National Cooperative Highway Research Program

NCHRP Synthesis 285

Maintenance of Highway Edgedrains

A Synthesis of Highway Practice

Transportation Research Board
National Research Council

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Synthesis of Highway Practice 285

Maintenance of Highway Edgedrains

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PREFACE

A vast storehouse of information exists on nearly every subject of concern to highway administrators and engineers. Much of this information has resulted from both research and the successful application of solutions to the problems faced by practitioners in their daily work. Because previously there has been no systematic means for compiling such useful information and making it available to the entire community, the American Association of State Highway and Transportation Officials has, through the mechanism of the National Cooperative Highway Research Program, authorized the Transportation Research Board to undertake a continuing project to search out and synthesize useful knowledge from all available sources and to prepare documented reports on current practices in the subject areas of concern.

This synthesis series reports on various practices, making specific recommendations where appropriate but without the detailed directions usually found in handbooks or design manuals. Nonetheless, these documents can serve similar purposes, for each is a compendium of the best knowledge available on those measures found to be the most successful in resolving specific problems. The extent to which these reports are useful will be tempered by the user's knowledge and experience in the particular problem area.

FOREWORD

By Staff
Transportation Research Board

This synthesis report will be of interest to pavement design, construction, maintenance, and materials engineers; geologists and hydrologists; highway contractors; and others interested in the maintenance of highway edgedrains. It describes the current state of the practice for the maintenance of highway edgedrain systems (i.e., outlet, headwall, connection, longitudinal/mainline pipe) and procedures to reduce and facilitate the maintenance of edgedrains. Information is provided on the maintenance of edgedrains, its relation to pavement drainage and performance, and the importance and cost benefits of providing good drainage in highways. Information for the synthesis was collected by surveying U.S. and Canadian transportation agencies and by conducting a literature search to document North American and European practices.

Administrators, engineers, and researchers are continually faced with highway problems on which much information exists, either in the form of reports or in terms of undocumented experience and practice. Unfortunately, this information often is scattered and unevaluated and, as a consequence, in seeking solutions, full information on what has been learned about a problem frequently is not assembled. Costly research findings may go unused, valuable experience may be overlooked, and full consideration may not be given to available practices for solving or alleviating the problem. In an effort to correct this situation, a continuing NCHRP project has the objective of reporting on common highway problems and synthesizing available information. The synthesis reports from this endeavor constitute an NCHRP publication series in which various forms of relevant information are assembled into single, concise documents pertaining to specific highway problems or sets of closely related problems.

This report of the Transportation Research Board is an extension to the information provided by *NCHRP Synthesis of Highway Practice 239: Pavement Subsurface Drainage Systems*. Design, material, and construction details and techniques, obtained from a survey of North American transportation agenices, are provided to demonstrate effective edgedrain maintenance practices that promote highway drainage. Agency policies and procedures for edgedrain maintenance are also provided. In addition, strategies to reduce edgedrain maintenance costs and methods of increasing maintenance effectiveness are included.

To develop this synthesis in a comprehensive manner and to ensure inclusion of significant knowledge, the available information was assembled from numerous sources, including a large number of state highway and transportation departments. A topic panel of experts in the subject area was established to guide the author's research in organizing and evaluating the collected data, and to review the final synthesis report.

This synthesis is an immediately useful document that records the practices that were acceptable within the limitations of the knowledge available at the time of its preparation. As the processes of advancement continue, new knowledge can be expected to be added to that now at hand.

CONTENTS

ACKNOWLEDGMENTS

Barry R. Christopher, Ph.D., P.E., Roswell, Georgia, was responsible for collection of the data and preparation of the report.

Valuable assistance in the preparation of this synthesis was provided by the Topic Panel, consisting of John S. Baldwin, Geologist, Division of Highways, West Virginia Department of Transportation; Robert H. Baumgardner, Hydraulics Engineer, Office of Pavement Technology, Federal Highway Administration; Mohamed K. Elfino, Assistant State Materials Engineer, Virginia Department of Transportation; Frank N. Lisle, Engineer of Maintenance, Transportation Research Board; Victor E. Mottola, Project Manager, New Jersey Department of Transportation; David G. Riley, Hydraulic Roadway Engineer, Structural Engineering Department, Ohio Department of Transportation; Steven Sawyer, Research Project Manager, Oklahoma Department of Transportation; and Robert F. Steffes, Assistant to the Research Engineer, Materials Department, Iowa Department of Transportation.

This study was managed by Stephen F. Maher, P.E., Manager, Synthesis Studies, who worked with the consultant, the Topic Panel, and the Project 20-5 Committee in the development and review of the report. Assistance in project scope development was provided by Donna L. Vlasak, Senior Program Officer. Don Tippman was responsible for editing and production. Cheryl Keith assisted in meeting logistics and distribution of the questionnaire and draft reports.

Crawford F. Jencks, Manager, National Cooperative Highway Research Program, assisted the NCHRP 20-5 Committee and the Synthesis staff.

Information on current practice was provided by many highway and transportation agencies. Their cooperation and assistance are appreciated.

MAINTENANCE OF HIGHWAY EDGEDRAINS

SUMMARY

Maintenance groups are well aware of the performance problems that can result from water infiltration into pavement systems. Effective removal of water from pavement systems through the use of edgedrains has been proven to help fulfill the pavement service life. Maintenance of edgedrains at the outlets and within is therefore important.

A previous survey on pavement subsurface drainage systems (*NCHRP Synthesis of Highway Practice 239: Pavement Subsurface Drainage Systems*) indicated that many respondents (mostly designers) have little information on maintenance activities within their agency. Almost all respondents agreed that maintenance was the most important factor contributing to long-term performance of pavement subsurface drainage systems. The primary purpose of the present synthesis study was to identify practices and procedures for maintaining the edgedrain system (e.g., outlet, headwall, connection, longitudinal pipe). A secondary purpose of the synthesis was to identify design and construction procedures that will reduce and facilitate the maintenance of edgedrains.

This synthesis provides a review of maintenance and its relation to pavement drainage and performance. The importance and cost benefit of maintaining good drainage in roads is also reviewed. Results of a survey of state highway agencies on current edgedrain usage and maintenance practices are presented and compared with the 1993/94 subsurface drainage survey performed for *NCHRP Synthesis 239*. Designs, materials, construction details, and maintenance techniques to provide effective highway drainage obtained from the responding agencies are presented along with policies and procedures for edgedrain maintenance.

