 22161.

5. Cedergren, H.R., *Drainage of Highway and Airfield Pavements*, 1987, Robert E. Krieger Publishing Co. Inc., Krieger Drive, Malabar, Florida 32950.

6. *Concrete Pavement Restoration Performance Review*, Federal Highway Administration, April 1987.

7. Federal Highway Administration, *Federal Highway Administration Pavement Rehabilitation Manual*, Chapter 10, Longitudinal Edgedrains, FHWA-ED-88-025. Last Supplemented March 1988. Available from: NTIS, Springfield, Virginia 22161.

8. *Geotextile Design and Construction Guidelines*, Federal Highway Administration, Washington, D.C., Publication No. FHWA-89-002, May 1989.

9. *Geotextile Specifications for Highway Applications*, Federal Highway Administration, Washington, D.C., Report No. FHWA-89-TS-026, February 1989.

10. Hoover, T.P., *Nonwoven Geotextile Fabric: Evaluation and Specification for Subdrainage Filtration*, FHWA/CA/TL-8111, May 1981, Office of Transportation Laboratory, California Department of Transportation, Sacramento, California 22161.

11. Hough, B.K., *Basic Soils Engineering*, 1957, The Ronald Press Company, New York.

12. Koerner, R.M., *Designing with Geosynthetics*, 1986, Prentice-Hall, Englewood Cliffs, New Jersey 07632.

13. Kozlov, G.S., Mottola, V., Mehalchick, G., *Improved Drainage and Frost Action Criteria for New Jersey Pavement Design - Volume II, Experimental Subsurface Drainage Applications*, New Jersey Department of Transportation, January 1984, Report No. FHWA/NJ-84/012.

14. Mathis, D.M., *Permeable Base Design and Construction*, Proceedings, Fourth International Conference on Concrete Pavement Design and Rehabilitation, Purdue University, April 18-20, 1989.

15. Moulton, L.K., *Determination of the In Situ Permeability of Base and Subbase Courses*, Report No. FHWA-RD-79-88, May 1979.

16. Moulton, L.K., *Highway Subdrainage Design*, Report No. FHWA-TS-80-224, 1980, Offices of Research and Development, Federal Highway Administration, Washington, D.C. 20590.

17. Ridgeway, H.H., *Pavement Subsurface Drainage System*, NCHRP Report No. 96, November 1982, Transportation Research Board, National Research Council, Washington, D.C.

18. Snyder, M.B., Reiter, M.J., Hall, K.T., Darter, M.I., *Rehabilitation of Concrete Pavements*, July 1989, University of Illinois at Urbana-Champaign, Publication No. FHWA-RD-88-071.

19. *Technical Guidance for Design of the Subsurface Drainage for Military Pavements* (Draft), U.S. Army Corps of Engineers, April 1990.

20. Wells, F.K., *Evaluation of Edgedrain Performance*, FHWA/CA/TL-85/15 November 1985, Office of Transportation Laboratory, California Department of Transportation, Sacramento, California 95807. Available from: NTIS, Springfield, Virginia 22181.

21. Wells, G.K. and Nokes, W.A.; *Performance Evaluation of Selected Retrofit Edge Drain Projects Through March 1988*, January 5, 1989, California Department of Transportation, Caltrans Laboratory, Sacramento, CA.

APPENDIX A

"Filter-Separator Layer Design" Example Problem

A typical subgrade gradation and the unstabilized permeable base gradation from page 10 were selected for this problem. The first step is to plot the gradation of both the permeable base and the subgrade on a gradation chart (shown by the solid lines on Figure A-1).

Then using Figure A-1, determine the D_{85}, D_{50}, and D_{15} particle sizes from the permeable base and subgrade gradation curves:

	Permeable Base (mm)	Subgrade (mm)
D_{85}	17.0	0.65
D_{50}	6.0	0.13
D_{15}	1.85	0.038

where the D_x equals the grain size that "X" percent of the particles, by weight, are smaller.

The next step is to apply the design equations (from page 12) to the filter-separator/subgrade interface and plot the points on a gradation chart (Figure A-1):

EQ. 1 D_{15} (Filter-Separator) $\leq 5\ D_{85}$ (Subgrade)

D_{15} (Filter-Separator) $\leq 5 \times 0.65$

D_{15} (Filter-Separator) ≤ 3.25 mm

EQ. 2 D_{50} (Filter-Separator) $\leq 25 D_{50}$ (Subgrade)

D_{50} (Filter-Separator) $\leq 25 \times 0.13$

D_{50} (Filter-Separator) < 3.25 mm

The equation 1 and 2 criteria are superimposed on the gradation curves as shown by the triangular points on Figure A-1.

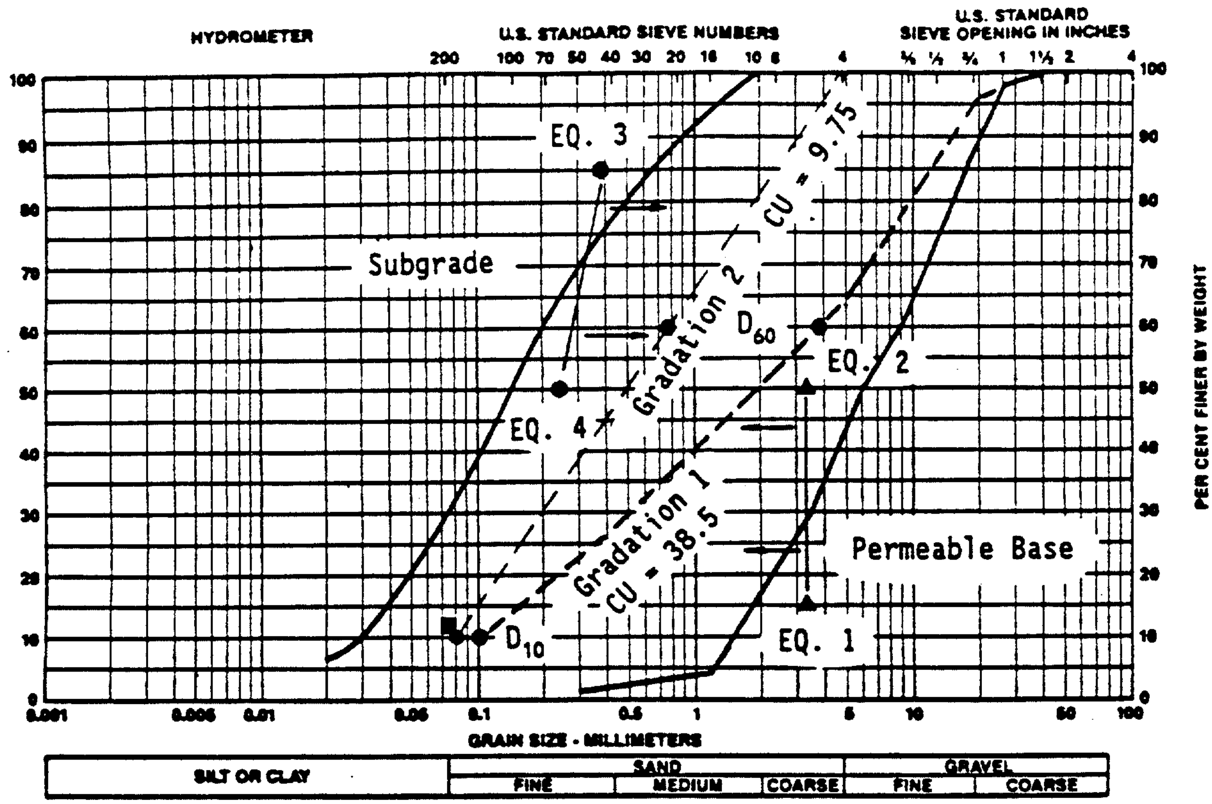


Figure A-2

Once the mid-points of the gradation band are plotted the CU (D_{60}/D_{10}) can be determined. It is recommended that the gradation meet the requirement that the CU be ≥ 20 and ≤ 40 (requirement from page 12) to ensure that the gradation is well-graded and stable. For example, when plotted on Figure A-2, Gradation No. 1 indicates that the gradation meets the filter-separator criteria and the maximum 12 percent fines criteria.

The final step is to pick out the D_{60} and D_{10} on the dashed line (circular points) and calculate the CU. The CU for this gradation is 38.5 (D_{60}/D_{10} = 3.85 mm/0.1 mm) which falls within the recommended criteria indicating a well-graded and stable gradation.

Sieve Size	Percentage Passing Gradation No. 1	Percentage Passing Gradation No. 2
1 1/2 inch	100	-
3/4 inch	85-100	-
No. 4	50-80	100
No. 16	-	60-75
No. 40	20-35	35-50
No. 100	-	15-30
No. 200	5-12	5-12

Gradation No. 2 (on Figure A-2) is a coarse sand gradation which also meets the filter-separator criteria and the maximum 12 percent fines criteria. However, it has a CU of 9.75 (D_{60}/D_{10} = 0.78 mm/0.8 mm) indicating a more uniform, less stable gradation which doesn't meet the recommended criteria.

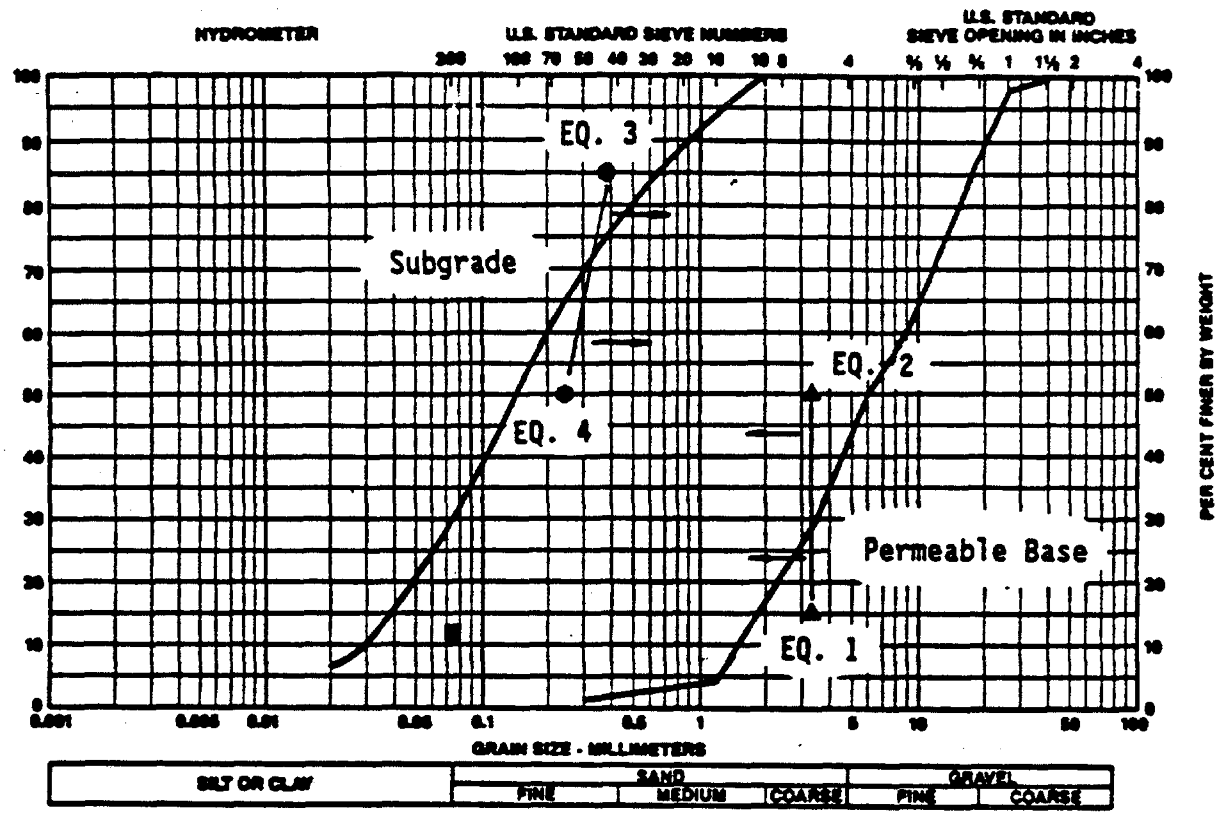


Figure A-1

The next step is to apply the design equations (from page 12) to the permeable base/filter-separator interface and plot the points on the gradation chart:

EQ. 3 D_{15} (Base) $\leq$ 5 D_{85} (Filter-Separator)

1.85 $\leq$ 5 D_{85} (Filter-Separator)

D_{85} (Filter-Separator) $\geq$ .37 mm

EQ. 4 D_{50} (Base) $\leq$ 25 D_{50} (Filter-Separator)

6.0 $\leq$ 25 D_{50} (Filter-Separator)

D_{50} (Filter-Separator) $\geq$ .24 mm

The equation 3 and 4 criteria are superimposed on the gradation curve as shown by the hexagonal points on Figure A-1.

The mid-point of the filter-separator layer gradation band must fall within the lines joining the two triangular and two hexagonal points determined by the previous equations to meet the criteria. In addition, it is recommended that the gradation have 12 percent or less of the material passing the No. 200 sieve (square point on Figure A-1).

APPENDIX B

TABLE 1
PHYSICAL REQUIREMENTS [1,2]
FOR DRAINAGE GEOTEXTILES

From AASHTO-AGC-ARTBA Task Force 25

Property	Drainage [3] Class A[4]	Drainage [3] Class B[5]	Test Method
Grab Strength (lbs.)	180	80	ASTM D-4632
Elongation (%)	N/A	N/A	ASTM D-4632
Seam Strength[6] (lbs.)	160	70	ASTM D-4632
Puncture Strength (lbs.)	80	25	ASTM D-4833 (Mod.)
Burst Strength (psi)	290	130	ASTM D-3786
Tear Strength (lbs.) (Trapezoidal Tear)	50	25	ASTM D-4533
Apparent Opening Size US Std. Sieve	1. Soil with 50 percent or less particles by weight passing US No. 200 Sieve, AOS less than 0.6 mm (greater than No. 30 US Std. Sieve)		ASTM D-4751
	2. Soil with more than 50 percent particles by weight passing US No. 200 Sieve, AOS less than 0.3 mm (greater than No. 50 US Std. Sieve)		ASTM D-4751
Permeability[7] (cm/sec)	k geotextile > k soil for all classes		ASTM D4491
Ultraviolet Degradation at 150 hours	70 percent Strength retained for all classes		ASTM D4355

---

[1] Acceptance of geotextile material shall be based on Task Force 25 acceptance/rejection guidelines.

[2] Contracting agency may require a letter from the supplier certifying that its geotextile meets specification requirements.

[3] Minimum - Use value in weaker principal direction. Numerical values represent minimum average roll value (i.e., [average] test results from any sampled roll in a lot shall meet or exceed the minimum values in the Table). Stated values are for non-critical, non-severe applications. Lots sampled according to ASTM D4354.

[4] Class A Drainage applications for geotextiles are where installation stresses are more severe than Class B applications, i.e., very coarse sharp angular aggregate is used, a heavy degree of compaction (95 percent or greater AASHTO T99) is specified or depth of trench is greater than 10 feet.

[5] Class B Drainage applications are those where geotextile is used with smooth graded surfaces having no sharp angular projections, no sharp angular aggregate is used; no compaction requirements are light, (less than 95 percent AASHTO T99), and trenches are less than 10 feet in width.

[6] Values apply to both field and manufactured seams.

[7] A nominal coefficient of permeability may be determined by multiplying permittivity value by nominal thickness. The k value of the geotextile should be greater then the k value of the soil.

APPENDIX B

TABLE 2
PHYSICAL REQUIREMENTS
FOR SEPARATION APPLICATIONS[1]
(From AASHTO-AGC-ARTBA Task Force 25)

< 50 PERCENT ELONGATION / > 50 PERCENT ELONGATION[2,3]

SURVIVABILITY LEVEL	GRAB STRENGTH ASTM-D 4632 (LBS)	PUNCTURE RESISTANCE ASTM D 4833 (LBS)	TRAPEZOIDAL TEAR STRENGTH ASTM D 4533 (LBS)
HIGH	270/180	100/75	100/75
MEDIUM	180/115	70/40	70/40

ADDITIONAL REQUIREMENTS	TEST METHODS
APPARENT OPENING SIZE (AOS)	ASTM D 4751
1. Less than 50% soil passing a Std. US No. 200 sieve, AOS < 0.6 mm.	
2. More than 50% soil passing a Std. US No. 200 sieve, AOS < 0.3 mm.	
PERMEABILITY	ASTM D 4491
1. k of the geotextile > k of the soil (permittivity times the nominal geotextile thickness).	
ULTRAVIOLET DEGRADATION	ASTM D 4355
1. At 150 hours exposure, 70% strength retained for all cases.	
GEOTEXTILE ACCEPTANCE	ASTM D 4759

---

[1] Values shown are minimal roll average values.
Strength values are in the weaker principle direction.

[2] Elongation as determined by ASTM D 4632.

[3] The values of geotextile elongation do not imply the allowable consolidation properties of the subgrade soil. These must be determined by a separate investigation.