Maintenance involvement actually begins at the design stage where maintenance personnel can provide comments on the maintainability of the proposed edgedrain system. Maintenance requirements can be significantly reduced when given due consideration during design. In addition, maintenance should be considered during construction of the edgedrain system, as many of the maintenance problems identified in this synthesis are related to improper installation. Video inspection prior to acceptance was identified as the only effective means of uncovering construction-related problems. The functional relations between maintenance and design and maintenance and construction are discussed in this synthesis along with methods of communication between functional groups used by various state agencies.

An important element of this synthesis was a review of the cost of maintenance and the corresponding cost of no maintenance on edgedrain systems. Strategies to reduce maintenance costs and methods of increasing maintenance effectiveness are reviewed.

An apparent conclusion from this study was that a commitment to long-term maintenance would lead to optimum performance of the edgedrain and ultimately the pavement system. It was also found that the cost of the required maintenance effort is far outweighed by the anticipated design life of the road that comes with edgedrains that perform efficiently. Conversely, there is a significant cost in terms of poor performing pavements to agencies that are using edgedrains and do not have an effective preventative maintenance program. Quantitative information to substantiate the cost savings was limited and identified as a research need.

Most edgedrainage system failures could be traced to poor construction and inadequate inspection. Training of construction and inspection staff was thus identified as an important need to improve drainable pavement performance. A significant effort could be spent in the development of national and local training programs, with emphasis on the importance of proper installation and maintenance of edgedrains for all personnel involved with the pavement systems, including administrative, design, construction, and maintenance units.

CHAPTER ONE

INTRODUCTION

BACKGROUND

This synthesis was developed in direct response to a need identified by a previous synthesis, *NCHRP Synthesis of Highway Practice 239: Pavement Subsurface Drainage Systems* (Christopher and McGuffey 1997). In that synthesis, maintenance was identified as one of the most important factors in realizing the benefits of drainage in maintaining or even extending the design life of a road. The synthesis identified that inadequate maintenance of drainage systems could be a significant detriment to a road, most likely resulting in its premature failure. However, the pavement design groups surveyed for that synthesis had little information on the maintenance activities of their agencies. There appeared to be a lack of confidence by designers that maintenance support would be consistent and could be relied upon when making design decisions. This synthesis was performed to provide a closer examination of current maintenance practices from the perspective of maintenance groups and to identify successful design, construction, and maintenance practices and procedures for maintaining edgedrain systems. Hopefully, maintenance and construction groups can enhance their practice through the review of this synthesis and designers can gain the confidence they need to incorporate good drainage in roadway designs.

SCOPE

The primary purpose of this synthesis was to identify practices and procedures for maintaining the edgedrain system (e.g., outlet, headwall, connection, longitudinal/mainline pipe). A secondary purpose of the synthesis was to identify design and construction procedures that will reduce and facilitate the maintenance of edgedrains. The synthesis was also to consider the benefits and limitations of maintaining edgedrain systems, including performance obtained through maintenance, maintenance issues, maintenance practices, and rehabilitation options. This synthesis was prepared as an extension of *NCHRP Synthesis 239,* which provides complimentary information on the current practice in design and construction of drainable pavement systems of which the edgedrain is an essential component. Different drainage strategies are reviewed in that document along with the corresponding influence on pavement life.

To accomplish the scope of this synthesis, the experiences of many U.S. and Canadian transportation agencies were collected by means of a survey of representatives from their respective maintenance, design, and construction divisions, and are summarized. Perspectives on various types of edgedrains, connectors, and headwalls, along with inspection, routine, and preventive maintenance procedures are summarized. The best practices as obtained from the survey and the literature are highlighted in cases where there is consensus. The results of a separate international survey on the state of the practice of roadway subdrainage performed for the World Road Association (PIARC) Committee on Earthworks, Drainage, and Subgrade (Hoppe 1998) were also reviewed to provide an insight on the European practice.

COMPONENTS OF AN EDGEDRAIN SYSTEM

An edgedrain system is a necessary component for the drainage of pavement. The purpose of an edgedrain is to intercept and remove infiltration water from a pavement section. It is usually located at the edge of the pavement (between the travel lane and the shoulder) at an appropriate depth to intercept water from the pavement layers and the longitudinal joint at the edge of the pavement. An edgedrain is distinguished from an underdrain by its purpose and location. An underdrain is a deep subsurface drain located alongside the roadway at a depth sufficient to intercept and lower the groundwater to a required design level. The essential components of an edgedrain system are shown in Figure 1 and include:

- A trench filled with filter-graded aggregate, open-graded aggregate wrapped with a geotextile filter, or a prefabricated geocomposite drain;
- A longitudinal conduit consisting of a perforated pipe or other hollow plastic core; and
- An outlet consisting of nonperforated, smooth-walled pipe and/or a headwall.

These and other terms associated with the edgedrain system, as used in this synthesis, are defined as follows:

- Connection: Connector between the longitudinal mainline pipe or prefabricated geocomposite edgedrain (PGED) and the outlet pipe.
- Drainage aggregate: Open-graded aggregate used to conduct flow into a longitudinal slotted drainage pipe. For low inflow, well-graded aggregate or sand may also be used.

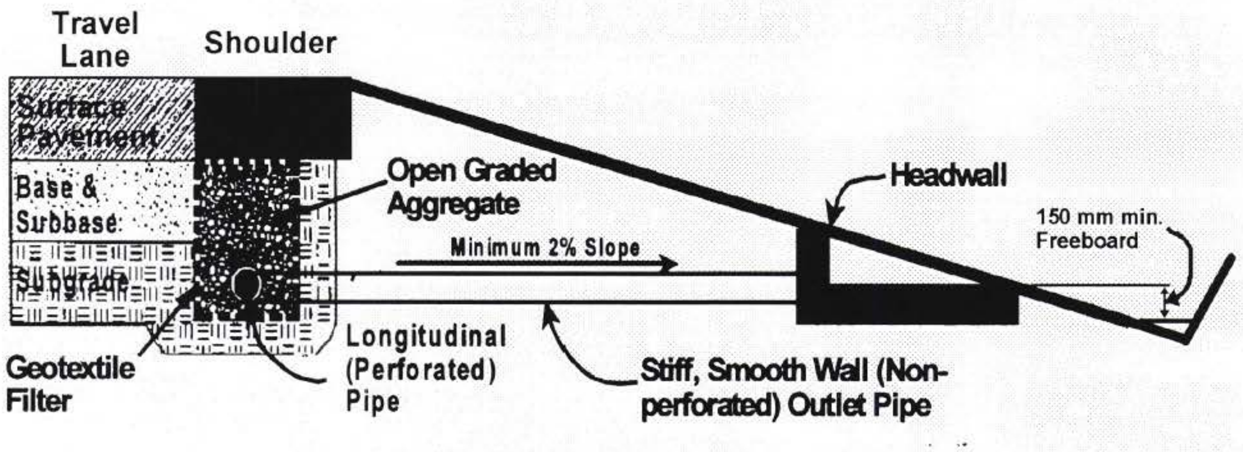


FIGURE 1 Typical components of an edgedrain system.

- Dual-pipe edgedrain: Edgedrains designed with a parallel collector pipe to reduce the number of outlets.
- Edgedrain: A subsurface drain usually located at the edge of the pavement (between the travel lane and the shoulder) at an appropriate depth to intercept and remove infiltration water from the pavement section.
- Filter: Usually a geotextile used to line the drainage trench and designed to prevent the adjacent soil from entering the drainage aggregate while maintaining flow over the life of the system. Well-graded drainage aggregate or sand used for low-inflow drains may also be designed to act as the filter.
- Headwall: A protective structure at an edgedrain outlet.
- Longitudinal mainline pipe: A perforated pipe required to convey the flow to the outlet pipe.
- Loop edgedrain system: An edgedrain with outlet pipes located at both the upstream and downstream ends to facilitate flushing and video inspection.
- Outlet: The point of discharge of an edgedrain. It may be the pipe or a headwall.
- Outlet pipe: The lateral connection from the edgedrain to the outlet. Usually a nonperforated, smooth-wall, durable pipe to prevent damage.
- Prefabricated geocomposite edgedrain (PGED): An edgedrain consisting of an extruded plastic drainage core covered with a geotextile filter (also known as panel drains or fin drains).
- Underdrain: A deep subsurface drain located at a sufficient depth to intercept and lower the groundwater to a required design level.

APPROACH

This synthesis is oriented around the tools and practices for maintenance of edgedrains. In this report, maintenance and its relation to highway drainage and performance is reviewed in chapter 2. The importance and cost benefit of maintaining good drainage in roads is also reviewed. Current edgedrain usage is presented from the survey and compared with that of the 1993/94 subsurface drainage survey performed for *NCHRP Synthesis 239*. Design, materials, construction details, and maintenance techniques to provide effective highway drainage are also presented. In chapter 3, the results of the U.S./Canadian survey on policies and procedures for edgedrain maintenance is discussed. Information on cost effectiveness of maintenance programs is also reviewed. In chapter 4, the functional relation between maintenance and design and maintenance and construction is discussed. Good design and construction practices that have been found to reduce or facilitate edgedrain maintenance are identified. An international perspective on edgedrain design, construction, and maintenance from a survey performed by the World Road Association (PIARC) is also presented. The effectiveness of current maintenance practices is reviewed in chapter 5. In chapter 6, the cost of maintenance and the cost of no maintenance are examined. Strategies to reduce maintenance costs are presented. Edgedrain monitoring methods and modern methods of increasing maintenance effectiveness are also reviewed. The findings and conclusions of this synthesis are presented in chapter 7.

As previously indicated, this synthesis is supported by a U.S./Canadian survey, the results of which are discussed throughout the document. The survey questionnaire and a summary of comments from the responding agencies are contained in Appendixes A and B, respectively. The survey was distributed in the spring of 1999 to 52 U.S. and 13 Canadian transportation agencies. Responses were received from a total of 41 agencies. A follow-up survey was performed in the fall of 1999 to confirm the annual edgedrain usage and obtain an estimate of the total amount of edgedrain installed in North America.

CHAPTER TWO

MAINTENANCE AND ITS RELATION TO PAVEMENT DRAINAGE AND PERFORMANCE

INTRODUCTION

The previous synthesis (Christopher and McGuffey 1997) found a preponderance of evidence supporting the philosophy that "good sealing and good drainage, along with a commitment to long-term maintenance, will lead to optimum performance of a pavement system." Proper pavement drainage has been found to extend pavement life from several years to more than twice that of a conventional "undrained" pavement (Cedergren 1987; Forsyth et al. 1987; and Christory 1990). Designers can take advantage of improved pavement performance afforded by good drainage through use of a drainage coefficient (C_d) for rigid pavement design and a drainage modifier (m) for flexible pavement design that are included in the American Association of State Highway and Transportation Officials (AASHTO) pavement design guidelines (AASHTO 1993). For example, in high rainfall areas, the base section of a flexible pavement system can be reduced by as much as a factor of 2, or the design life extended by an equivalent amount, if excellent drainage (i.e., defined by AASHTO as "adequate to drain the road within two hours after a rain event") is provided versus poor drainage (i.e., does not drain). Likewise, an improvement in drainage (i.e., increase in C_d) leads to a reduction in rigid pavement slab thickness. However, to take advantage of a longer pavement design life or a reduced section, the designer must assume that good drainage will be maintained throughout the anticipated life of the pavement system. Everyone is searching for a maintenance-free drainage system, but unfortunately, this synthesis did not discover one. Thus, long-term maintenance is essential to achieving the anticipated high pavement design life associated with drainable pavement systems. Without adequate maintenance, the pavement system will most likely fail prematurely, with less than 50 percent of the expected life anticipated (*NCHRP Synthesis 239*). The edgedrain and its outlets are the essential components of the drainage system to maintain.