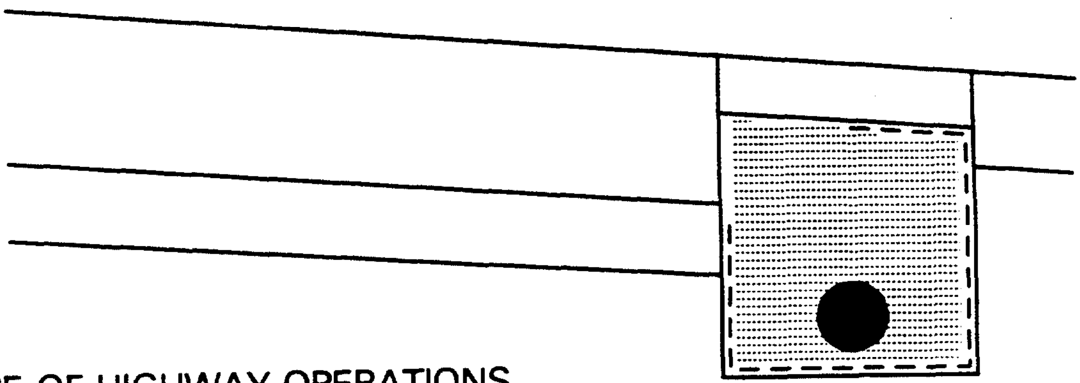
U S Department of Transportation
Federal Highway Administration

Experimental Projects Program

EXPERIMENTAL PROJECT 12

Concrete Pavement Drainage Rehabilitation

Technology Transfer



OFFICE OF HIGHWAY OPERATIONS
DEMONSTRATION PROJECTS DIVISION
400 7TH STREET S.W.
WASHINGTON D.C. 20590

Experimental Project No. 12

Concrete Pavement Drainage Rehabilitation

State of the Practice Report

By

Robert H. Baumgardner

Daniel M. Mathis

U.S. Department of Transportation
Office of Highway Operations
Pavement Division
and
Demonstration Projects Division

April 1989

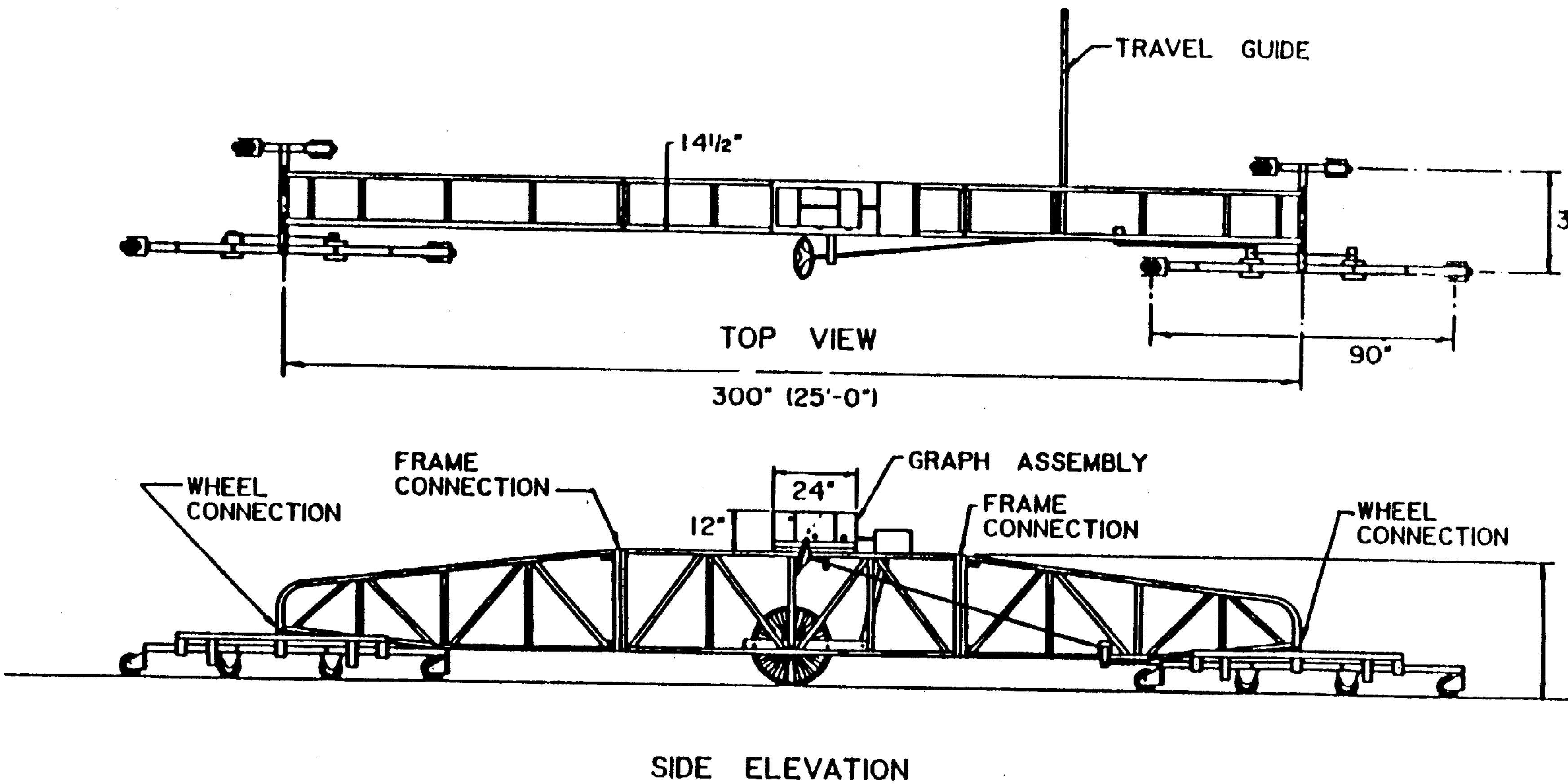


Figure 1. Schematic of California type profilograph.

to develop a state-of-the-practice report on edgedrain design by the States reviewed.

In the third phase, In-depth Analysis, the pavement at the test sites will be instrumented and data will be collected over a 1-year period. Rainfall and edgedrain outlet discharge rates and patterns will be recorded. Soil moisture and pressure transducer gauges will be installed in an attempt to identify moisture conditions under the pavement. Dye will be injected into the pavement structure in an effort to identify subsurface flow patterns.

Nondestructive testing will be accomplished by viewing the edgedrain pipe with a borescope. Faulting and deflection measurements may be taken to determine the condition of pavements.

Test pits will be dug, and the edgedrain trench excavated. Visual observations will be made of the pipe, filter fabric, backfill material, base material and slab/base interface. Permeability tests will be run on the filter fabric and backfill material.

The fourth phase, Analysis and Evaluation, will analyze the data that has been gathered and attempt to evaluate the performance of longitudinal edgedrains. A final report outlining the findings of the study will be prepared.

The Water Resources Division of the U.S. Geological Survey (USGS) has been retained to instrument the pavements, analyze the data, and prepare the final report. Since the USGS has a District office in each State, they will have easy access to the test site. USGS's experience in water data collection and testing should enhance the quality of the project.

Individual SHA's will provide the necessary traffic control, core drilling, saw cuts, and trench excavation.

1.3 Project Selection Criteria and State Selection

It was necessary to develop project selection criteria for selecting the State and projects to be included in the review. The first criteria was that the States selected should have a geographic spread so that the study would represent nationwide conditions.

The most important criteria was that the retrofit longitudinal edgedrains were installed 3 to 10 years prior on PCC pavements showing only a moderate amount of distress. It is believed that this condition will best represent the merits of providing retrofit longitudinal edgedrains. Another criteria that works in concert with this one is the need for a control section. By identifying a similar pavement that was not retrofitted with edgedrains, the rates of deterioration can be compared. If a control section was not available, consideration will be given to plugging of the drain on the selected section to simulate an undrained condition.

A PCC pavement not having received an asphalt concrete (AC) overlay was also a project criteria. The need to have the pavement directly subject to rainfall was recognized. A lesser criteria was that the project be located relatively near the State Capital so that it would receive the necessary attention during the instrumentation phase.

Submissions describing the projects available in the individual States were forwarded to FHWA for review. After an in-depth review the following States were selected; Alabama, Arkansas, California, Illinois, Minnesota, New York, North Carolina, Oregon, West Virginia, and Wyoming.

2.0 SUMMARY OF STATES' PHILOSOPHY ON RETROFIT EDGEDRAIN DESIGN

The basic approach to edgedrain design varied among the States reviewed. Each State believes that its particular design best meets the needs of the State. The following is a discussion of each State's basic approach to edgedrain design.

2.1 Alabama

Rehabilitation of high-type (Interstate) PCC pavements in Alabama includes installation of longitudinal edgedrains (an aggregate trench drain). New PCC pavements also are constructed with the same longitudinal edgedrain design. Since water is being drained the State feels that edgedrains are beneficial. The State is pleased with its edgedrain design and believes edgedrains extend the service life of its PCC pavements. Alabama's standard PCC pavement section is a dowelled jointed plain concrete pavement (JPCP) consisting of 9 inches of PCC over 6 inches of soil subbase which has been stabilized with 7 percent cement. Beneath this is a 6-inch layer of soil subbase on top of 12 inches of improved roadbed. The soil subbase contains up to 40 percent minus No. 200 sieve material.

2.2 Arkansas

Arkansas has been installing longitudinal edgedrains on PCC pavements since 1975/76. Approximately 150-200 lane miles of edgedrains have been installed in that time with the basic edgedrain design remaining the same. Arkansas' edgedrains are designed to rapidly drain the water that migrates to the slab/base interface and to permit the draining of infiltrated moisture trapped in the poor draining base (the majority of PCC pavements in Arkansas were constructed on a crushed stone or gravel base with very low permeability).

Arkansas' PCC pavements are generally 10-inch jointed reinforced concrete pavements (JRCP) with dowelled contraction joints at 45-foot spacing. Warping joints are also constructed at 15-foot intervals in the slab. Rehabilitation of PCC pavements in Arkansas generally consists of installing edgedrains in conjunction with concrete pavement restoration (CPR). It is hoped that rehabilitation will give an additional 10 years of service life to the pavement. Arkansas does not have any quantitative criteria for when to install retrofit longitudinal edgedrains. Installation is based on visual observations of moisture related distress.

2.3 California

Retrofit longitudinal edgedrains were California's first attempt at pavement drainage. They have been installing retrofit longitudinal edgedrains (on PCC pavements only) on a routine basis since 1978. Over 500 lane miles of edgedrains have been installed since then. Most of California's PCC pavements are plain jointed undowelled with short joint spacing (15 feet) constructed over a cement treated base (CTB) or lean concrete base (LCB) placed over a minimum 24 inches of aggregate subbase with an R-value of 50. Their edgedrains are designed to rapidly drain the water that migrates to the slab/base interface. Generally, no other work is performed on the pavement at the time retrofit longitudinal edgedrains are installed. It is hoped that edgedrains will give an additional 10-15 years of service life to the pavement. Edgedrains are installed along the outside lane only, except in superelevated sections where they are installed along the inside lane as well.

California was the only State that evaluated the effect retrofit longitudinal drains have on PCC pavement performance. Based on this evaluation, the following criteria were developed for installing retrofit longitudinal edgedrains on PCC pavement:

PCC pavement:

1) with no more than 10 percent first stage cracking (one crack per panel) and/or 1 percent third stage cracking (fragmentation of the slab as evidenced by three or more interconnecting cracks);
2) that is no more than 10 years old; and
3) with less than 13 million accumulated ESAL's (equivalent single axle loads).

2.4 Illinois

Illinois has been installing longitudinal edgedrains (on PCC pavements primarily) on a routine basis since 1971. From 1976 to 1985 an average of 1.9 million feet of edgedrain was installed. Illinois' edgedrains are designed to rapidly drain the water that migrates to the slab/base interface, to permit the draining of infiltrated moisture trapped in the poor draining base (the majority of PCC pavements in Illinois were constructed on a dense graded aggregate base (DGAB) or bituminous aggregate material (BAM)), and to drain the subgrade. Rehabilitation of PCC pavements (both JRCP and continuously reinforced concrete pavement (CRCP)) in Illinois generally consists of installing edgedrains prior to shoulder reconstruction or overlaying with AC. Approximately one-half of new high-type pavements are constructed of CRCP and one-half are constructed of JRCP.

Illinois believes that any drainage is better than no drainage. There is no expectation of additional service life with retrofit longitudinal edgedrains although it is believed that drainage does increase the life of the pavement.

The cost of edgedrains has remained in the $2-$3 per linear foot range since 1977. Edgedrains are installed along the outside lane and where feasible, are installed along the inside lane (in the median) as well.

2.5 Minnesota

Minnesota has been installing longitudinal edgedrains (on PCC pavements only) on a routine basis since 1979/80. Over 1100 lane miles of edgedrains have been installed since then. Minnesota's edgedrains are designed to rapidly drain the water that migrates to the slab/base interface, to permit the draining of infiltrated moisture trapped in the poor draining base (the majority of PCC pavement in Minnesota were constructed on a DGAB), and to prevent the stripping in the AC overlay, when used. Rehabilitation of PCC pavement in Minnesota generally consists of installing edgedrains prior to overlaying with AC. It is hoped that rehabilitation will give an additional 10 years of service life to the pavement.

Minnesota has not been able to conclusively prove edgedrains are cost-effective. The State feels that the drains are so inexpensive ($1.00 $1.25 per linear foot) that they can't afford not to put them in. Retrofit longitudinal edgedrains are looked upon as cheap insurance. The State feels that if retrofit longitudinal edgedrains give only an additional 2-3 years of service life to the pavement the edgedrains will have paid for themselves. Edgedrains are installed along the outside lane and where feasible, are installed along the inside lane (in the median) as well.

2.6 New York

New York has been installing longitudinal edgedrains on PCC and AC pavements since 1977. Approximately 600 miles of new and retrofit edgedrains have been installed since then. New York's edgedrains on PCC pavements are designed primarily to rapidly drain infiltrated water that migrates to the slab/base interface and secondarily to permit the draining of infiltrated moisture trapped in the poor draining base (the majority of PCC pavements in New York were constructed on a granular base daylighted to the ditch). Rehabilitation of PCC pavements in New York generally consists of installing edgedrains prior to overlaying with AC.

Installation of longitudinal edgedrains varies from state region to state region. Edgedrain installation is based on field inspection of perceived need. Edgedrains are relatively expensive to install in New York; therefore, good engineering requires discriminate application. Cost is estimated from $10-$12 per linear foot. Cost of edgedrains in New York is believe to be much higher because of increased labor costs. Edgedrains are installed along the outside lane and where feasible, along the inside lane (in the median) as well.

2.7 North Carolina

North Carolina has been installing longitudinal edgedrains on PCC pavements on a routine basis since 1979/80. North Carolina's edgedrains are designed to rapidly drain the water that migrates to the slab/base interface and to permit the draining of infiltrated moisture trapped in the poor draining base (the majority of PCC pavements in North Carolina were constructed on a DGAB). Rehabilitation of PCC pavements in North Carolina generally consists of installing edgedrains as part of CPR. It is hoped that rehabilitation will give an additional 10 years of service life to the pavement. All new construction receive edgedrains on the low side of the pavement. They are looked upon as cheap insurance.

2.8 Oregon

Oregon has been installing longitudinal edgedrains on PCC pavements on a routine basis since 1978/79. Oregon's edgedrains are designed to rapidly drain the water that migrates to the slab/base interface and to permit the draining of infiltrated moisture trapped in the poor draining base (the majority of PCC pavements in Oregon were constructed on a DGAB). Edgedrains are also used to control groundwater. New or reconstructed PCC pavements are generally continuously reinforced placed over LCB. Edgedrains are installed on new and reconstructed PCC pavements if moisture related distress is anticipated or has been a problem in the past. Rehabilitation of PCC pavements in Oregon generally consists of installing edgedrains prior to overlaying with AC. It is hoped that rehabilitation will give an additional 10 years of service life to the pavement. There are no quantitative criteria for the installation of retrofit longitudinal edgedrains. Installation is based on perceived need (i.e., pumping or some other moisture related distress). Edgedrains are considered on all Interstate rehabilitation projects on a case by case basis. Most of the edgedrain projects have been in the I-5 corridor because of the higher precipitation experienced on the western side of the Cascade Mountain Range. Edgedrains have not been used extensively on other road systems.

Oregon has not developed data proving edgedrains are cost-effective. However, they are inexpensive (approximately $2.50 per linear foot). Edgedrains are installed along the outside lane primarily and along the inside lane (in the median) on superelevated sections.

2.9 West Virginia

West Virginia has been installing longitudinal edgedrains on cracked and seated (C&S) PCC pavements only since 1981/82. West Virginia's edgedrains are designed to drain surface water that infiltrates through the pavement and water that migrates up through the underlying layers. The edgedrain also drains water that is trapped in the poor draining base (the majority of PCC pavements in West Virginia are constructed on 6 inches of DGAB). Most PCC pavements are 9-inch jointed reinforced and dowelled with 61.5-foot joint spacing. Rehabilitation of PCC pavements in West Virginia generally consists of installing edgedrains prior to cracking the PCC into 12- to 18-inch pieces and overlaying with 3 to 4 inches of AC. The age of the PCC pavements at rehabilitation is generally 18 years. It is hoped that this rehabilitation will give an additional 10-15 years of service life to the pavement. At present, the State does not install edgedrains on rehabilitated AC pavements. The State does not have any quantitative criteria for installing retrofit longitudinal edgedrains. Evidence of pumping and/or other moisture related distress is the determining factor on whether edgedrains are to be installed. Edgedrains are installed along the outside lane primarily and along the inside lane (in the median) on superelevated sections.

2.10 Wyoming

Late in 1987, Wyoming began installing longitudinal edgedrains on PCC pavements only. Wyoming's edgedrains are designed to rapidly drain water that migrates to the slab/base interface and to permit the draining of infiltrated moisture trapped in the poor draining base (the majority of PCC pavements in Wyoming were constructed on a 6-inch DGAB). Most PCC pavements constructed in Wyoming are 8-inch JPCP with skewed joints (2 feet in 12 feet) spaced at 18, 19, 13, and 12 feet. Rehabilitation of PCC pavements in Wyoming is also just beginning and, to date, consists of some CPR techniques (i.e., patching and slab replacement) and the installation of retrofit longitudinal edgedrains. The State hopes that edgedrains will help reduce the faulting (1/4- to 1/2-inch) that is occurring on their JPCP's. There is not much evidence of pumping on their pavements. Wyoming's edgedrains are installed along the outside lane primarily and along the inside lane in superelevated sections. It is hoped that rehabilitation will give an additional 10 years of service life to the pavement.

A comparison of pavement types and criteria for edgedrain installation is provided in Table 1.

Table 1. Listing of Pavement Types and Installation Criteria

	Pavement Type	Subbase	Edgedrain Installation Criteria
Alabama	JPCP	CTS	Observed Need
Arkansas	JRCP	DGAB	Observed Need
California	JPCP	CTB/LCB	All PCC Meeting State Criteria (1)
Illinois	CRCP	DGAB	All PCC Rehabilitation
Minnesota	JRCP	DGAB	All PCC Rehabilitation
New York	JRCP	DGAB	Observed Need
North Carolina	JPCP	DGAB	All PCC Rehabilitation
Oregon	JPCP	DGAB	Observed Need
West Virginia	JRCP	DGAB	Observed Need
Wyoming	JPCP	DGAB	All Current PCC Rehabilitation

(1) Project must meet State criteria as discussed in Section 2.3.