Part of the problem is that very few edgedrains are designed with due consideration for maintenance. Edgedrain systems can be significantly improved by first understanding the nature of the problems that are likely to occur over the life of the system and then making the necessary adjustments to mitigate these problems (Sawyer 1998). Problems that have been identified include vegetative growth, debris, and fines discharging from the pavement system; all of which will eventually plug the outlet pipe. Mice nests, grass clippings, and sediment collecting on rodent screens at the headwalls are also common maintenance problems (Federal Highway Administration 1992). Often, outlets cannot be found because they are hidden by vegetation. Solutions to these and other maintenance problems discussed in this chapter start with the selection of an appropriate edgedrain system and a good understanding of design and construction.

USE OF EDGEDRAINS

The current survey indicates that the installation of edgedrains has apparently leveled off since the 1993 survey. The current survey found that 29 respondents were using edgedrains. Eighteen of those respondents reported using more that 16 km/yr (10 mi/yr) and 14 reported using more that 100 km/yr (60 mi/year), which is similar to the 1993 findings assuming that the major user states not responding to the current survey have maintained their usage. However, many of the maintenance units representing large user groups from the previous survey were not aware of the actual usage and answered this question as "unknown" or "not available." This would imply that the present survey underestimates the actual amount of edgedrains installed annually. If the annual usage from the previous survey is used for the respondents that indicated "unknown," it would appear that approximately 5200 lane-km (3,200 lane-mi) of edgedrains are installed annually, which is about 800 lane-km (500 lane-mi) fewer than indicated by the 1993 survey. Most of the decrease appears to be in retrofit applications. Several states reported that they have now completed their retrofit programs for their interstate highway systems, which dominated the retrofit application in the 1993 survey.

Although the annual usage may be decreasing, the total amount of installed edgedrain in North America is significant. Based on the annual usage from both the 1993 and current surveys, plus the follow-up survey performed for this synthesis, it is estimated that more than 55 000 km (34,000 mi) of edgedrain have been installed in the past 10 years, all requiring some level of maintenance.

A majority (69 percent) of the current edgedrain usage for both new construction and reconstruction is for PCC pavements, most of which are used under concrete shoulders. However, there is also a reported significant usage of edgedrains with asphalt concrete, generally in conjunction with asphalt shoulders. Only one agency reported using edgedrains with no shoulders.

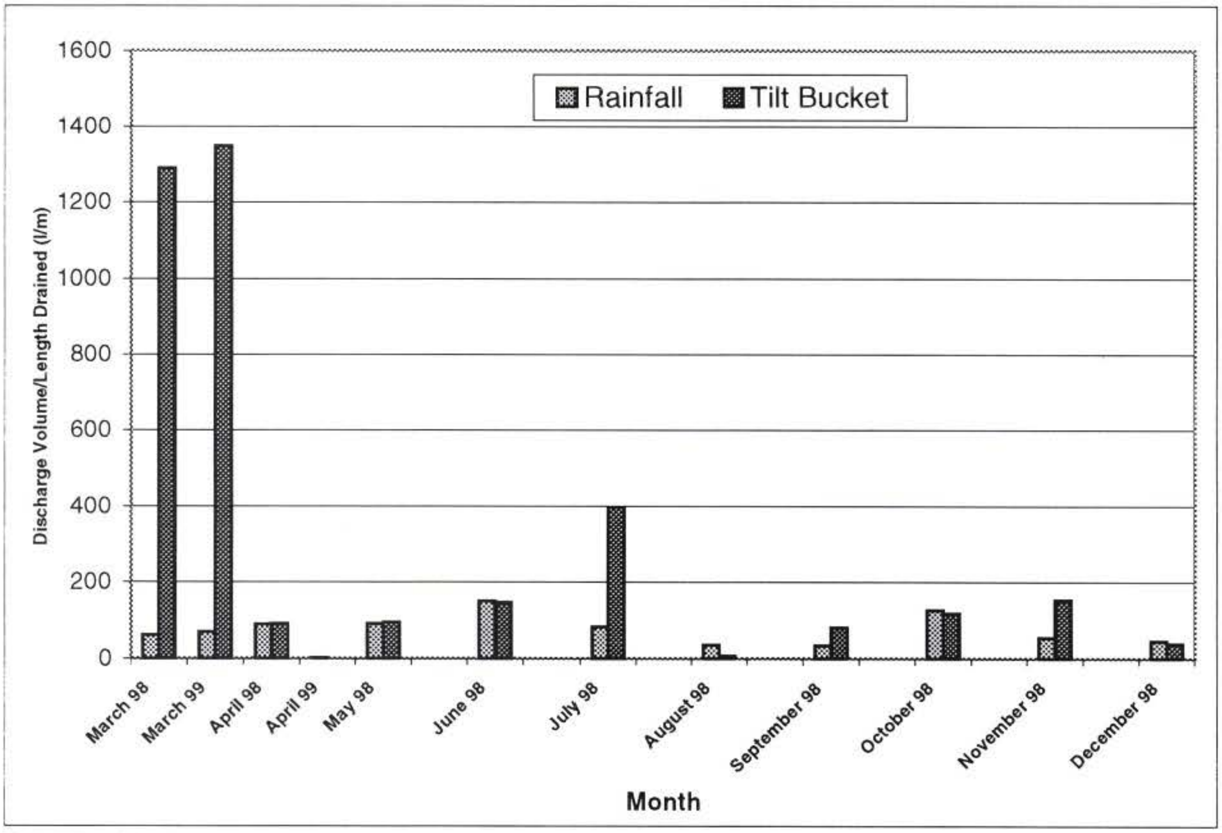


FIGURE 2 Monthly discharge volumes (per length of drained section) and rainfall for a project in Maine showing largest water discharge volume during spring thaw (Christopher et al. 1999).

A significant amount of retrofit edgedrain is still being installed. Based on the current survey, more than 600 lane-km (370 lane-mi) of retrofit drains are installed annually. These attempts have been reasonably successful, with several states (e.g., Kentucky, Minnesota, and Virginia) reporting a significant increase in the performance and design life of the roadway. Unsuccessful attempts have occurred mainly in poorly draining bases, emphasizing the importance of using free draining base and incorporating subsurface drainage into the initial design.

In addition to the decrease in the number of retrofit edgedrain applications is an apparent decrease in the use of PGED. Retrofit applications are the primary use for this type of drain. However, based on the percentage of use and the comments contributed by several of the agencies (e.g., Indiana, Ohio, and Pennsylvania), this reduction is also due to the reported problems that have discouraged the continued use of PGEDs by some agencies. Indiana and Pennsylvania reported problems related to siltation, "J" bending, and crushing of the drain. These reports are somewhat contrary to the PGED research described in *NCHRP Report 367* (Koerner et al. 1994), which found good performance of these materials, and reported that most failures were predictable and related to either the absence of design, misapplication, or improper construction techniques. Extensive evaluation of installations in Canada (Raymond and Bathurst 1999) also led to conclusions similar to those of *NCHRP Report 367*. Ohio also reported construction problems; however, the state found that the drains are still working as a secondary drainage system as designed. Several states (e.g., Kentucky and Virginia) have incorporated the design and installation recommendations described in *NCHRP Report 367*, and in the current survey reported good performance along with construction cost savings as compared with conventional aggregate/pipe drains.

Based on the results of the survey, there appears to be a perception by many of the northern agencies that edgedrains do not work in cold regions. However, edgedrain studies in Maine, Minnesota, Michigan, Ontario, and Wisconsin tend to strongly refute this claim. To the contrary, edgedrains may have their greatest benefit in cold regions as an aid to the rapid removal of water from the pavement during spring thaw. Separate studies of edgedrains in Minnesota (Hagen and Cochran 1996) and Maine (Christopher et al. 1999) found that more water comes out of the pavement section during the spring thaw than from any rain event during the year. Figure 2 shows the outflow results from a special drainage test section constructed in Maine along with the monthly amount of rainfall to illustrate this point. The challenges of designing, installing, and maintaining edgedrains in cold regions are discussed in detail by Raymond and Bathurst (2000) and Raymond et al. (1996).

DESIGN

Design of edgedrains essentially consists of calculating the flow from the base material to the edge of the road and any additional infiltration anticipated from surface water entering joints at the edge of the road and from the shoulders. The edgedrain (usually the longitudinal pipe in the edgedrain) is then sized to handle the estimated maximum flow into and through the pipe. In addition, details such as a filter (aggregate or geotextile) surrounding the edgedrain must be designed to prevent the adjacent soil from entering the edgedrain while maintaining flow (not clogging) over the life of the system. The grade of the invert must also be established to maintain flow and the outlets must be sized and appropriately spaced to prevent backup in the edgedrain system.

The design of edgedrains for new construction or major reconstruction projects is usually straightforward, using existing guides from the Federal Highway Administration (FHWA) Demo 87 workbook (FHWA 1992) or other design procedures (Moulton 1980). The Demo 87 workbook has simplified, easy-to-follow procedures for edgedrain design. The design ensures that the trench backfill and edgedrain pipe have the necessary capacity to handle the design flow from the permeable base. Trench backfill aggregate could be the same as the permeable base (i.e., open-graded base) or a material with a greater permeability than the base. For open-graded drainage aggregate, a geotextile filter must be used to wrap the edgedrain trench. The geotextile should be designed considering both the subbase and subgrade soils using the filter criteria in the FHWA geosynthetics design manual (Holtz et al. 1998). The geotextile should not be extended up between the interface of the permeable base and trench backfill aggregate (Figure 3), because it may form a barrier. For construction with dense-graded base or for retrofit of poorly draining base, graded aggregate or sand is sometimes substituted for geotextile-wrapped, open-graded aggregate. When using these lower permeable materials, the trench size may need to be increased to obtain the required flow capacity.

When geotextile filters are not used, the gradation of the aggregate used to fill the trench must also be designed to be compatible with the subbase and subgrade soils using standard soil mechanics filter criteria (see for example Cedergren 1987). With sand backfill, a geotextile is often used to wrap the perforated drainage pipe to prevent the sand from moving into it. For open-graded or graded aggregate, a geotextile should not be wrapped around the perforated pipe, because any fine soils moving through the aggregate will most likely clog the geotextile.

The size of the longitudinal perforated pipe in the edgedrain is often based on maintenance requirements for cleaning capabilities and having a reasonable distance between outlets. Maintenance personnel should be consulted before finalizing these dimensions. The smallest diameter suitable for cleaning is 75 mm (3 in.); however, many state highway agencies and the FHWA suggest a minimum pipe size of 100 mm (4 in.) based on maintenance considerations (FHWA 1992). The FHWA also recommends the use of outlet spacing of 75 m (250 ft) for maintenance considerations. Surface caps for cleanouts should be located in areas of minimum damage potential and with sufficient strength to withstand traffic and environmental influences (e.g., ice, salt, contaminant chemicals, and vandalism).

One of the most critical items for edgedrains is the grade of the invert. Construction control of very flat grades is usually not possible, leaving ponding areas that result in subgrade weakening and premature failures. Although not a popular concept, it may be more economical to raise the pavement grade to develop adequate drain slopes for the subsurface drainage facilities (e.g., Florida). To achieve a desirable drainage capacity, a minimum slope that is greater than the slope of the road may be required for the edgedrain. However, this requirement may not be practical and the pipe will mostly be sloped to match the roadway. It is suggested that rigorous maintenance be anticipated, especially when adequate slopes cannot be achieved (FHWA 1992).

The ditch or storm drain pipe must be low and large enough to accept the inflow from the edgedrain without backup. The FHWA recommends the outlet be at least 150 mm (6 in.) above the 10-year-stormflow line of the ditch or structure (Figure 4). The outlet should also be at a location and elevation that will allow access for maintenance activities (both cleaning and repair). Outlets and shallow pipes should be located well away from areas of expected future surface maintenance activities, such as sign replacement and catch basin cleanout or repair. The FHWA also recommends angled or radius outlet connections to facilitate cleanout and video inspection. Locations of guardrail, sign, signal, and light posts need to be adjusted to prevent damage to the subsurface drainage facilities.

EDGEDRAIN COMPONENTS

As indicated in the design section, edgedrains for new construction generally consist of pipe in a geotextile-wrapped aggregate-filled trench. Of those agencies that use edgedrains, 20 of 29 are using this system. However, there are several variations that are used. More than one-third of the respondents use graded aggregate in the trench with no geotextile filter. Sand is used to backfill the trench by three agencies, presumably in conjunction with dense-graded base (as reported by Minnesota).