3.0 REVIEW OF CURRENT EDGEDRAIN PRACTICE

One of the objectives of the Field Review Phase was to determine the current edgedrain practices in the States selected for study. Drainage elements such as edgedrain backfill material, edgedrain location, filter fabric, headwalls, etc., were investigated. This information is presented in the following discussions of each design element.

3.1 Type of Edgedrain

Alabama, North Carolina, and West Virginia are the only States that use a stone filled trench without a continuous drain pipe. The trench is wrapped with a filter fabric and backfilled with a open-graded aggregate. A drainage pipe is installed in the last 200 feet of trench in North Carolina and the last 10 feet of trench in the other States before being outletted. This design is a "french drain" approach. Figure 1 shows the aggregate trench type of edgedrain used by these States.

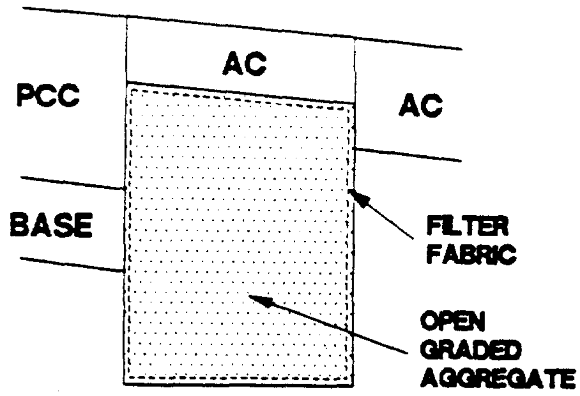


Figure 1. AGGREGATE TRENCH EDGEDRAIN

Illinois, Minnesota, and New York do not wrap the trench with filter fabric but rather use a filter aggregate or coarse sand backfill around a perforated pipe. In this design approach, although generally much slower draining, the drainage aggregate is believed to act as the filtering media to prevent eroded fines from plugging the edgedrain system. Illinois and Minnesota wrap the pipe with filter fabric to prevent the backfill material from entering the pipe. This approach is shown in Figure 2.

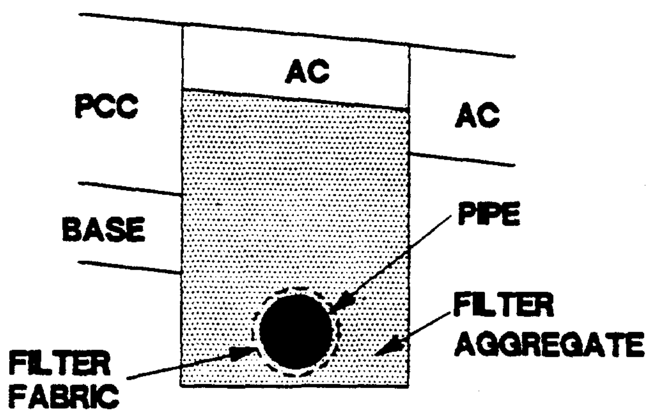


Figure 2. FILTER AGGREGATE EDGEDRAIN

California's edgedrain design consists of a 3-inch slotted rigid PVC pipe which is placed at the bottom of a relatively shallow, partially filter fabric lined trench (12 inches wide and 10 inches deep) excavated slightly into the cement treated base and backfilled with a treated permeable material (TPM) (either asphalt treated at approximately 2 1/2 percent or cement treated at 2 to 4 bags per cubic yard). The purpose of the filter fabric is to prevent aggregate base and subgrade fines from contaminating the edgedrain system. The filter fabric is omitted in the slab/base interface to allow infiltrated water and eroded fines that have migrated to the interface to jet directly into the drain. California's design is unique in that the trench is very shallow. The purpose of the edgedrain system is to drain water which collects at the slab/subbase interface and water entering the pavement/shoulder joint. The invert of the drainage pipe is approximately 1-inch below the slab/subbase interface. California's design approach is shown in Figure 3.

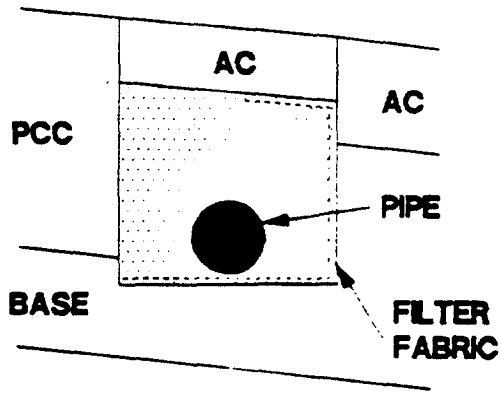


Figure 3. CALIFORNIA EDGEDRAIN DESIGN

All of the remaining States (Arkansas, Oregon and Wyoming) use basically the same design; that is, the trench is completely wrapped with a filter fabric. A 3-4 inch drainage pipe is placed in the bottom of the trench. The trench is then backfilled with an open graded aggregate. A conventional perforated pipe edgedrain is shown in Figure 4.

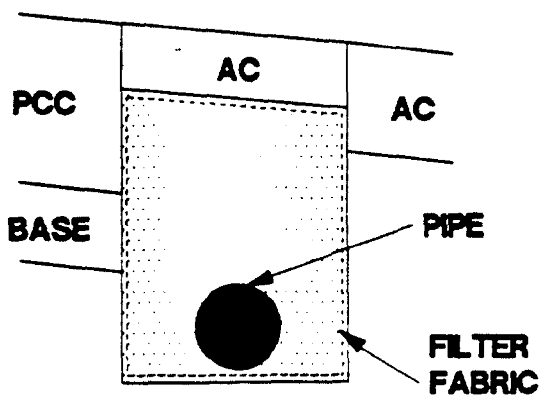


Figure 4. PERFORATED PIPE EDGEDRAIN

Geocomposite fin drains have been used by many States reviewed (Alabama, Arkansas, Illinois, Minnesota, North Carolina, West Virginia, and Wyoming) primarily on an experimental basis. Figure 5 shows a typical geocomposite fin drain. Table 2 provides a comparison of edgedrain types used.

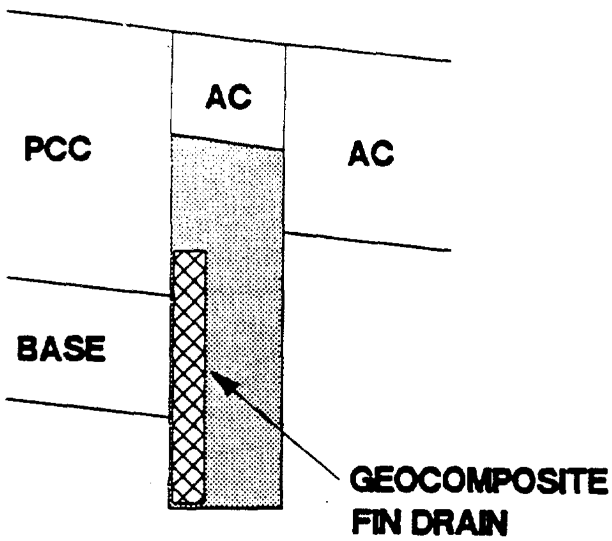


Figure 5. GEOCOMPOSITE EDGEDRAIN

Table 2. Comparison of Edgedrain Types.

	Type of Edgedrain	Geocomposite Fin Drain
Alabama	Aggregate Trench	Experimental
Arkansas	Conventional Pipe	Experimental
California	Shallow Trench	Not Allowed
Illinois	Sand Backfill	Allowed as Alternate
Minnesota	Sand Backfill	Experimental
New York	Filter Aggregate	Experimental
North Carolina	Aggregate Trench	Experimental
Oregon	Conventional Pipe	Allowed as Alternate
West Virginia	Aggregate Trench	Experimental
Wyoming	Conventional Pipe	Experimental

3.2 Edgedrain Location

All of the States reviewed place the edgedrain under the shoulder immediately adjacent to the pavement/shoulder joint.

3.3 Trench Backfill

Both Illinois and Minnesota use a coarse sand backfill. The aggregate gradations are given in Tables 3 and 4, respectively. Illinois and Minnesota anticipate coefficient of permeabilities of 50 to 100 feet per day with these backfill materials. Use of the Illinois gradations is based on local availability of materials.

Table 3. Illinois' Sand Gradations.

	Percent Passing	
Sieve Size	FA 1	FA 2
3/8-inch	100	100
No. 4	94-100	94-100
No. 16	45-85	45-85
No. 50	3-29	10-30
No. 100	0-10	0-10
No. 200	0-3	0-3

Table 4. Minnesota's Sand Gradation.

Sieve Size	Percent Passing
3/8-inch	100
No. 4	90-100
No. 10	45-90
No. 40	15-45
No. 200	0-3

California uses either asphalt treated permeable material (ATPM) at approximately 2 1/2 percent or cement treated permeable material (CTPM) at 2 to 4 bags per cubic yard. Coefficient of permeabilities are approximately 4,000 feet per day for the CTPM and 15,000 feet per day for the ATPM. The gradations for ATPM and CTPM are given in Tables 5 and 6, respectively.

Table 5. California's ATPM Aggregate Gradation.

Sieve Size	Percent Passing
1-inch	100
3/4-inch	90-100
1/2-inch	35-65
3/8-inch	20-45
No. 4	0-10
No. 8	0-5
No. 200	0-2

Table 6. California's CTPM Aggregate Gradation.

Sieve Size	Percent Passing
1 1/2-inch	100
1-inch	86-100
3/4-inch	X ± 22
3/8-inch	X ± 22
No. 4	0-18
No. 8	0-7

Where "X" is the gradation which the contractor proposes to furnish for the specific sieve size.

New York uses a filter aggregate consisting of a crushed stone, sand gravel, or screened gravel with varying degrees of permeability. The filter material gradations are given in Table 7. Gradation type is selected by the State regional soils engineer based on the amount of fines in the native soil. The Type I gradation is used approximately 75 percent of the time. Type III is used if silt is encountered.

Table 7. New York's Aggregate Gradations.

	Percent Passing		
Sieve Size	Type I	Type II	Type III
1-inch	100	-	-
1/2-inch	30-100	100	-
3/8-inch	-	-	100
1/4-inch	0-30	20-100	90-100
No. 8	-	-	75-100
No. 10	0-10	0-15	-
No. 16	-	-	50-85
No. 20	0-5	0-5	-
No. 30	-	-	25-60
No. 50	-	-	10-30
No. 100	-	-	1-10
No. 200 (wet)	-	-	0-3

Oregon uses a gap graded (permeable) aggregate with coefficients of permeability greater than 3000 feet per day. The three gradations used by Oregon are given in Table 8. The type of gradation used is determined by the engineer.

Table 8. Oregon's Aggregate Gradations.

	Percent Passing		
Sieve Size	1 1/2-3/4" size	1 1/4-3/4" size	3/4-1/2" size
2-inch	100	-	-
1 1/2-inch	95-100	100	-
1 1/4-inch	-	90-100	-
1-inch	-	-	100
3/4-inch	0-15	0-15	90-100
1/2-inch	0-2	0-2	0-15
1/4-inch	-	-	0-3

Alabama and North Carolina both use the AASHTO No. 57 gradation as backfill material while West Virginia allows any AASHTO gradation between the No. 2 and No. 57 to be used. Wyoming's gradation is the same as the gradations used by California. Table 9 provides a comparisons of the backfill material used by the States that were reviewed.

Table 9. Comparison of Backfill Material

	Backfill Material	Gradation	Estimated Coefficient of Permeability
Alabama	Aggregate	AASHTO No. 57	3,000 +
Arkansas	Pea Gravel	3/8-inch	200
California	ATPM/CTPM	California Standard	4,000 CTPM 15,000 ATPM
Illinois	Coarse Sand	Illinois Standard	50
Minnesota	Coarse Sand	Minnesota Standard	50-100
New York	Filter Aggregate	New York Standard	1,000 Type I 100 Type III
North Carolina	Aggregate	AASHTO No. 57	3,000 +
Oregon	Pea Gravel	Oregon Standard	3,000 +
West Virginia	Aggregate	AASHTO No. 2 to No. 57	3,000 +
Wyoming	ATPM/CTPM	California Standard	4,000 CTPM 15,000 ATPM

3.4 Pipe Material and Size

Seven of the 10 States reviewed (Arkansas, California, Illinois, Minnesota, New York, Oregon, and Wyoming) used perforated or slotted drainage pipe in the entire length of edgedrain trench to convey the accumulated water from the pavement structure. Two of the States (California and Wyoming) used smooth, rigid polyvinyl chloride (PVC) pipe. The other five States (Arkansas, Illinois, Minnesota, New York, and Oregon) specified corrugated polyethylene (CPE) pipe. The three remaining States (Alabama, North Carolina, and West Virginia) did not use pipe in the entire length of edgedrain trench. Pipe sizes were 3 or 4 inches as shown in Table 10.

Table 10. Pipe Material and Size.

	Pipe Material	Pipe Size (inches)
Arkansas	CPE	4
California	PVC	3
Illinois	CPE	4
Minnesota	CPE	3
New York	CPE	4
Oregon	CPE	4
Wyoming	PVC	3-4

In California and Wyoming, if the pipe is to be installed in trenches that are to be backfilled with asphalt treated permeable material, the pipe shall be PVC 90 degrees C electric plastic conduit, EPC-40 or EPC-80 conforming to the requirements of NEMA Specification TC-2.

3.5 Trench Widths and Depths

Table 11 provides a tabulation of the trench widths and depths encountered in the field reviews.

Table 11. Trench Widths and Depths.

	Trench Width (inches)	Trench Depth(1) (inches)
Alabama	12	27
Arkansas	12	18 (2)
California	8 Min	10 (3)
Illinois	10	30
Minnesota	6-10	15 Min (4)
New York	12	30
North Carolina	12	18 Min (5)
Oregon	8	18 Min
West Virginia	6-10	12 Min (6)
Wyoming	6 Min	18

(1) Measured from the pavement surface.
(2) Invert of pipe is located 12 inches below slab\subbase interface.
(3) Invert of pipe is just below slab/subbase interface.
(4) Invert of pipe is located 3 inches below lowest layer to be drained.
(5) Bottom of edgedrain trench is located 4 inches below the subbase/subgrade interface.
(6) Top of edgedrain is located 3 inches below the top of the slab.

3.6 Filter Fabric Placement

Filter fabric placement is perhaps the most difficult and controversial item in edgedrain design. There are three distinct design approaches to filter fabric placement.

In the first approach, the trench is wrapped in filter fabric to prevent fines from entering the trench backfill as shown in the top sketch of Figure 6. Fines that are eroded from the base course may migrate to and clog the filter fabric.

The second approach leaves the slab/base interface open so that any eroded fines are not retained. Therefore, they will not clog the filter fabric. This approach would have the shortest time to drain and thus less time of saturation. This design is shown in the middle drawing of Figure 6.

The third approach is a compromise in which the pipe is wrapped in a filter fabric and the trench is backfilled with a filter aggregate or coarse sand as shown in the bottom sketch of Figure 6. In this approach, the aggregate acts as a filter keeping the fines from clogging the filter fabric. The coefficient of permeability of the filter aggregate material varies, but it is generally much lower than an open-graded aggregate backfill.

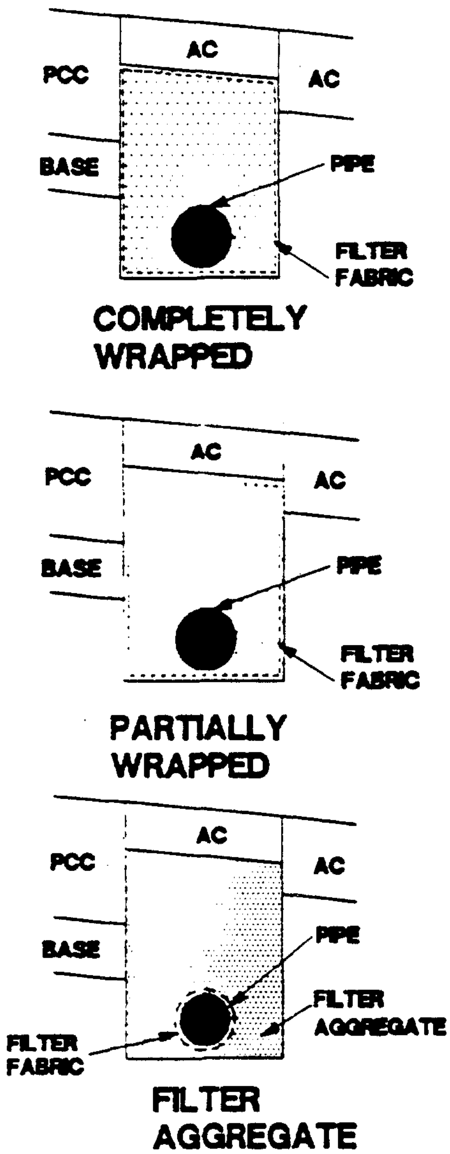


Figure 6. COMPARISON OF EDGEDRAIN DESIGN

It is pointed out that in all of the approaches any erodible fines in the base course will be washed out. The difference in the approaches is the manner in which the fines are handled.

It should be noted that there is no way to prevent a filter adjacent to a material with a high percentage of fines from eventually clogging. If there are no voids or if the voids are small, the filter won't clog up as rapidly, and the filter will function for a longer period of time. If, however, voids are present between the material to be drained and the filter, soil particles are provided an opportunity to go into suspension and will eventually clog the filter. Likewise, filter fabrics need intimate contact with the material to be drained. A filter placed along a pavement with voids between the slab and base would be comparable to the above noted situation.

A study of the three approaches reveals that each approach has advantages and disadvantages. This study indicates that fabric placement is one of the most important elements of edgedrain design, and perhaps, the most unresolved. Each State must be careful to wrap the trench in a fashion that best meets the pavement conditions encountered.

Illinois and Minnesota wrap the drainage pipe with filter fabric using the trench backfill to help filter out fines; however, New York does not use any filter fabric.

California partially wraps the trench leaving the interface with the base course open to prevent the fabric from clogging. A TPM (either ATPM or CTPM) is used as the trench backfill.