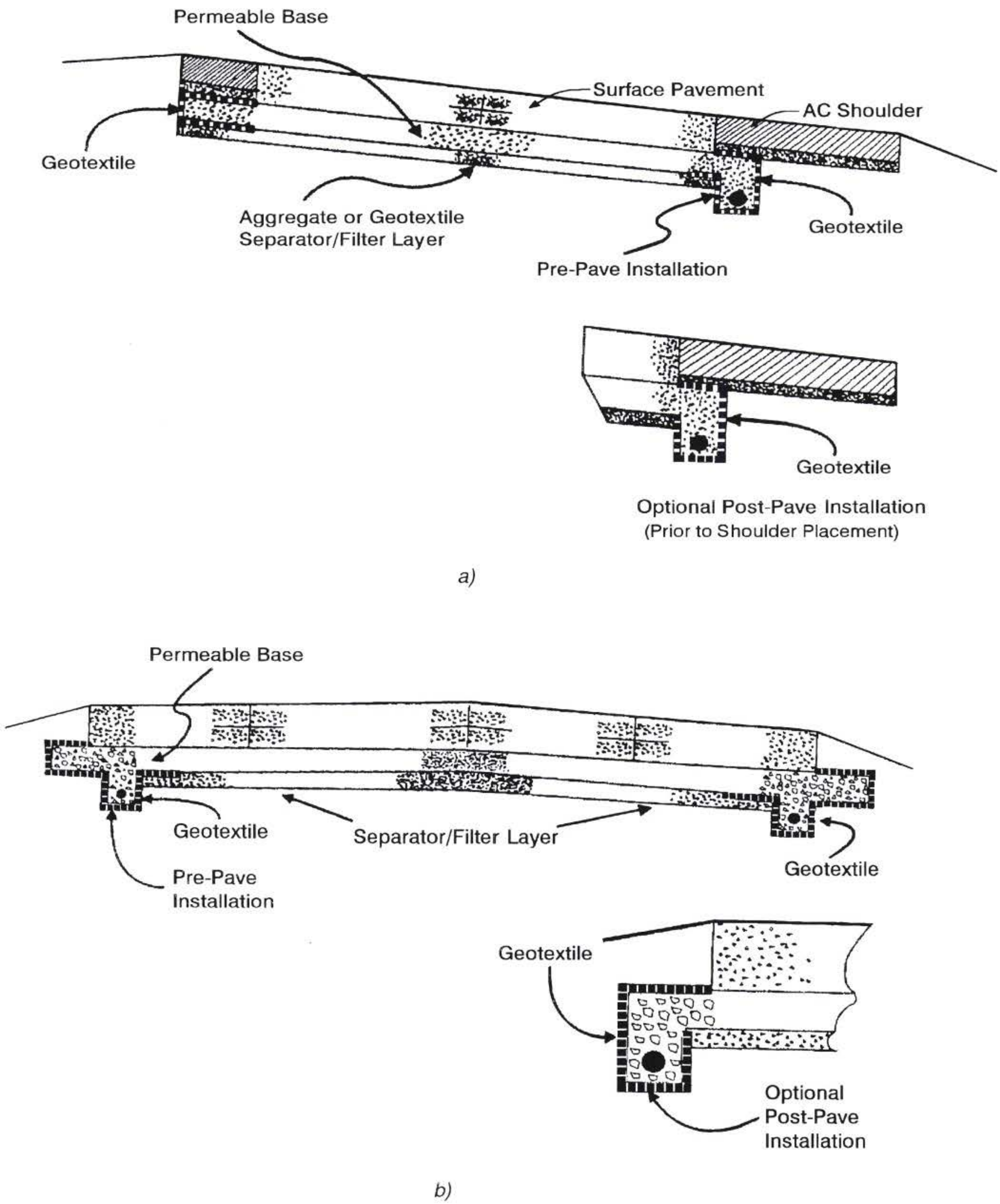
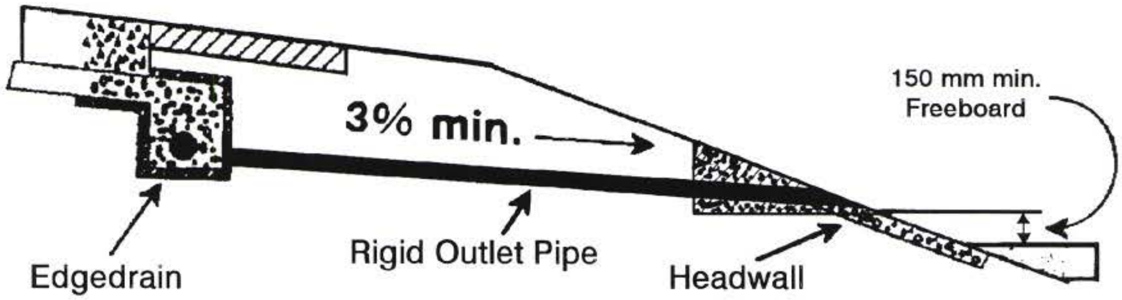
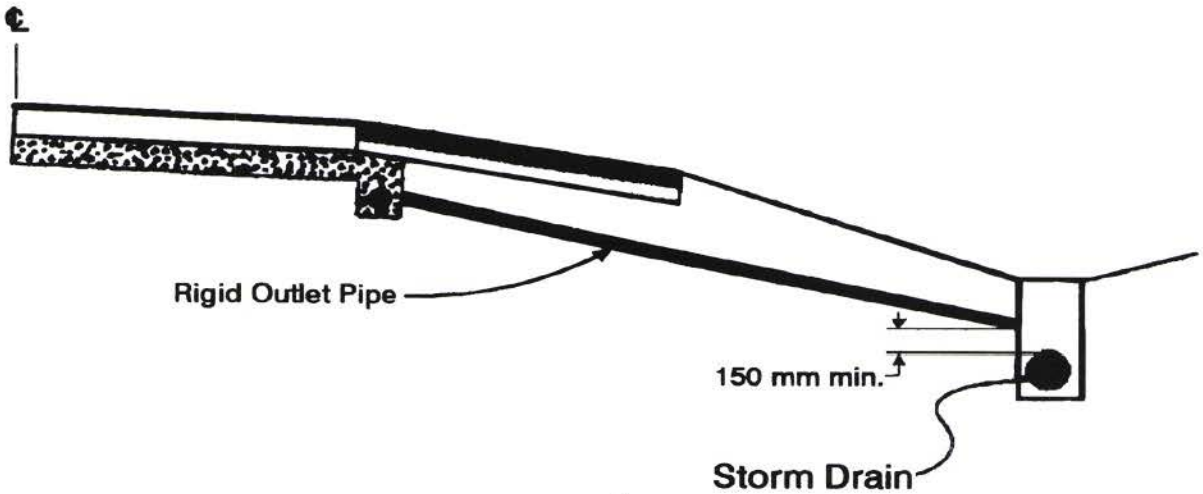