All of the remaining States (Alabama, Arkansas, North Carolina, Oregon, West Virginia, and Wyoming) completely wrap the trench.

Table 12 provides a comparison of filter fabric placement.

Table 12. Filter Fabric Placement

	Filter Fabric Placement
Alabama	Wrapped Trench
Arkansas	Wrapped Trench
California	Partially Wrapped Trench
Illinois	Wrapped Pipe
Minnesota	Wrapped Pipe
New York	None
North Carolina	Wrapped Trench
Oregon	Wrapped Trench
West Virginia	Wrapped Trench
Wyoming	Wrapped Trench

3.7 Outlet Spacing

Outlet spacing varied considerably among the States reviewed. Table 13 lists the outlet spacing. Since the purpose of the edgedrain is to remove water from the pavement structure, outlet spacing should not be. excessive.

Table 13. Outlet Spacing.

	Outlet Spacing (feet)
Alabama	200-1000
Arkansas	300
California	200-300
Illinois	500
Minnesota	500
New York	250
North Carolina	500
Oregon	400
West Virginia	500
Wyoming	300

3.8 Headwalls

Headwalls are used to protect the outlet pipe from damage, to prevent slope erosion, and to ease the locating of the outlet pipes. Table 14 provides a tabulation of the headwall types encountered in the field reviews.

There was a large variety in the types of headwall used. Alabama provides a large cast-in-place concrete headwall that is flush with the slope so that there is no damage from mowing operations. California's design is a simple precast concrete splash pad that allows the discharge to spread out thus preventing slope erosion. Minnesota and Illinois use a flush, precast concrete headwall with a removable rodent screen. Minnesota's precast concrete headwall design is shown in Figure 7.

3.9 Rodent Screens

Many States believe that rodent screens are necessary to protect the edgedrain system. Table 14 lists the States that used rodent screens in the review.

Some States not included in the review have experienced considerable damage to geocomposite fin drains from field mice.

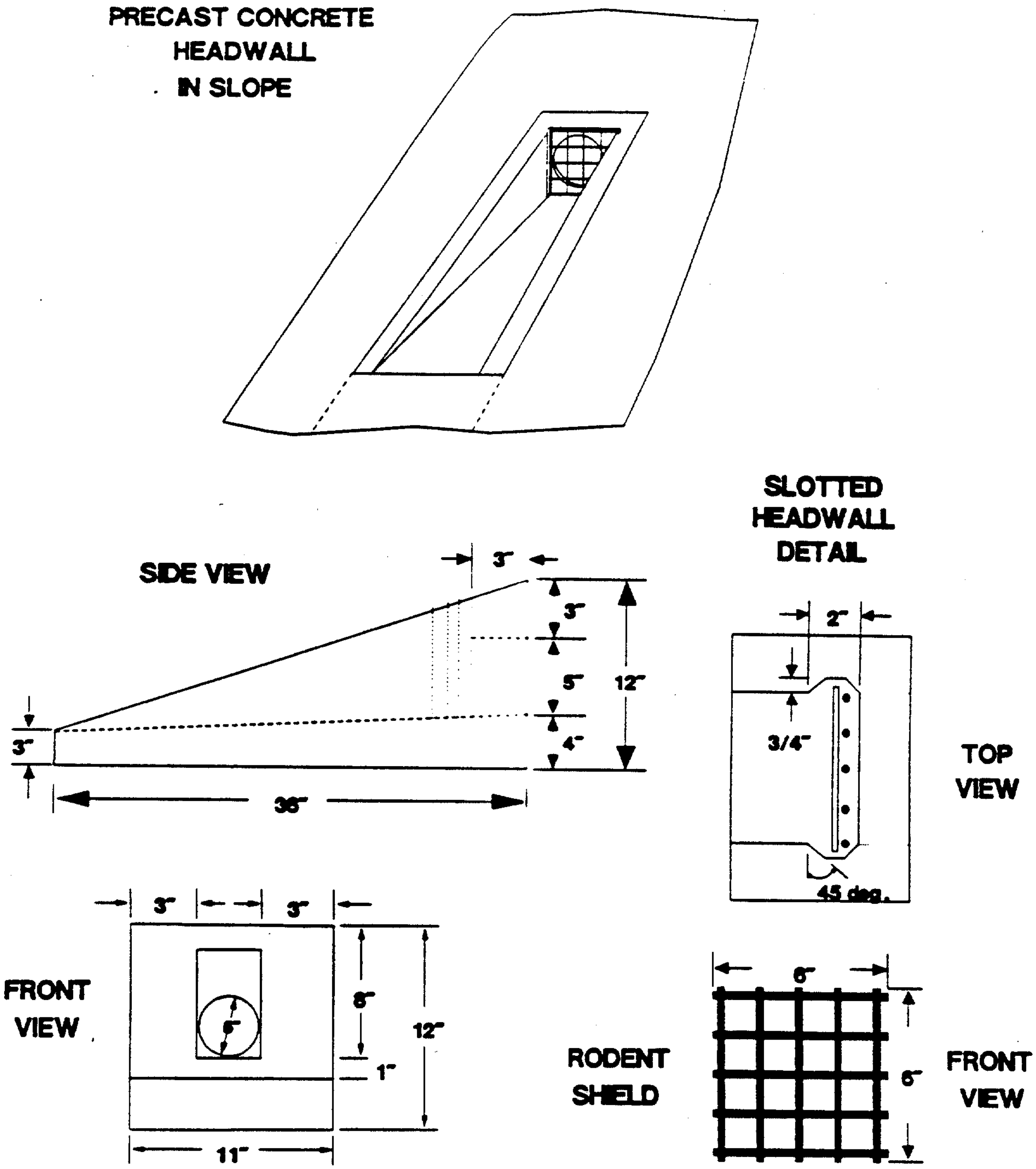


Figure 7. Minnesota's Precast Concrete Headwall

3.10 Reference Markers

Reference markers are used to locate the outlets for maintenance or observation purposes. Reference markers are extremely important in directing maintenance personnel to the pipe outlet. Table 14 indicates which States use reference markers.

California places a raised ceramic pavement marker on the shoulder edge adjacent to the outlet pipe while Minnesota paints a small arrow or stripe on the edge of the shoulder adjacent to the outlet pipe. California and Oregon use a small sign on a metal post to mark the pipe outlet.

Table 14. Headwalls, Rodent Screens, and Reference Markers.

	Headwall	Rodent Screen	Reference Marker
Alabama	Concrete	No	No
Arkansas	Concrete	Yes	No
California	Splash Pad	Yes	Yes
Illinois	Concrete	Yes	No
Minnesota	Precast Concrete	Yes	Yes
New York	None (1)	No	No
North Carolina	Concrete	No	No
Oregon	Concrete	Yes	Yes
West Virginia	Concrete	Yes	No
Wyoming	Splash Pad	Yes	No

(1) A 6-foot section of 6-inch corrugated metal pipe is used to protect the plastic outlet pipe.

3.11 Maintenance

Maintenance is critical to the continued success of any longitudinal edgedrain system. Inadequate maintenance was an universal problem in the States reviewed. The combination of vegetative growth, roadside slope debris, and fines discharging from the edgedrain plugged a number of outlet pipes. At one outlet, a 3-foot long mass of bermuda grass runners and eroded fines was pulled from the outlet pipe. It was impossible for the edgedrain system to discharge any water from this outlet until the mass of material was removed.

On one project, where pumping stains were noted on the right shoulder, it was found that this pumping was occurring on pavement sections where the outlets were plugged. On adjacent sections, where edgedrains outlets were open, there were no signs of pumping. At another outlet, the pipe was completely covered and plugged with vegetative growth. When the pipe was unplugged water drained from the pipe. Many outlets could not be found because of dense vegetative growth. It is obvious that if maintenance crews cannot find the outlet, no maintenance of the edgedrain system can occur.

Based on the observations made during this review , increased emphasis should be placed on maintenance of longitudinal edgedrains, especially the outlets.

3.12 Construction Related Problems Observed

Since all of the edgedrain projects reviewed were previously constructed, it was not possible to identify any construction problems of the longitudinal edgedrain collector system. However, some problems were observed with the lateral outlets. In a few States, headwalls were observed with a reverse grade. Because of improper construction, placement, or settlement, the headwall apron sloped back towards the pipe. Although the outlet would drain when sufficient water had accumulated, sedimentation at the outlet will occur restricting the flow and eventually plugging the pipe. Another problem observed in several States was the curling up of the last few feet of flexible outlet pipe resulting in a nondraining outlet. This may not be a big concern where the edgedrain trench was continuous and where subsequent outlets down grade would allow the water to drain. However, restricted flow from the edgedrain system would increase the time the pavement structure is subject to moisture. This has the potential for increased pavement problems by not allowing accumulated free water adjacent to the pavement structure to drain as rapidly. The pipe curling problem was not observed in those States that used a rigid lateral outlet pipe.

Based on the observations made during this review, increased emphasis should be placed on construction inspection of longitudinal edgedrain systems, especially the outlets. It was apparent that more attention needs to be focused on maintaining the grade of the outlet trench, ensuring the proper placement of the pipe in the trench, and the construction or placement of the outlet headwall. Proper construction is essential for the edgedrain system to perform as intended.

4.0 SUMMARY AND CONCLUSIONS

4.1 Design Philosophy

Retrofit longitudinal edgedrains are an important technique in CPR. Most likely other CPR techniques such as full-depth slab repair, slab stabilization, grinding or joint and crack resealing would be used in concert with retrofit longitudinal edgedrains to provide complete upgrading of the pavement. The engineer must coordinate the construction schedule so that the retrofit longitudinal edgedrains will dovetail with other CPR techniques.

Regardless of which type of retrofit edgedrain is selected, it is a good practice to seal all joints and cracks so that the amount of water infiltrating into the pavement structure is kept to a minimum.

4.2 Design Analysis

In any design analysis of existing concrete pavement rehabilitation, there are three steps that must be analyzed to determine if the proposed design will accomplish its goal of pavement drainage.

The first step in the design analysis of retrofit longitudinal edgedrains is to identify the water that is to be drained. Retrofit longitudinal edgedrains will drain water that enters the pavement/shoulder joint and any water that infiltrates the concrete pavement slabs and collects along the slab/base interface. This is free water that follows the path of least resistance and is strongly influenced by the affects of gravity. Any water that enters and ultimately saturates an impermeable dense graded aggregate base course will not be drained by a retrofit longitudinal edgedrain in a reasonable amount of time.

The second step is to evaluate the erodibility of the subbase material. The best guide for evaluating is past experience with the particular subbase material. If the subbase contains a high percentage of material passing the No. 200 sieve, the subbase will probably be highly erodible. As noted previously, a filter fabric does not prevent fines from being eroded from the subbase material, it only controls what happens to the fines after they migrate to the trench area. If an excessive amount of fines are eroded from the base course, any retrofit edgedrain will probably not be effective in extending the pavement life.

The third step is to determine if there is enough relief provided by the cross-section of the highway surface to provide positive drainage to the roadside ditches. Subsurface and surface drainage must be coordinated.

4.3 Unresolved Issues of Drainage Design

Currently, there are two unresolved issues of drainage design; filter fabric placement and trench backfill permeability. Filter fabric placement was previously discussed in Section 3.6, The three design approaches for filter fabric placement are; completely wrapped trench, partially wrapped trench, and wrapped pipe with sand backfill. There are advantages and disadvantages to each approach as discussed in section 3.6. Any trench backfill must be permeable enough to transmit the accumulated water to the drainage pipe. The backfill must also be stable enough to resist the loads applied to it. In the wrapped pipe with sand backfill approach, the sand backfill will filter the eroded fines preventing the filter fabric around the pipe from clogging. Unfortunately, it is believed that most of the sand backfill currently used does not have enough permeability to rapidly drain the section and significantly reduce the time of saturation. A coarse aggregate backfill will have the necessary permeability to drain the pavement section keeping saturation time to a minimum. Use of asphalt or cement treated backfill will increase stability with little decrease in permeability.

It is hoped that the findings of Experimental Project No. 12 will provide positive guidance to help resolve these issues.

4.4 Design Details

Listed below is a consensus that was developed on the design elements for retrofit longitudinal edgedrains based on this review:

- The edgedrain should be located under the shoulder immediately adjacent to the pavement/shoulder joint.

- Remembering that the filter fabric does not prevent erosion of fines from under the pavement slab, based on our observations, it is believed that the second approach, the partially wrapped trench, is the most promising compromise of design factors. By eliminating the filter fabric at the subbase/edgedrain interface, eroded fines can not clog the filter fabric. This approach will maximize the drainage of the pavement section keeping saturation time to a minimum.

- Trench backfill should be permeable enough to transmit water to the longitudinal edgedrain pipe and it must be stable enough to withstand traffic loads. Asphalt or cement treated backfill increases stability with little or no loss of permeability.

- The most commonly used trench width was 12 inches. The trench depth is determined by the vertical location of the pipe. Locating the top of the pipe at the bottom of the layer to be drained is recommended. This ensures that the flow zone of the pipe is below the layer to be drained.

- Since the purpose of the edgedrain system is to rapidly remove free water from the pavement structure, the outlet spacing should not exceed 500 feet, in most cases. The length of cleaning equipment available may dictate the outlet spacing. Shorter spacing eases maintenance of the edgedrain system, however, more outlets are the result. Conversely, greater spacing lengthens the time to drain. Additional outlets should be provided at the bottom of sag vertical curves.

- Because of the tendency of flexible corrugated plastic pipe to curl, use of rigid PVC pipe is recommended for outlet laterals. Rigid PVC pipe helps to maintain the proper outlet pipe grade and provides more protection from crushing. A few States included in this review have since modified their outlet design specifying the use of rigid PVC.

- Headwalls protect the outlet pipe from damage, prevent slope erosion, and ease in the locating of the outlet pipe. Because, these factors are so important in edgedrain design, the use of headwalls is recommended.

- Use of removable rodent screens is recommended. Removable screens ease cleaning of the screen itself as well as the edgedrain system.

- Since vegetative growth can quickly obscure the outlet pipe, reference markers are also recommended.

5.0 FUTURE ACTIVITIES

The study of pavement drainage is an on-going activity. The first step is the completion of Experimental Project No. 12. After the effectiveness of retrofit longitudinal edgedrains has been determined, FHWA will be in a good position to provide guidance to the field. When pavement design and rehabilitation reviews are conducted in a State, the pavement drainage designs can also be reviewed so that a nationwide assessment can be developed. Most likely a combination drainage demonstration project and training package will be developed. This will allow FHWA to provide needed technology transfer for this important pavement engineering item.

6.0 REFERENCES

Bradley M., Larsen, T.J., Temple, W., Gaines, R., Thomas, A., "Longitudinal Edgedrains in Rigid Pavement Systems," FHWA-TS-86-208, July 1986, Available from: NTIS, Springfield, Virginia 22161.

Cedergren, H. R., O'Brien, K. H., Arman, J. A., "Guidelines for the Design of Subsurface Drainage Systems for Highway Structural Sections," FHWA-RD-72-30, June 1972, Federal Highway Administration, Washington, D.C. 20590. Available from: NTIS, Springfield, Virginia 22161.

Cedergren, H. R., "Drainage of Highway and Airfield Pavements," 1987, Robert E. Krieger Publishing Co. Inc., Krieger Drive, Malabar, Florida 32950.

Federal Highway Administration "Surface Pavement Drainage," Technical Advisory T5040.14, dated March 21, 1980, Washington, D.C. 20590.

Federal Highway Administration, "Federal Highway Administration Pavement Rehabilitation Manual," Chapter 10, Longitudinal Edgedrains, FHWA-ED-88-025. Last supplemented March 1988, available from: NTIS, Springfield, Virginia 22161.

Hoover, T. P., "Nonwoven Geotextile Fabric: Evaluation and Specification for Subdrainage Filtration," FHWA/CA/TL-8111, May 1981, Office of Transportation Laboratory, California Department of Transportation, Sacramento, California 95807. Available from: NTIS Springfield, Virginia 22161.

Moulton, L. K., "Highway Subdrainage Design," Report No. FHWA-TS-80-224, 1980, Offices of Research and Development, Federal Highway Administration, Washington, D.C. 20590.

Ridgeway, H. H., "Pavement Subsurface Drainage Systems," NCHRP Report No. 96, November 1982, Transportation Research Board, National Research Council, Washington, D.C.

Wells, G. K., "Evaluation of Edge Drain Performance," FHWA/CA/TL-85/15 November 1985, Office of Transportation Laboratory, California Department of Transportation, Sacramento, California 95807. Available from: NTIS, Springfield, Virginia 22161.

THIS PAGE LEFT BLANK
INTENTIONALLY

PERMEABLE BASE

DESIGN AND CONSTRUCTION

BY

DANIEL M. MATHIS

Federal Highway Administration
Office of Highway Operations
Pavement Division and Demonstration Projects Division
400 Seventh Street, S.W.
Washington, D.C. 20590

A paper prepared for presentation at the "Fourth International Conference on Concrete Pavement Design and Rehabilitation," April 18-20, 1989 at Purdue University.

INTRODUCTION

This paper will present the state-of-the-practice in pavement drainage (i.e., permeable bases) for new or reconstructed asphalt concrete (AC) and Portland cement concrete (PCC) pavements.

Rather than using impermeable dense-graded materials many States have gone to using open-graded or "permeable" bases to allow infiltrated moisture to rapidly drain through the base and out from beneath the pavement structure.

Because of the relative unfamiliarity with permeable base pavement structures and with the varying designs in use, this paper synthesizes permeable base pavement systems being used in this country.

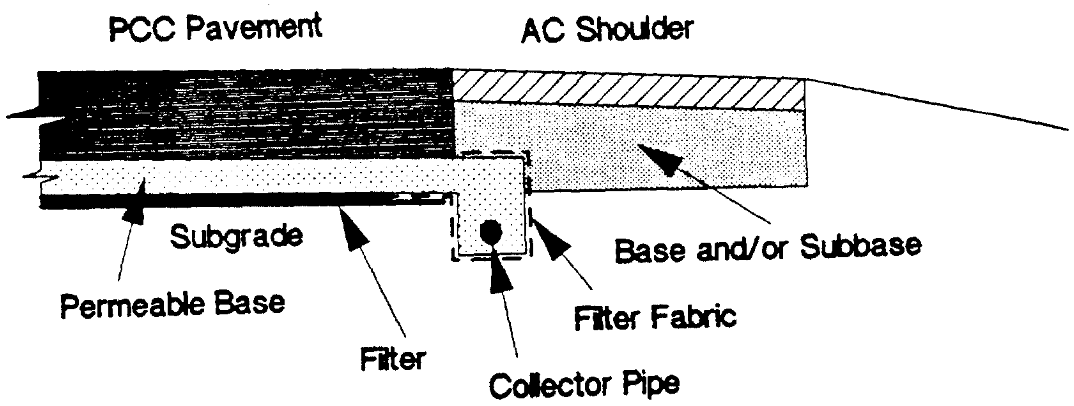
BACKGROUND

The pavement structure is the most costly element of the highway system and its premature failure is of major concern. Among the reasons cited for pavement failures, inadequate drainage of the pavement structure has been identified as a primary cause of pavement distress. The newly published AASHTO Guide for the Design of Pavement Structures (1986) addresses this as a problem by including drainage as an essential element of pavement design. Also, the Federal Highway Administration's (FHWA) pavement management and design policy encourages performing a drainage analysis for each new, rehabilitation, and reconstruction pavement design.

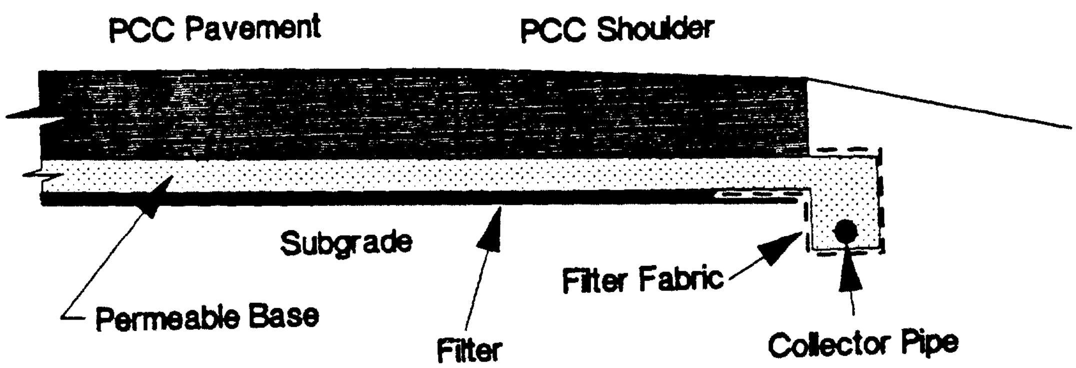
In designing pavement sections in the past, the primary function of the base was to provide uniform support. However, with increasing traffic loads, erosion and pumping of the underlying material resulted. This led to construction of what were thought to be strong nonerodible bases (i.e., dense-graded aggregate bases, cement treated bases, asphalt concrete bases). These materials were not only impermeable, they were also found to be erodible in many cases. Infiltrated moisture was trapped in the pavement structure and, under the effects of heavy loads, led to a weakening or erosion of the base, subbase, and/or subgrade often resulting in premature distress of the pavement structure.

A significantly different pavement design philosophy is now receiving a great deal of consideration. Rather than using impermeable dense-graded materials, several States have opted to use open-graded or permeable bases to allow infiltrated moisture to rapidly drain through the base and out from beneath the pavement structure. A permeable base is normally characterized by an open-graded crushed angular aggregate with essentially no fines. Recognizing the problems moisture distress has played on pavements, primarily on PCC pavements, many States are routinely using or experimenting with permeable bases beneath new or reconstructed high-type pavements. A longitudinal edgedrain collector system is commonly used to rapidly drain the moisture that collects in the permeable base. Typical permeable base pavement sections are shown in Figure 1.

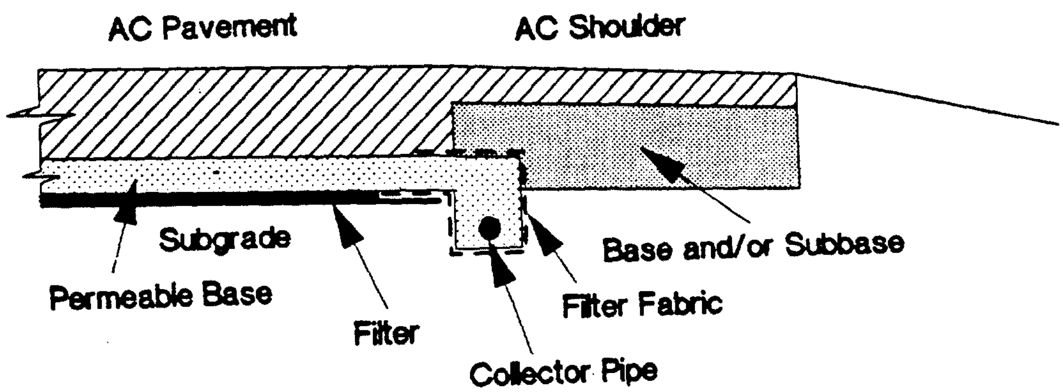
Figure 1. Typical Permeable Base Pavement Sections



PCC Pavement/AC Shoulder Section



PCC Pavement/PCC Shoulder Section



AC Pavement/AC Shoulder Section

OBJECTIVE

The primary objective of this paper is to synthesize the design and construction of permeable base pavement systems being used in this country. It is the intent to summarize the findings, to communicate the experiences of various States, and to demonstrate that permeable base pavements can be designed and constructed without significant changes to conventional practices.

SCOPE

Reviews were conducted in those States that were known to have recently constructed permeable base pavements. States included in the review were California, Iowa, Kentucky, Michigan, Minnesota, New Jersey, North Carolina, Pennsylvania, West Virginia, and Wisconsin. The review included gathering information from each State in design, use, construction, cost, and performance of permeable bases.

FIELD SURVEY RESULTS

In general, the States that are using permeable base pavements can be grouped into two categories -- those that use an untreated permeable base and those that use a treated permeable base. The untreated permeable base materials generally have a lower coefficient of permeability, whereas treated permeable bases have a much higher coefficient of permeability. The untreated permeable base material contains more smaller sized aggregate to give it stability and, thus, it tends to be less permeable. On the other hand, a treated permeable base had a cementing agent, generally 2-3 percent asphalt cement, for stability. The result was a more open material with high permeability.

Summary of State's Philosophy on Permeable Base Pavement Design

The approach to permeable base design varied among the States reviewed with California, Michigan, New Jersey, and Pennsylvania having the most experience. Most of the other States constructing permeable bases investigated the designs used by these States and modified them for their own use. The majority of States are primarily using permeable bases beneath PCC pavements, however, several States are using permeable bases beneath AC pavements as well.

Although the philosophies differ with respect to degree of permeability, the end result is that all States believe that rapid base drainage is extremely important. Some States believed that the highest permeability that could be obtained with readily available materials was best. Whereas, other States believed that a less permeable material which was similar to their existing base material in availability, cost, and stability, but which had some of the fines removed to provide drainability, was sufficient.

Review of Current Permeable Base Pavement Design

Type of Permeable Base

Those States that are predominantly using untreated permeable bases include: Iowa, Kentucky, Michigan, Minnesota, New Jersey, Pennsylvania, and Wisconsin. Iowa's, Minnesota's, and Pennsylvania's permeable base gradation is essentially derived from their conventional dense-graded aggregate base gradation with some of the fines removed. Kentucky's and New Jersey's gradations are based on readily available AASHTO aggregate gradations (i.e., Kentucky uses the AASHTO No. 57 stone and New Jersey uses a 50/50 blend of AASHTO No.'s 57 and 9 stone). Michigan's and Wisconsin's gradations were developed through testing of various permeable gradations. Both Iowa and Michigan allow recycled PCC pavement with some of the fines removed to be used for their permeable base.

Those States that are using treated permeable bases include California, North Carolina, and West Virginia. The predominant material used for stabilization is asphalt cement at approximately 2 percent, although California allows Portland cement at 2-4 bags per cubic yard as an option. Both North Carolina and West Virginia utilize AASHTO's No. 57 stone gradation. California's gradation is similar.

Degree of Permeability

There was a wide range in permeabilities desired. The untreated permeable bases generally had a lower coefficient of permeability -- in the range of 200 to 3,000 feet per day. The treated permeable bases all had a very high coefficient of permeability -- from 3,000 to 20,000 feet per day or higher. The permeabilities were determined using either a falling head or constant head permeameter using standard test procedures. The gradations used by the 10 States reviewed for the treated and untreated permeable bases, respectively, follow.

TREATED PERMEABLE GRADATIONS

Sieve Size	Percent Passing California	Percent Passing North Carolina/West Virginia
1 1/2-inch	. -	100
1-inch	100	95-100
3/4-inch	90-100	-
1/2-inch	35-65	25-60
3/8-inch	20-45	-
No. 4	0-10	0-10
No. 8	0-5	0-5
No. 200	0-2	0-2
Coefficient of Permeability (feet per day)	15,000	20,000

UNTREATED PERMEABLE GRADATIONS

Sieve Size	IA	KY	MI	MN	NJ	PA	WI
				Percent Passing			
2-inch	-	-	-	-	-	100	-
1 1/2-inch	-	100	100	-	100	-	-
1-inch	100	95-100	-	100	95-100	-	100
3/4-inch	-	-	-	65-100	-	52-100	90-100
1/2-inch	-	25-60	0-90	-	60-80	-	-
3/8-inch	-	-	-	35-70	-	35-65	20-55
No. 4	-	0-10	0-8	20-45	40-55	8-40	0-10
No. 8	10-35	0-5	-	-	5-25	-	0-5
No. 10	-	-	-	8-25	-	-	-
No. 16	-	-	-	-	0-8	0-12	-
No. 30	-	-	-	-	-	0-8	-
No. 40	-	-	-	2-10	-	-	-
No. 50	0-15	-	-	-	0-5	-	-
No. 200	0-6	0-2	-	0-3	-	0-5	-
Coefficient of Permeability (feet per day)	500	20,000	1000	200	2000	1000	18,000

Extent of Use

Nine of the 10 States use their permeable base under new or reconstructed high-type PCC pavements. Also, most States have constructed at least one permeable base AC pavement experimentally. Kentucky has only constructed permeable bases under AC pavements to date. It has been within the past 5 years that permeable bases beneath high-type PCC pavements has become standard in these States, with California specifying them beneath AC pavements, as well.

Thickness and Width of Permeable Base

The thickness of permeable bases varied from 3 to 6 inches, with 4 inches being the most common. Although the thickness required for drainage can be calculated, 4 inches seems to provide sufficient capacity, is easily constructed, and provides for construction tolerances. California specifies 0.25-feet (3 inches) for its asphalt cement treated permeable base and 0.35-feet (approximately 4 inches) for its Portland cement treated permeable base. The difference in thickness specified is attributed to the asphalt cement treated permeable material having a higher coefficient of permeability -- approximately 15,000 feet per day -- than the Portland cement treated material -- approximately 4,000 feet per day.

The width of permeable base, whether treated or untreated, was generally placed 1 to 3 feet outside either pavement edge. In most cases, the tracks of the paver ran on this widened section. Kentucky, New Jersey, and West Virginia carried the permeable base layer out to the edge of either shoulder.

Method Used to Drain Permeable Base

All States reviewed use a longitudinal edgedrain collector system to drain accumulated water from their permeable bases. Seven of the 10 States used an excavated trench design exclusively. Kentucky, West Virginia, and Wisconsin have also used a V-ditch design for the longitudinal edgedrain collector. Both Kentucky and West Virginia noted problems with this design. Not only is constructing and maintaining the V-ditch a problem, but protecting the pipe from crushing under construction traffic was also noted as a problem. Several States that use the excavated trench design also expressed a concern with possible crushing of the pipe, however, there is generally more cover over the pipe than with the V-ditch design. Both Minnesota and Wisconsin allow the contractor to construct the longitudinal edgedrain collector system either before or after pavement construction. They were concerned with the possible damage to the pipes in the longitudinal trenches and the outlet lateral trenches by construction equipment.

Generally, the inside edge of the edgedrain trench is located immediately below the longitudinal pavement/shoulder joint (see Figure 1). To avoid settlement or crushing of the collector pipe beneath construction equipment, several States locate the trench 2-3 feet out from the joint beneath the shoulder. Michigan, however, installs the trench beneath the PCC pavement.

Most States that construct crowned pavement sections install a longitudinal edgedrain collector system along both the inner and outer pavement edge. This effectively shortens the drainage path and significantly lessens the time for the permeable base to drain.

Most States backfill the edgedrain trench with the same permeable material that is used for the permeable base. A few used a more permeable material as backfill. All 10 States used an outlet pipe to convey the accumulated water from the edgedrain collector to the ditch or other inlet structure. West Virginia tried a fabric wrapped pea gravel outlet system. After several years, these outlets became increasingly difficult to locate because they had become overgrown with vegetation and/or plugged with roadside slope debris. Daylighting of the permeable base to the ditch slope is not recommended because of these reasons.

A number of States had experienced problems with maintaining the proper outlet grade with flexible corrugated plastic pipe and now specify the use of rigid PVC pipe for outlet laterals. Iowa is the only State that does not use a filter fabric lined edgedrain collector trench. The subbase and subgrade material acts as a filter and is compatible with the permeable trench backfill material. Also in Iowa, edgedrains are installed 4 feet below the pavement surface and are generally installed 2-3 years prior to reconstruction, primarily to drain the subbase and subgrade before reconstruction.

Type of Filter Layer Used

Those States that use an untreated permeable base use a filter aggregate layer, which in most cases, is the States's conventional dense-graded aggregate base material. The gradation of this material is compatible with the permeable material to prevent intrusion of fines from the subgrade. Those States that use a treated permeable base predominantly, use a filter fabric (primarily non-woven) to protect the permeable base layer from intrusion of fines. One State, West Virginia, allows the use of a woven fabric. It is interesting to note that research by Penn State University in the use of filter fabrics, found that filter fabrics act a as a wick or blotter actually holding moisture in the material immediately below the filter fabric and may act as an internal source of moisture.(1) California was the only State that used an impermeable aggregate subbase as a separator or filter layer with a treated permeable base.

Structural Value

Five of the seven States that predominantly use an untreated permeable material believe it was structurally equivalent to a dense-graded aggregate base. New Jersey had gyratory shear and repeated load triaxial tests performed on their untreated and asphalt cement treated permeable materials at the Corps of Engineers Waterways Experiment Station (WES). Results indicated that both had bearing capacities similar to dense-graded aggregate base. Also, 1/2 million wheel loads were applied to the same test section which was subject to periodic flooaing and it exhibited good performance.(2) Pennsylvania had tests performed on their untreated permeable material at the Penn State University Test Track and found that it provided support similar to a dense-graded aggregate base.(3) Kentucky and Minnesota do not give the untreated permeable material credit in their structural sections.

The three States that used a treated permeable base believed that the permeable material provided support similar to a dense-graded AC base. West Virginia performed a plate load bearing test on their first asphalt treated permeable base. A resultant K-value of 200 pounds per cubic inch (psi).(4) California performed laboratory compressive tests on their asphalt cement treated permeable material and found that it provided more support than dense-graded aggregate material.

Review of Current Permeable Base Construction Practices

Construction Considerations

Overall, construction of permeable base pavements requires more care than unstabilized or stabilized dense-graded aggregate bases. The treated permeable bases have sufficient stability for construction traffic, however, extra care is needed to prevent contamination of the layer. Untreated permeable bases, although sufficiently stable to pave on, are more easily displaced than dense-graded base. Additional care is required by equipment operators and truck drivers when placing and finishing the pavement. Quite often, a roller was used to "dress up" the permeable material immediately in front of the paver.

Most States restrict construction equipment other than the paving and finishing equipment from traversing the permeable base. Also, most States found that when placing an AC pavement on a permeable base, rubber-tired pavers rutted and displaced the permeable material. They now specify tracked pavers which better distribute the

Another concern with the untreated ... eable aggregate material was the possible segregation of the material during placement and degradation of the aggregate under construction traffic. Several States specify that untreated permeable aggregate be placed at a certain percent moisture to reduce segregation.

The grade of the treated permeable materials was more difficult to modify once it had been placed and compacted. High and/or low spots at the longitudinal joint between asphalt cement treated paving passes was common and some method of modifying the grade (i.e., trimming with a blade or autograder) was required. Also, keeping the highly permeable base material clean and free from contamination was a concern. Both North Carolina and West Virginia require that the filter fabric between the subgrade and permeable base layer be wrapped or lapped up around both edges of the permeable base. California required sufficient filter fabric to line the edgedrain collector trench and to wrap up and over the low side of the permeable base layer.

Equipment Modifications

Only very minor equipment modifications are required to more easily construct permeable base pavements. One modification noted in a couple States was the use of wider rubber tires on the reinforcing mesh cart (for jointed reinforced concrete pavements (JRCP)) to distribute the load over a larger area of the permeable base, thereby, reducing the potential displacement of the untreated material. Also, as mentioned previously, when placing an AC pavement use of tracked pavers on untreated permeable bases in lieu of rubber-tired pavers was specified. In addition, use of longer pins to hold dowel baskets in place was necessary on permeable bases.

Stability

No stability problems were observed or indicated by any of the States that were reviewed. Many State and contractors' personnel expressed reservations regarding the paving on the more open-graded permeable treated or untreated base materials on their initial contact with it. However, in all cases, after working with the material the doubts vanished. All States required at least 85 percent crushed material which provided additional stability through aggregate interlock.

There were no problems noted with stability of the asphalt cement treated permeable materials under construction equipment even under high ambient air temperatures. All three States used a conventional paving grade asphalt cement as the stabilizing material. California noted a problem on one project where the asphalt treated permeable base did not set up properly and took up to a week to provide sufficient stability to pave on. The State attributed this to the permeable aggregate temperature not being in the 275-375 degree F range specified at the time the asphalt cement was introduced.

As expected, stability was more of a concern with untreated permeable materials. Although stability varied from state to state and gradation to gradation, all untreated permeable materials were stable under paving equipment. However, many States did not allow any equipment other than that needed to place and finish the paving to traverse the material. Those States that did allow construction traffic on the untreated base, required a roller in front of the paving operation to compact and smooth out any disturbance to the material from trucks hauling on the base. Both Minnesota and Pennsylvania require a minimum coefficient of uniformity (D_{60}/D_{10}) of 4 to ensure a stable gradation.