FIGURE 3 Typical edgedrain installations with open-graded base: *(a)* installation for portland cement concrete or asphaltic concrete surface pavement with asphalt shoulders (after Ridgeway 1982 and FHWA 1992); *(b)* installation for portland cement concrete surface pavement with tied concrete shoulders (FHWA 1992).



a)



b)

FIGURE 4 Location of outlet pipe (FHWA 1992): *(a)* flowing into drainage ditch; *(b)* connected to storm drain.

Perforated corrugated plastic pipe is used predominantly for the longitudinal mainline (96 percent of the responding user agencies) and stiff, smooth-walled plastic pipe is used for the outlet (78 percent of the responding user agencies). Several agencies were using stiff, smooth-walled pipe for both the longitudinal mainline pipe and the outlets. Many maintenance groups have reported crushing and sediment trapping problems with corrugated pipe used for the outlets (Sawyer 1998). Even so, five of the respondents indicated that they were using corrugated outlet pipe. Several agencies are using metal outlet pipe on a limited basis (5 percent of the time) and one agency indicated occasionally using metal for the longitudinal mainline pipe.

A variety of connections are being used between the longitudinal mainline pipe and the outlet pipe including tee, angled, radius, wye, and elbows. Tee, angle, and radius connections are the most predominant, with several agencies using all three. As recommended by the FHWA, radius bend and angle (i.e., two 45° bends) type connections are installed by about 60 percent and 40 percent, respectively, of the agencies using edgedrains. However, about one-half of the user agencies use tee type connections, even though they are not recommended by the FHWA. Two agencies report using wye type connections, which provide a similar benefit to angled connections, and one agency on occasion uses elbows.

One of the more unexpected statistics is the relative wide spacing used for outlets by most of the agencies. Only eight agencies reported following the FHWA recommended spacing [75 m (250 ft) or less outlet spacing with a drainable base]. A majority use spacings of 150 m (490 ft) or more, with one agency reporting a 300 m (980 ft) typical spacing. Most agencies using edgedrains with dense-graded base maintained the same outlet spacing being used for drainable base, while two of the agencies doubled the spacing. Again the maximum spacing for edgedrains with dense-graded base was on the order of 300 m (980 ft).

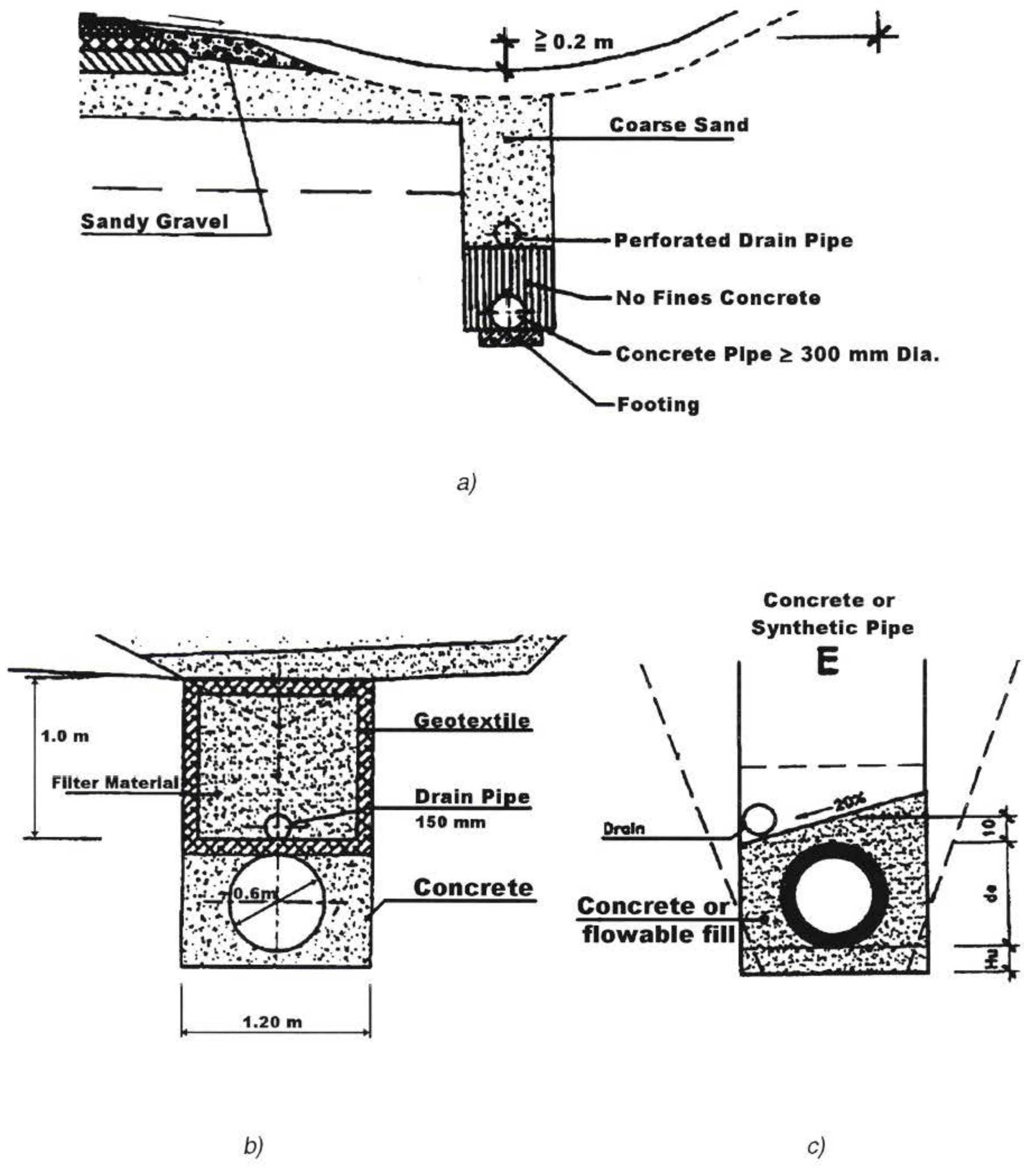


FIGURE 5 Representative dual-pipe drainage systems used in Europe (after Hoppe 1998); *(a)* Germany; *(b)* Spain; *(c)* Switzerland.