Performance of Existing Permeable Base Pavements

Performance information available to date indicates that properly designed and constructed permeable bases virtually eliminate pumping, faulting, and cracking. There is no long-term performance data available (in excess of 15 years). However, based on a comparison of the performance of existing permeable base sections to undrained sections. States anticipate a 50 percent increase in PCC pavement service life.

California continues to evaluate their permeable base pavements versus those that are not drained. On PCC, they found that in terms of percent cracked slabs, the permeable base (drained) sections had significantly lower rates of slab cracking. Of the four permeable base sections evaluated, three of which were constructed in 1980, two of the permeable base sections had no cracking, whereas the undrained control sections had 18 and 47 percent cracking. A drained section constructed in 1965 had 5 percent cracking compared to 10 percent for the undrained section. One project with both a permeable base and an undrained section had exhibited no cracking yet. A 500-foot section of AC pavement on a logging road was reconstructed in 1967 using a highly permeable open-graded base drainage layer after it had failed twice in just a few years. The State conducted a review in 1986 and found that the original pavement was still in excellent condition with no patching, whereas, the adjoining pavement had been extensively patched. The 19-year service life of this section (to date) is well beyond the normal 12-year life of AC pavements in California. Studies performed by California suggest a minimum service life increase of 33 and 50 percent, respectively, for AC and PCC pavements constructed on a permeable base.(5)

Iowa has performed a substantial amount of nondestructive testing (NDT) with a Road Rater on their PCC pavements. They indicated that permeable base pavements provide greater structural support than undrained pavements. The support on undrained pavement sections deteriorates for approximately 5 years, whereas support on permeable base sections does not deteriorate. They felt the constant support of the permeable base sections was equivalent to 3 to 5 inches of effective pavement. In addition, crack surveys which are performed every 2 years revealed that permeable base pavements have virtually no cracks, unlike conventional undrained pavements of the same age.

Michigan's oldest permeable base sections are on the Clare test road (US 10) constructed in 1975. An inspection of the three 1/2-mile permeable base test sections in comparison to the other sections was conducted during the review. There was no faulting or cracking and less apparent D-cracking on the permeable base sections than on the other two base types (i.e., bituminous base and dense-graded aggregate base). The dense-graded bituminous base sections were the worst performing in terms of pavement distress (i.e., faulting, cracking, D-cracking, and spalling). Pumping was noted on these sections as well. Some spalling of the longitudinal joints was noted on all test sections, but was noticeably worse on the bituminous base sections.

Minnesota's oldest permeable base pavement section, a 1600-foot section of JRCP with 27-foot skewed dowelled joints on Trunk Highway 15 near Fairmont constructed in 1983, was evaluated. After 5 years, only one of the 59 permeable base slabs had a mid-panel crack, whereas the undrained JRCP with conventional dense-graded aggregate base adjacent to either end of the pavement was found to have approximately 50 percent mid-panel cracking. The section adjacent to the south had 15 of 33 slabs that exhibited mid-panel cracks and the section north had 5 of 10 slabs with mid-panel cracks.

New Jersey reported the performance of their experimental permeable base pavement sections constructed in 1979-1980 at the 1988 Transportation Research Board Meeting. Their initial observations/findings on the AC sections were that the thinner sections were performing as well as the thicker sections with rutting being about the same. On PCC pavement sections, there was less deflection, no faulting or pumping, and substantially reduced frost penetration.

Pennsylvania rated the performance of their experimental permeable base sections constructed in 1980 much better than dense-graded aggregate base sections. Based on the positive interim results of these sections, a permeable base layer between the PCC pavement and dense-graded aggregate subbase became the State standard in 1983.(3)

Rideability

All of the States indicated that the rideability of permeable base pavements was no different than that on dense-graded bases. This was substantiated in California and North Carolina (asphalt cement treated) and Michigan (untreated). The rideability of some recently constructed PCC pavements in these States had been measured using the California and Rainhart profilographs at 0-5 inches per mile. In general, those States using a stringline for both horizontal and vertical control had a substantially better ride quality than those that did not. Also, those States that had incentives/disincentives for rideability had projects with very good ride quality.

Cost

Bids for permeable base materials were generally found to have slightly higher costs per unit weight than the impermeable dense-graded materials they replaced. Five of the seven States that used an untreated permeable base found that they were slightly more costly per unit measure than conventional dense-graded aggregate bases while two States, Iowa and Michigan, indicated that the unit costs for their permeable base material were the same or sometimes less.

As expected, the treated permeable base materials were two to three times more costly per unit measure than conventional dense-graded aggregate bases. However, all three States that predominantly used treated permeable base material found that the unit costs for it were about the same as those for dense-graded AC base. In addition, all three noted that because of the higher void content of the permeable material, the yield was 15-30 percent higher than dense-graded AC. California found that asphalt cement treated permeable base was generally less costly per unit measure than cement treated base (CTB) and lean concrete base (LCB). The material unit costs were the same or slightly more than asphalt concrete base but because of the large void content the yield was 20 percent higher. Kentucky, which had used some asphalt treated permeable base within the past year, also found that its material unit costs were about the same as the dense-graded bituminous base, but the permeable base material had 25-30 percent higher yield.

SUMMARY

A review of current design and construction practices has proven that permeable base pavements can be designed and constructed to rapidly drain moisture that infiltrates the pavement surface without significant changes to conventional practices.

REFERENCES

1. "Fourth Cycle of Pavement Research at the Pennsylvania Transportation Research Facility," Research Project 82-11, Final Report, Volume 5, "Open-Graded Permeable Subbases at the Pavement Durability Research Facility," by D. A. Anderson and M. E. Shamon December 1984.

2. "Design and Implementation of Internal Roadway Drainage," by V. Mottola, New Jersey Department of Transportation, discussion of paper entitled "Subsurface Drainage Systems," by G. W. Ring, Federal Highway Administration, in the proceedings from the National Crushed Stone Association Conference on Crushed Stone for Road and Street Construction and Reconstruction, June 14-15, 1984.

3. "Subbase Permeability and Pavement Performance," by K. L. Highlands, and G. L. Hoffman, Pennsylvania Department of Transportation, paper No.870717 prepared for the 67th Annual TRB Meeting, January 1988.

4. "Evaluation of a Free Draining Base Course," by J. S. Baldwin and J. G. Jarvis, West Virginia Department of Highways, February 1986.

5. "Economic Impact of Pavement Subsurface Drainage," by R. A. Forsyth, G. K. Wells, and J. H. Woodstrom, California Department of Transportation, paper prepared for presentation at the annual meeting of the Transportation Research Board (TRB), January 1987.

U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL HIGHWAY ADMINISTRATION

DATE: June 8, 1989

FIELD TRIP REPORT

TO: Mr. Lou Papet, Chief
Pavement Division

FROM: Mr. Daniel M. Mathis
Highway Engineer

THRU: Mr. Paul Teng, Chief
Pavement Design & Rehabilitation Branch

Mr. John P. Hallin
Team Leader

INCLUSIVE DATES: April 11-14, 1989

PURPOSE: To participate in a pavement edgedrain review.

ACCOMPLISHMENTS OR RESULTS:

The State noted staining from fine soil particles on the shoulder of several recently cracked, seated, and overlaid Portland cement concrete (PCC) pavement sections. These appeared to be the result of moisture being pumped through the asphalt concrete (AC) overlay in the vicinity of the lane/shoulder joint. Since edgedrains were installed on these sections as part of the crack and seat project, the State felt that an investigation was warranted to determine if the drains had failed.

On Tuesday afternoon (4/11), we were briefed on the pavement staining problem and the State's work plan for investigation. They met with individuals from the State to discuss the procedure and operations for the investigation of the pavement edgedrain and pavement structure which were to take place on Wednesday and Thursday. The majority of shoulder staining was occurring on cracked and seated and overlaid PCC projects which were constructed in 1988 using a geocomposite edgedrain manufactured by Advanced Drainage Systems known as AdvanEdge. The State was considering a ban on this particular geocomposite edgedrain, but was encouraged to undertake an investigation of the problem in the field.

On Wednesday morning, numerous edgedrain outlets were observed on a section which exhibited some of the heaviest shoulder staining. All of the outlets were clear and functioning as evidenced by the red stains from eroded subgrade fines on the concrete headwall. At several outlets, a crystalline growth was observed on the rodent screens and outside the outlet pipe. It was speculated that this was the result of latent calcium carbonate precipitate being released from the cracked and seated PCC. Although all the outlets observed had drained, several of the flexible outlet pipe laterals had a slight reverse grade which inhibited the flow from the edgedrain system.

After traffic control had been set up, four cutouts approximately 9 inches square were jack hammered through the shoulder pavement to expose the top of the geocomposite edgedrain for observation and for insertion of the borescope. The edgedrain was located approximately 1-foot from the longitudinal pavement/shoulder joint interface area as shown in figure 1. In the afternoon, the operation moved to another location further south in the vicinity of post mile 109 to borescope another section of geocomposite edgedrain where the staining was apparent. Again, four 9-inch square cutouts were made to expose the top of the geocomposite edgedrain. The top of the edgedrain was cut open to expose the inside and to allow insertion of the borescope. Again the edgedrain was found to be approximately 1-foot away from the edge of the PCC pavement. In both areas borescoped, fines were observed in the bottom of the edgedrain core and a small amount of water was observed as well. Once the borescope was inserted into the edgedrain, fines could be observed coming from the slots with the bottom row of slots in many cases being completely silted up. Fines were observed adhering to the inside of the geotextile encapsulating the plastic core and being carried away in the outflow in the core. The geocomposite edgedrain did not show any signs of crushing. Also, fine material at 3/4 to 1 inch depth was noted in the bottom of the edgedrain.

On Thursday morning, a section of the right shoulder in the vicinity of post mile 108 (southbound) which exhibited the heaviest shoulder staining was excavated. A trench approximately 20 feet long, 3 feet wide, and 3 1/2 feet deep, 1-foot out from the pavement structure was excavated. Midway in the excavated trench, a 2-foot section of the geocomposite edgedrain (ADS' AdvanEdge) was carefully excavated and cut out from the edgedrain system for testing and evaluation. The bottom of the edgedrain contained 1 to 1 1/2 inches of silt/clay (minus No. 200 sieve) material. Excavation of the material between the edgedrain and the pavement structure ensued. Very little free moisture was apparent in the material surrounding the edgedrain or in the base material beneath the pavement and shoulder. This material was moist but not saturated until the excavation came within a half-inch of the pavement structure. Once the material had been removed adjacent to the PCC pavement, water was observed flowing through the cracks of the cracked and seated PCC pavement, along voids between the PCC and shoulder base material, and at the PCC/AC overlay interface. No moisture was observed traversing the slab/subbase interface as the PCC was well cracked and seated on the subbase. Observations of the AC overlay in the staining areas, revealed a high percentage of voids in the mix. Also, fines were observed adhering to the AC overlay aggregate throughout the base course and the surface course layers.

Two crude percolation tests were conducted on the AC overlay. A paper cup with the bottom cut out was placed on the surface and sealed with grease. Water was then poured into the cup and the movement of water in relation to a reference point was observed. The first test was performed in the right wheelpath and the second was performed near the lane lines between the two southbound lanes. Very little water percolated through the traffic compacted AC in the wheel path. However, the second area tested, which was not in the wheelpath, accepted water at a surprising rapid rate -- an inch of water in the 2 1/2-inch diameter cup percolated through the AC surface in approximately 30 seconds. Again this was a crude test but it gave a good indication of the permeability of the AC overlay. This suggests that poor compaction of the AC overlay is allowing water to permeate down through the overlay and the cracked and seated PCC before being pumped back up through the overlay and staining the shoulder.

A closeout discussion was held at the site. The recommendations suggested are those that appear below.

We then went on to review other previously cracked and seated and overlaid PCC pavements from this section on up to the stateline. Staining of the right shoulder was observed at isolated locations. The longitudinal edgedrain used on the sections varied from two different types of geocomposite edgedrain types to the State's conventional geotextile wrapped pipe edgedrain. The extent and degree of staining on these sections was less than that noted on sections on projects that were observed previously.

CONCLUSIONS:

The staining of the shoulder is the result of moisture infiltrating down through the insufficiently compacted AC overlay and into the cracked and seated PCC pavement. There it travels laterally through the cracks to the pavement/shoulder interface. The base material surrounding the cracked and seated PCC is dense-graded and impermeable. In addition, location of the edgedrain prevents the free flow of moisture from the cracked and seated PCC to the edgedrain. As a result, moisture is trapped in the cracked and seated pavement. Under traffic loadings, sufficient pressures are developed to pump water and fines through the AC overlay and out onto the surface.

RECOMMENDATIONS:

There were several recommendations suggested:

1) Retrofit longitudinal edgedrains, whether conventional trench or geocomposite, should be placed such that a large area of the edgedrain is in contact with the cracked and seated PCC pavement. Moisture cannot be effectively drained from a very dense impermeable material (i.e., the aggregate base or clay subgrade) and as a result more surface area of the edgedrain should be provided adjacent to the PCC pavement to drain the moisture that moves through the cracked pavement (see figure 2).

2) Additional attention to AC paving and compaction is recommended. Tighter more compacted AC pavement layers will reduce the amount of moisture infiltrating the pavement structure. This, in turn, will reduce other potential problems such as stripping of the asphalt cement from the aggregate from occurring.

3) It is recommended that rigid PVC pipe be used for outlet laterals to ensure a proper grade for the outlet.

4) It is recommended that various types of geocomposite edgedrains, conventional aggregate pipe edgedrains (with different geotextile placements), and a control section be evaluated to determine which if any edgedrain performs better and if retrofit longitudinal edgedrains themselves increase the service life of the pavement.

REMARKS:

The State and the FHWA Division should be commended for undertaking this type of investigation to determine the probable cause for the problem noted. Good engineering is extremely important in understanding the problem and in making sound decisions on modifications to design and construction practices and procedures to alleviate the problem.

ADDITIONAL INFORMATION:

On June 5, 1989 another section of cracked and seated and overlaid PCC pavement further north was excavated. This 9-inch PCC pavement had been rehabilitated with a geocomposite edgedrain and a 4-inch AC overlay approximately 1 year ago. A section of the pavement exhibited staining on the shoulder similar to that discussed previously. The geocomposite edgedrain used on this section was Monsanto's Hydraway. Again, it had been placed approximately 1-foot from the edge of the pavement, however, because of the different nature of the subbase material, water was able to flow through the material and into the drain. Outlets were located 200 feet south and 300 feet north of the excavation. When material surrounding the geocomposite edgedrain was excavated, water seeped through the geotextile and into the trench. A section of the geocomposite edgedrain was cut out for laboratory testing. When the section was removed, water drained into the trench from either end indicating that this section of edgedrain was located in a sag vertical curve with no outlet. The accumulated water ponded and filled the edgedrain. When sufficient pressure was exerted water and fine material was forced up through the AC overlay and out onto the shoulder. An edgedrain outlet was installed by State personnel at this location to rectify the problem.

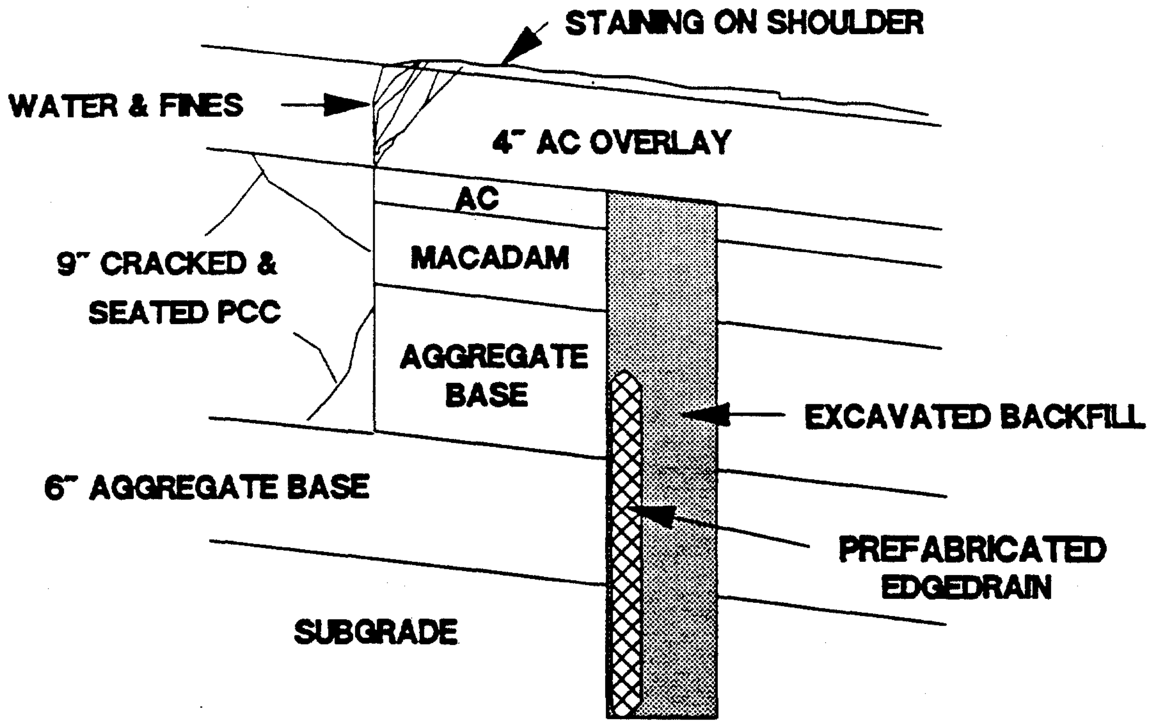


Figure 1. ACTUAL PREFABRICATED EDGEDRAIN PLACEMENT

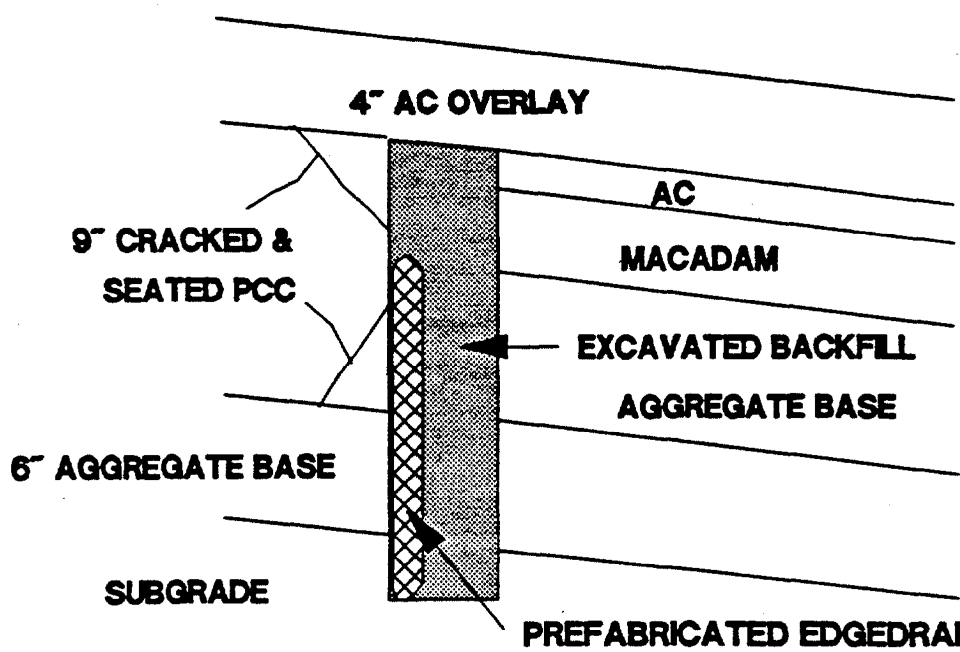
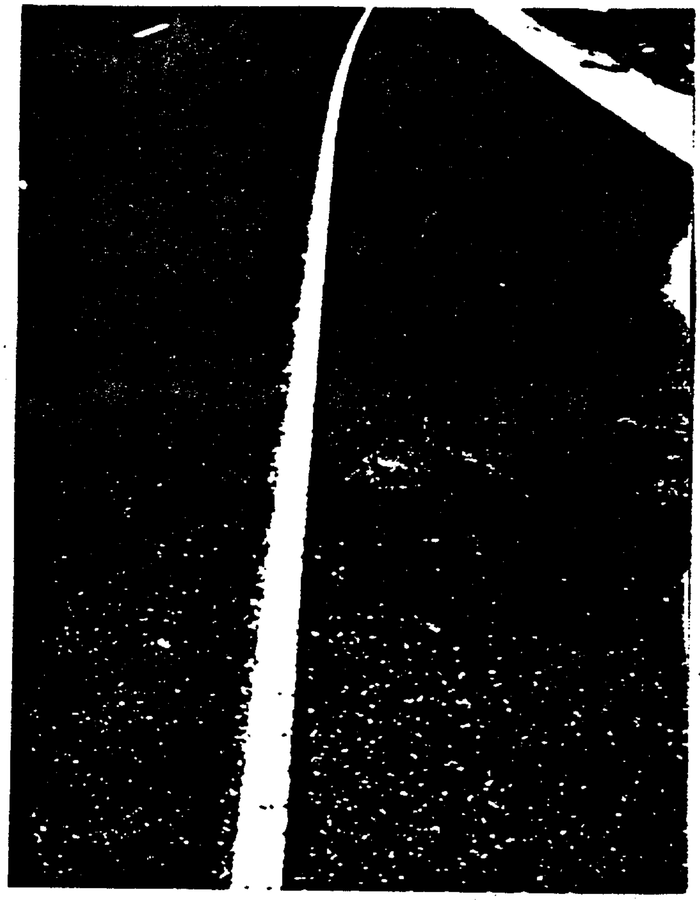
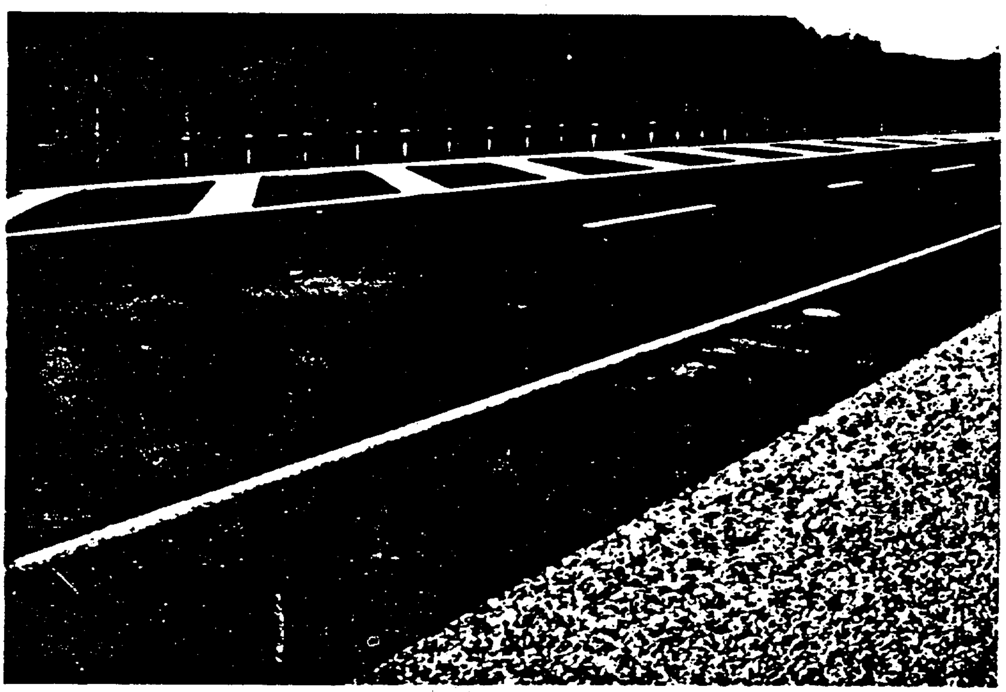


Figure 2. RECOMMENDED PREFABRICATED EDGEDRAIN PLACEMENT

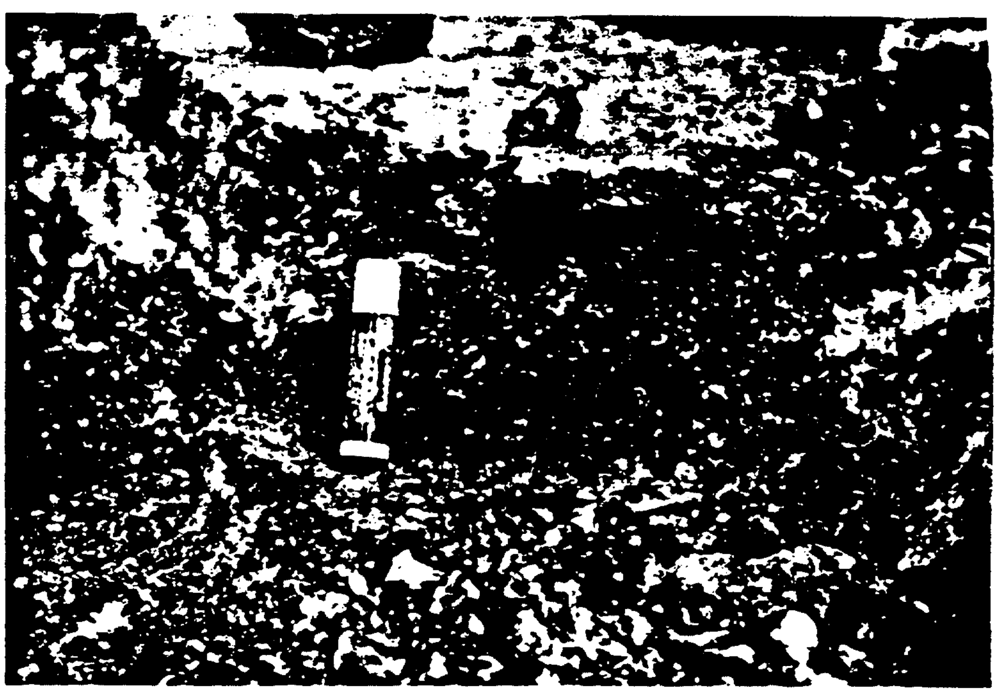


Subbase/subgrade fines staining shoulder.



Subbase/subgrade fines staining AC overlay on superelevated section.

Geocomposite edgedrain (lower left) located
approximately 1-foot from cracked and seated
PCC pavement (upper right). Impermeable material
lies between edgedrain and pavement.



Subbase\subgrade fines adhering to
AC overlay aggregate.

SUBSURFACE DRAINAGE
OF
PORTLAND CEMENT CONCRETE PAVEMENTS

WHERE ARE WE?

December 1991

BACKGROUND

The drainage of concrete pavements has been a significant activity in the Pavement Division, since the formation of the Division in 1986. The AASHTO Guide for the Design of Pavement Structures (1986) had been recently published and addressed drainage as an essential element of pavement design. The Federal Highway Administration's (FHWA) January 13, 1989 Pavement Policy encouraged a drainage analysis for each new, rehabilitation, and reconstruction pavement design.

During the summers of 1987 and 1988 reviews were conducted in those States that were constructing permeable bases under portland cement concrete (PCC) pavements. The States identified were California, Iowa, Michigan, Minnesota, New Jersey, North Carolina, Pennsylvania, West Virginia, and Wisconsin. During the previous 5 years permeable bases beneath high-type PCC pavements had become standard in these States, with California specifying them beneath AC pavements, as well. The review included gathering information from each State on design, use, construction, cost, and performance of permeable bases.

In general, the States that were using permeable base pavements could be grouped into two categories -- those that used an untreated permeable base and those that used a treated permeable base. The untreated permeable base materials generally had a lower coefficient of permeability, whereas treated permeable bases had a much higher coefficient of permeability. The untreated permeable base material contained more smaller sized aggregate to give it stability and, tended to be less permeable. On the other hand, a treated permeable base had a cementing agent, 2 to 3 percent asphalt cement or 2 to 4 bags of cement per cubic yard, for stability. The result was an open material with high permeability.

The approach to permeable base design varied among the States with California, Michigan, New Jersey, and Pennsylvania having the most experience. Most of the other States constructing permeable bases investigated the designs used by these States and modified them for their own use.

Although the philosophies differed with respect to degree of permeability, the end result was that the States believed that rapid base drainage was extremely important. Some States believed that the highest permeability that could be obtained with readily available materials was best. Whereas, other States believed that a less permeable material which was similar to their existing base material in availability, cost, and stability, but which had some of the fines removed to provide permeability, was sufficient.

States using untreated permeable bases were; Iowa, Michigan, Minnesota, New Jersey, Pennsylvania, and Wisconsin. Iowa's, Minnesota's, and Pennsylvania's permeable base gradation was derived from their conventional dense-graded aggregate base gradation with some of the fines removed. New Jersey's gradations were based on a 50/50 blend of AASHTO No.'s 57 and 9 stone. Michigan's and Wisconsin's gradations were developed through testing of various permeable gradations. Both Iowa and Michigan allowed recycled PCC pavement, with some of the fines removed, to be used for their permeable base.

States using treated permeable bases were California, North Carolina, and West Virginia. The predominant material used for stabilization was asphalt cement at approximately 2 percent, although California allowed portland cement at 2-4 bags per cubic yard as an option. Both North Carolina and West Virginia utilized AASHTO's No. 57 stone gradation. California's gradation was similar to the AASHTO No. 57.

There was a wide range of permeability. The untreated permeable bases generally had a lower coefficient of permeability -- in the range of 200 to 3,000 feet per day. The treated permeable bases all had a very high coefficient of permeability -- from 3,000 to 20,000 feet per day or higher. The permeability was determined using either a falling head or constant head permeameter following standard test procedures.

The States that used an untreated permeable material believed it was structurally equivalent to a dense-graded aggregate base. New Jersey had gyratory shear and repeated load triaxial tests performed on their untreated and asphalt cement treated permeable materials at the Corps of Engineers Waterways Experiment Station (WES). Results indicated that both had bearing capacities similar to dense-graded aggregate base. Also, 1/2 million wheel loads were applied to the same test section, which was subject to periodic flooding, and it exhibited good performance. Pennsylvania had tests performed on their untreated permeable material at the Penn State University Test Track and found that it provided support similar to a dense-graded aggregate base. Kentucky and Minnesota did not give the untreated permeable material credit in their structural sections.

The States that used a treated permeable base believed that the permeable material provided support similar to a dense-graded AC base. West Virginia performed a plate load bearing test on their first asphalt treated permeable base. A resultant K-value of 200 pounds per cubic inch (pci). California performed laboratory compressive tests on their asphalt cement treated permeable material and found that it provided more support than dense-graded aggregate material.

Overall, construction of permeable base pavements was found to require more care than dense-graded aggregate bases. The treated permeable bases had sufficient stability for construction traffic, however, extra care was needed to prevent contamination of the layer. Untreated permeable bases, although sufficiently stable to pave on, were more easily displaced than dense-graded base. Additional care was required by equipment operators and truck drivers when placing and finishing the pavement. Quite often, a roller was used to "dress up" the permeable material immediately in front of the paver.

Another concern with the untreated permeable aggregate material was the possible segregation of the material during placement and degradation of the aggregate under construction traffic. Several States specified that untreated permeable aggregate be placed at a certain percent moisture to reduce segregation.

The grade of the treated permeable materials was more difficult to modify once it had been placed and compacted. High and/or low spots at the longitudinal joint between asphalt cement treated paving passes was common and some method of modifying the grade (i.e., trimming with a blade or autograder) was required. Also, keeping the highly permeable base material clean and free from contamination was a concern. Both North Carolina and West Virginia required that the filter fabric between the subgrade and permeable base layer be wrapped or lapped up around both edges of the permeable base. California required sufficient filter fabric to line the edgedrain collector trench and to wrap up and over the low side of the permeable base layer.

PROMOTION

The permeable base reviews conducted during 1987 and 1988 revealed that permeable bases could be constructed without significant changes to conventional practices. However, there were questions raised that needed to be addressed. In Michigan early distress on several projects were partially attributed to the lack of stability of the permeable base. The paving contractors raised a number of issues including: the cost effectiveness of using permeable bases on lower volume routes, adequate stability for normal construction operations, and the availability of aggregate in all locations (since a crushed gap graded aggregate is required there is more waste in a gravel source). The States also have raised questions on needed permeability and stability and the lack of long term performance data.

Reviews of existing pavement subsurface drainage systems indicated a general lack of maintenance. In every State visited, outlets were found that were completely plugged. There was a concern that, unless the maintenance of the outlets was given high priority, the use of permeable bases could cause more harm than good. An undrained permeable base would become a large reservoir of water under the pavement which could saturate and weaken the subgrade.

Since the findings of the review were generally positive it was concluded that an effort should be undertaken to promote the use of permeable bases, while continuing to evaluate existing and ongoing projects. The promotional activities can be grouped into three areas: Conferences and Presentations, Issuance of Technical Guidance, and Development of Demonstration Project 87.

Conferences and Presentations

Since 1988 members of the Pavement Division staff have made presentations on the design and construction of permeable bases to numerous seminars and meetings across the United States such as: Region 3 Quality Assurance Workshop, University of Wisconsin Short Courses, Fourth International Conference on Concrete Pavement Design and Rehabilitation, Illinois Transportation Conference, Western Concrete Pavements Conference, Nevada Transportation Conference, Annual Convention of the National Stone Association. In addition multi state drainage conferences were held in

Williamsburg, Virginia; Memphis, Tennessee; Denver, Colorado; and Madison, Wisconsin. The Pavement Division has also provided technical assistance to many individual States.

Issuance of Technical Guidance

Technical Guide Paper 90-01 on Subsurface Pavement Drainage was issued November 15, 1990 to provide interim guidance. Originally the information contained in the guide paper was going to be issued as a technical advisory (TA). However, State and industry reviewers voiced concerns that the technology had not developed to the point where it should be included in a TA, given the "policy" status that a TA sometimes implies. We concurred with this viewpoint. We plan to issue a TA when procedures have been fully developed and evaluated. The purpose of the guide paper is to provide guidance on the current state-of-the-art for the design construction and maintenance of subsurface drainage systems.

The Concrete Pavement Drainage Rehabilitation State of the Practice Report was published in April 1989. This report summarized the current edgedrain practices in ten States.

Chapter 10, FHWA Pavement Rehabilitation Manual, Longitudinal Edgedrains was issued. This chapter examines subsurface drainage and the need for and the use of longitudinal edgedrains in relation to the design, construction, rehabilitation and maintenance of pavements.

Development of Demonstration 87.

This Demonstration Project is being developed to focus on the proper design, construction, and maintenance of permeable bases under PCC pavements. In April 1990, a meeting was held with participants from FHWA, States, and the concrete paving industry to discuss the best approach to follow in the development of a Demonstration Project for permeable bases. It was consensus of the participants that we should develop a demonstration project which presented the benefits of permeable bases, discussed proper design and construction procedures, and highlighted the importance of proper maintenance.

It was the conclusion of the group that the information contained in the Highway Subsurface Design Manual needed to be updated. Therefore, as part of the development of the demonstration project a new text is being written. The group also recommended that models be developed to demonstrate visually the velocity of flow through aggregate gradations with different coefficients of permeability. These models have been constructed and used at several persentations.

There was also the recommendation that we participate with Wisconsin in a study of cement stabilized open graded base (CSOGB). This study was undertaken in cooperation with the State and contractor. The study resulted in a better understanding of the relationship between cement content, strength, and the ability of CSOGB to carry construction traffic.

A pilot of the demonstration project presentation was given in November 1991. Based on comments received at the pilot, revisions are now being made. The demonstration project is expected to be ready for presentation in March 1992.

OTHER ACTIVITIES

The Pavement Division has worked closely with the Strategic Highway Research Program (SHRP) in the development of permeable base sections for SPS-1 and SPS-2. These sections reflect the state-of-the-art and should provide the information needed to verify the structural capacity and performance benefits of permeable bases.

A research contract is underway to evaluate the effects of various design features on the performance of jointed concrete pavements. Subsurface drainage is one of the features which is being evaluated.

RESULTS TO DATE

Nineteen of the 43 States and Territories, that build PCC pavements, routinely use permeable bases under their PCC pavements. An additional 12 States have constructed an experimental permeable base project or plan to construct one. Table 1 is a list showing which States construct PCC pavements and the type of bases used. In addition, 19 States and Puerto Rico have State funded or HPR studies involving improved pavement drainage.

CONCLUSIONS AND RECOMMENDATIONS

We believe that permeable bases provide a viable alternative for PCC pavements on higher volume routes where pumping and moisture related distress are the principle cause of pavement failure.

The technology is gaining wide acceptance as evidenced by the large increase in the number of States which are now using or plan to use permeable bases.

It is recommended that FHWA focus its activities on providing the States with information on the best available technology and the results of performance and design studies currently underway. We also need to continue to emphasize the importance of proper maintenance. This can best be accomplished through the demonstration projects program, emphasizing the need to consider drainage in our public presentations, and working with the States on a one-on-one basis. We need to continue to work closely with the States and contractors to be aware of their successes and failures, so the latest information is included in our presentations.

Table 1

STATES	USE PCC	PCCP TYPE			TYPE OF BASE						TRY PERM. BASE?	COMMENTS
					Dense Graded			Open Graded				
		CRCP	JRCP	JPCP	AGG	CTB	ATB	OGAB	ATPB	CTPB		
Alabama	N										N	
Arizona	Y	X		X	X						N	
Arkansas	Y			X	X						N	
California	Y			X					X	X		
Colorado	Y			X		X	X				Y	
Connecticut	Y		X		X						N	
Delaware	Y			X					X	X		
Dist. of Columbia	N										N	
Florida	N										N	
Georgia	Y		X	X	X	X					N	
Hawaii	Y			X		X					N	
Idaho	Y			X			X				N	
Illinois	Y	X		X		X	X				Y	
Indiana	Y		X	X	X						Y	
Iowa	Y			X				X				
Kansas	Y		X	X	X						Y	
Kentucky	Y			X				X	X			
Louisiana	Y			X			X				Y	Use drainable shoulder base
Maine	N										N	
Maryland	Y			X					X	X		

able 1

STATES	USE PCC	PCCP TYPE			TYPE OF BASE						TRY PERM. BASE?	COMMENTS
					Dense Graded			Open Graded				
		CRCP	JRCP	JPCP	AGG	CTB	ATB	OGAB	ATPB	CTPB		
Massachusetts	N										N	
Michigan	Y		X					X				
Minnesota	Y			X				X				
Mississippi	Y			X					X			
Missouri	Y		X		X						Y	Use drainable shoulder base
Montana	Y			X	X						N	
Nebraska	Y			X							N	Have drainable subgrades
Nevada	Y			X		X					Y	
New Hampshire	N										N	
New Jersey	Y		X						X			
New Mexico	N										N	
New York	Y		X		X						N	Prefer dense graded bases
North Carolina	Y			X					X			
North Dakota	Y		X	X				X				ATPB in future
Ohio	Y			X	X						N	
Oklahoma	Y	X								X		
Oregon	Y	X					X		X			
Pennsylvania	Y			X				X				
Rhode Island	N										N	
South Carolina	Y			X					X			
South Dakota	Y		X	X	X						Y	OGAB in 1992

Table 1

STATES	USE PCC	PCCP TYPE			TYPE OF BASE						TRY PERM. BASE?	COMMENTS
					Dense Graded			Open Graded				
		CRCP	JRCP	JPCP	AGG	CTB	ATB	OGAB	ATPB	CTPB		
Tennessee	Y			X					X			Considering No. 57 perm.
Texas	Y	X	X	X		X	X				Y	Two projects being built
Utah	Y			X		X					N	
Vermont	N										N	
Virginia	Y	X								X		
Washington	Y			X	X		X				N	Use perm base if needed
West Virginia	Y			X					X	X		
Wisconsin	Y			X						X		
Wyoming	Y							X	X			
Puerto Rico	Y			X			X				Y	

U.S. Department of Transportation

Federal Highway Administration

Memorandum

Subject: **INFORMATION**: Distribution of Proceedings Western States Drainable PCC Pavement Workshop

Date: AUG 10 1994

From: Director, Office of Engineering
For: Director, Office of Technology Applications

Reply to Attn of: HNG-42

To: Regional Administrators
Federal Lands Highway Program Administrator
ATTENTION: Technology Transfer Coordinators

The Federal Highway Administration, in cooperation with the California Department of Transportation along with the Southwest Concrete Pavement Association, sponsored the subject conference in Sacramento, California, during July 21-22, 1993. This memorandum transmits copies of the proceedings (Publication No. FHWA-SA-94-045) and provides you with an update on our pavement drainage efforts.

Presentations describing the design and construction procedures used in the construction of permeable bases were made by the various western State highway agencies (Arizona, California, Nevada, Oregon, Washington, and Wyoming). The proceedings were compiled by Mr. James H. Woodstrom of the Southwest Concrete Pavement Association.

Currently, we have completed presentations of Demonstration Project No. 87 (DP 87), "Drainable Pavement Systems" in 42 States, Puerto Rico, and the District of Columbia. This demonstration project primarily covered drainage of Portland Cement Concrete (PCC) pavements. Unfortunately, one of the reoccurring comments during the presentation was that it did not cover drainage of flexible pavements or retrofit longitudinal edgedrains.

On June 6-8, a Technical Working Group (TWG) on Flexible Pavement Drainage Design was convened to develop input for the design and construction of permeable bases for flexible pavements. Discussions and input from the TWG are being reviewed by the Pavement Division and a design consensus will be formulated. This guidance will be provided to the field.

The National Highway Institute will also incorporate this new guidance on flexible pavement drainage design in its new NHI Course No. 13126, "Pavement Subsurface Drainage Design." This training course will be a complete drainage

Federal Highway Administration 1893 1993 package covering PCC and flexible pavements and retrofit longitudinal edgedrains. A Request for Proposal for the course has been developed and has been forwarded to the Office of Contracts and Procurement. The development time will be approximately 2 years.

Sufficient copies of the publication have been distributed to provide one copy to each regional office, and two copies to each division office. Direct distribution has been made to the division offices, which are asked to forward one copy to the State. If additional copies of the proceedings are desired, or if you have any questions regarding DP 87, the western States report, or pavement drainage, please contact Project Manager Bob Baumgardner at 202-366-4612.

Ray G. Griffith for

William A. Weseman

Attachment

U.S. Department of Transportation
Federal Highway Administration

Memorandum

Subject: ACTION: Demonstration Project No. 87 "Drainable Pavement Systems"

Date: APR 6 1992

From: Director, Office of Engineering
Director, Office of Technology Applications

Reply to Attn of: HNG-42

To: Regional Federal Highway Administrators
Federal Lands Highway Program Administrator
ATTN: Technology Transfer Coordinators
Regional Pavement Engineers

We are pleased to announce that the subject demonstration project is available to State highway agencies (SHA's).

The pavement structural section is the single most costly element of a highway system. Water in the pavement section has been determined to be a factor in premature pavement deterioration. Inadequate base drainage has been identified as a nationwide problem, particularly in concrete pavements. A number of SHA's have developed innovative pavement designs and construction practices that have been successful in draining the pavement section. Application of these innovative techniques can reduce premature pavement failures and extend the useful life and investment in the Nation's roadways.

To demonstrate these newer pavement drainage techniques and other concepts, the Federal Highway Administration's (FHWA) Office of Technology Applications and Office of Engineering have developed Demonstration Project No. 87, "Drainable Pavement Systems." The project centers around classroom discussions that provide current state-of-the-art guidance for designing, constructing, and maintaining permeable base drainage systems. Detailed guidance will be provided for the design and construction of both unstabilized and stabilized permeable bases. The staff will also demonstrate the permeability of different base course materials.

Forwarded under separate cover are additional copies of the attached project flyer. These flyers are for distribution to the State agencies in your region. Interested agencies should submit requests for the demonstration project through the local FHWA office.

Please call Project Manager Robert Baumgardner at (202) 366-4612, should you have any questions.

Douglas A. Bernard

for Thomas O. Willett

Attachments

U.S. Department of Transportation

Federal Highway Administration

Memorandum

Subject: **INFORMATION**: "Effectiveness of Highway Edgedrains," Experimental Project No. 12, Concrete Pavement Drainage Rehabilitation

Date: APR 14 1993

From: Chief, Pavement Division
Chief, Engineering Applications Division

Reply to Attn of: HNG-40
HTA-20

To: Federal Regional Highway Administrators
Division Administrators
Federal Lands Highway Program Administrator

Transmitted under separate cover are sufficient copies of the subject report for use by you and your States. This study measured concurrent rainfall and edgedrain discharges, piezometric water levels and soil moisture under the pavement and shoulders in 10 States (Alabama, Arkansas, California, Illinois, Minnesota, New York, North Carolina, Oregon, West Virginia, and Wyoming). This report should be of interest to State pavement design and research engineers in your region. We would like to take this opportunity to thank you and the participating State and division staffs for making this project a success.

We believe that a principal contribution that this report makes is that it provides an excellent guide to any State interested in developing a pavement drainage study. The pavement instrumentation necessary for drainage is well documented.

Your attention is particularly directed to the CONCLUSION, Effectiveness of Edgedrains, section on page 78 of the subject report. We feel that the following three statements have considerable impact on the national pavement subsurface drainage effort to reduce damage to the pavement structure caused by surface infiltration through joints and cracks:

- "Retrofitting longitudinal edgedrains to an existing highway provides a sink to collect water draining laterally off pavement surfaces, as well as water reaching the edgedrain through subgrade voids and channels."
- "Tight, low permeability subgrade material precludes ready, lateral drainage with or without edgedrains."
- "If highway restoration, as well as construction, includes provisions for a permeable subgrade (base), as well as edgedrains, the two together should prove the most efficient in restoring the highway."

We would like to direct your attention to Column (8) of Table 3 on page 64. The wide range of the percent of rainfall that shows up in the edgedrain discharges indicates how difficult it is to design edgedrain systems. Therefore, this study fully supports the "Time-to-Drain" concepts presented in Demonstration Project No. 87, "Drainable Pavement Systems" (Demo 87).

We would like to take this opportunity to update you on our pavement drainage efforts. Currently, we are making presentations of Demo 87. Attached is a map showing the progress of the project. It should be noted that this project only covers drainage of new or reconstructed portland cement concrete (PCC) pavements with permeable bases, a separator layer and edgedrains. Drainage of asphalt concrete (AC) pavements or retrofit longitudinal edgedrains is not covered in the demonstration project.

The next generation of our pavement drainage activities will include the development of the National Highway Institute Course No. 13126, "Pavement Subsurface Drainage Design." Drainage of pavement infiltration for both PCC and AC pavements, along with retrofit longitudinal edgedrains, will be covered. This project is in the conceptual stage with a National Highway Institute proposal under development.

A limited number of additional copies of the attached report are available from our Report Center, or by purchase from the Geological Survey (Report No. WRRI 92-4147, cost - $13.00, and telephone number (303) 236-7476):

U.S. Geological Survey
Books and Open-File Reports Section
Box 25286, Federal Center
Denver, Colorado 80225

If you have any additional questions, please contact Mr. Robert Baumgardner (202) 366-4612 in the Pavement Division.

Theodore R. Ferragut

Louis M. Papet

Attachments

U.S. Department of Transportation
Federal Highway Administration

Memorandum

Subject: **ACTION**: Maintenance of Pavement Edgedrain Systems

Date: MAR 21 1995

From: Associate Administrator for Program Development

Reply to Attn of: HNG-42

To: Regional Administrators
Federal Lands Highway Program Administrator
ATTENTION: Regional Pavement Engineers

The purpose of this memorandum is to strongly reiterate the need for maintenance of edgedrain systems. We have become increasingly concerned about the lack of maintenance of the edgedrain systems that we have observed around the country. Recently, one of our division offices made an extensive review of the maintenance of pavement edgedrain systems and prepared an excellent report documenting their findings. Attached is a copy of their report "Maintenance of Pavement Underdrain System." The reference to the identity of the division office and the State highway agency has been removed at their request. We recommend that the division offices in your region conduct similar field evaluations of existing edgedrain systems.

Sufficient copies of the publication are attached to provide one copy to each regional office, and two copies to each division office. We ask that this report be forwarded to the State. If additional copies of the report are needed, please contact Mr. Robert Baumgardner at (202) 366-4612.

We cannot over emphasize the importance of proper construction and maintenance of pavement edgedrain systems. If water is not rapidly removed from these systems, they will serve as reservoirs saturating pavement bases and causing rather than preventing accelerated pavement deterioration.

Currently, we are finalizing a service contract for the video inspection of highway edgedrains. This service will assist you and the State in evaluating pavement drainage systems. The video inspection will provide a qualitative picture of edgedrain conditions in the State.

For Thomas J. Ptak

1893 1993 Federal Highway Administration

U.S. Department of Transportation
Federal Highway Administration

Memorandum

Subject **INFORMATION**: Pavement Subsurface Drainage Activities

Date DEC 16 1994

From Chief, Pavement Divison

Reply to Attn of HNG-42

To Regional Administrators
Federal Lands Highway Program Administrator

The purpose of this memorandum is to update you on our pavement drainage activities and transmit a copy of the Demonstration Project No. 87, (Demo 87) "Drainable Pavement Systems Instructor's Guide". This publication provides a capsulized picture of pavement subsurface drainage design. Demo 87 was presented in over 40 States, Puerto Rico and the District of Columbia. Attached is a map showing participation.

With the successful completion of the first phase of Demo 87, we are moving into Phase II of Demo 87, which consists of three activities:

First, a Technical Working Group (TWG) on Flexible Pavement Drainage Design consisting of participants from FHWA, State highway agencies (SHA's), universities, and industries was convened in June of this year. The participants provided input as a TWG by drawing on their experience and expertise. Wide ranging discussions on the design and construction of flexible pavements revealed that there was no clear definition of the role of drainage in flexible pavements. One point of consensus was that, if a permeable base was provided in a flexible pavement, it would primarily combat pavement infiltration water; it would not solve ground water problems. A summary of the TWG workshop's notes was transmitted to each regional office by memorandum dated November 21, 1994.

Second, we have developed a Proposal (RFP) entitled "Video Inspection of Highway Edgedrains," which is now being considered for contract award. This will provide SHA's with a qualitative video picture of edgedrain conditions. Upon request of the SHA, the video contractor will be available to the SHA for up to a week to investigate the edgedrain in-situ conditions. Both existing edgedrains and new construction could be viewed on both AC and PCC pavements. After the inspection, the Contractor will provide the SHA with a copy of video tapes and 35 mm slides taken during the inspection. Also available will be Graphic Information System (GIS) output documenting both the vertical and horizontal alinement of the edgedrain system. We expect this activity to be available about March 1, 1995.

Third, we are interested in continuing to develop expertise and provide technical support in the construction of permeable base and drainage systems for both flexible and concrete pavements. We would appreciate feedback from your office to identify upcoming construction projects, so that we can assess developing construction techniques and practices and provide technical support as appropriate. We encourage studies to evaluate the effect of drainable systems on pavement performance (particularly AC pavements) which includes a non-drained control section. Please keep us informed of any studies underway or planned.

Attached is a brief one-page description of our current drainage activities that you may want to disseminate to your division offices and SHA's.

for T. Paul Teng

2 Attachments

SUMMARY OF FHWA'S CURRENT PAVEMENT SUBSURFACE DRAINAGE ACTIVITIES

December 1994

Demonstration Project No. 87, "Drainable Pavement Systems" (Demo 87) provided detailed design and construction guidance for drainage systems under Portland Cement Concrete (PCC) pavements. Established drainage design procedures were combined with the state-of-the-art in practical permeable base construction to provide a well balanced approach for the drainage of PCC pavements. Detail design and construction guidance was provided for permeable bases, separator layers and edgedrains. Demo 87 was presented in over 40 States, Puerto Rico and the District of Columbia. With the successful completion of the first phase of Demo 87, we are moving into Phase II of Demo 87 which consists of athree activities.

First, a Technical Working Group on Flexible Pavement Drainage Design (TWG) consisting of participants from FHWA, State highway agencies (SHA's), Universities, and Industry was convened in June of this year. The participants provided input as a TWG by drawing on their experience and expertise. Wide ranging discussions on the design and construction of flexible pavements revealed that there was no clear definition of the role of drainage in flexible pavements. The only point of consensus was that, if a permeable base was provided in a flexible pavement, it would primarily combat pavement infiltration water; it would not solve ground water problems. A summary of the TWG workshop is available.

Second, we are preparing to award a contract in response to a Request for Proposal (RFP) entitled "Video Inspection of Highway Edgedrains" contract. This will provide State highway agencies (SHA's) with a qualitative video picture of edgedrain conditions. Upon request of the SHA, the Contractor will be available to the SHA's for up the a week to investigate the edgedrain in situ conditions. Both existing edgedrains and new construction for AC and PCC pavements could be viewed. The equipment cannot inspect "fin" drains or round pipe less than 100 mm diameter. After the inspection, the Contractor will provide the SHA with a copy of video tapes and 35 mm slides taken during the inspection. Also, Graphic Information Systems (GIS) information on edgedrain vertical and horizontal alinement will be provided. We expect this activity to be available by March 1, 1995.

Third, we are interested in continuing to develop expertise and provide technical support in the construction of permeable base and drainage systems for both flexible and concrete pavements. To accomplish this activity, field trips will be made to view construction and provide technical support for placing permeable bases in both rigid and flexible pavements. We are also interested in studies evaluating the effect of these systems on pavement performance.

We are now finalizing a RFP entitled **"Pavement Subsurface Drainage Microcomputer Program."** This microcomputer program will replicate the design procedures contained in the Demo 87 Participant Notebook. This will provide engineers with a useful tool for drainage design.

The National Highway Institute (NHI) has advertised a RFP for developing a training course entitled **NHI Course No. 13126 "Pavement Subsurface Drainage Design."** Drainage guidance for PCC and flexible pavements, along with retrofit edgedrains, will be compiled into a comprehensive pavement drainage training course. The length of the course will be about 3 days and will follow a slide-lecture format. This training course will be available to all SHA's and Industry though NHI.

STATUS OF DEMO 87 PROJECTS