Support for reduced outlet spacing was provided by Michigan, who indicated having helped mitigate maintenance problems by reducing the outlet spacing from 150 m to 90 m (490 ft to 300 ft).

Outlet headwalls are an essential part of the edgedrain system. A survey of 100 underdrains in Oklahoma revealed that over one-half of the recorded problems could have been avoided with the construction of a headwall (Sawyer 1998). Outlet headwalls that are currently being used may be either prefabricated or cast-in-place concrete. Seventy percent of the agencies are using prefabricated units most of the time, with the other 30 percent using cast-in-place concrete at least 50 percent of the time. Several agencies reported using no headwall at least some of the time, and in one case more than 50 percent of the edgedrains were reported to have been installed with no headwall. About one-half of the agencies outlet the edgedrain into catch basins or cross-road culverts at least some of the time. There have also been some attempts to daylight the edgedrain on the shoulder by extending the drain line aggregate or even using no-fines concrete (Ghafoori and

Dutta 1995). However, this practice is not recommended because silty material or stormwater in ditches may enter the pavement structure and topsoil and vegetation will most likely blind the aggregate. Should the system clog, maintenance will be difficult if not impossible.

If outlets cannot be found, they cannot be maintained. Even so, six agencies reported that outlets were not marked. In the response from one agency, the central office reported that the outlets were marked, but the field maintenance personnel reported that they were not marked. Most of the remaining agencies use posts, either with signs or reflectors. Six agencies indicated that the locations were marked on the pavement, either with paint or tape and/or stamped. Several of those agencies indicated that they prefer pavement marking because it eliminates problems with mowing around the posts. At least one agency (North Carolina) reported using both a pavement mark (painted on asphalt shoulders and stamped on concrete shoulders) and a steel post with reflector at each outlet.

Representative edgedrain plans showing design details from several states are presented in Appendix C for comparative purposes only. Maintenance friendly designs will be reviewed in chapter 6.

THE EUROPEAN EXPERIENCE

According to the results of the PIARC survey (Hoppe 1998), most European countries are using aggregate-filled, geotextile-wrapped trenches with slotted longitudinal pipes for edgedrains, although increased use of PGED was reported from France and the United Kingdom. The majority of respondents to that survey indicated that the minimum diameter of the drainage pipe is on the order of 100 to 150 mm (4 to 6 in.). This pipe size is larger than the 75- to 100-mm (3- to 4-in.) minimum diameter typically used in the United States. Subsurface drainage outlets are also typically set at a closer spacing than the North American practice, with outlets reportedly placed at 40 to 60 m (130 to 160 ft) apart in the Slovak Republic, Spain, and Switzerland. In addition to longitudinal drains, transverse underdrains are typically installed at sag (low) points and at cut/fill transitions. For drainable pavements, a minimum cross slope is 4 percent at the road base in Belgium, Germany, Switzerland, and Turkey, whereas a 2 percent cross slope is typically recommended in the United States (e.g., FHWA 1992).

An interesting dual-pipe and manhole system is used in Germany, Portugal, Spain, Switzerland, and Turkey on some projects (Figure 5). A large diameter collector pipe (usually concrete) runs below a perforated drainage pipe to facilitate quick removal of subsurface water. In Germany, the minimum diameter of collector pipes is typically 300 mm (12 in.) and the minimum diameter of drainage pipes is 100 mm (4 in.). When the estimated flow rate is relatively low, a dual-purpose (drain and collector combined) pipe of 150 mm (6 in.) diameter is used (Hoppe 1998).

CHAPTER THREE

CURRENT MAINTENANCE PRACTICES

INTRODUCTION

The *NCHRP Synthesis 239* survey indicated that many agency design groups have little information on the maintenance activities within their organizations and that many agencies have more than one policy, depending on the responsible individuals in each maintenance jurisdiction (district or region). Effective maintenance begins with a maintenance policy to ensure that all concerned parties are aware of the importance of providing adequate maintenance to the edgedrain system and that resources are made available to carry out the required program. Program managers should be aware that the lack of edgedrain maintenance has a negative effect on pavement performance and therefore on future system costs. A complete maintenance program includes routine inspection and monitoring, preventive maintenance strategies, spot detection of an actual or potential problem, repair, and continued monitoring and feedback to design and construction groups. In this chapter, the current polices and procedures for edgedrain maintenance as they relate to each of these phases of maintenance will be reviewed. Information obtained from the agencies on the cost effectiveness of maintenance programs will also be presented.

MAINTENANCE POLICIES

It is evident from the previous synthesis (*NCHRP Synthesis 239*) that maintenance strategies with regard to pavement drainage are as important to pavement life as design strategies. Without a routine maintenance policy, drainage problems may not be identified until damage is done and early pavement distress becomes visible on the surface. A formal maintenance policy also implies that management is clearly aware of this importance and fully supports maintenance activities that are essential in achieving the design life of the road. In the survey for this synthesis only seven of the responding agencies (California, Illinois, Indiana, Iowa, Michigan, New Jersey, and Wyoming) reportedly have a formal edgedrain maintenance program. Lack of funding and manpower was the predominant reason given for not having such a program. Several states indicated that maintenance was decentralized and handled independently by individual districts. Others (including one of the major users) indicated that there was not enough edgedrain use (at this time) to justify a formal system or give edgedrains a priority status. Some agencies felt that maintenance on an as-need basis was sufficient, or at least the norm, for all maintenance activities. One agency indicated that maintenance officials do not yet appreciate the damage caused by poor drainage.

Those agencies that had a formal edgedrain maintenance program described their programs as preventive by project, preventive by network, inspection and repair, and annual cleaning frequency. Copies of several policies were provided. The cleaning policies ranged from annual cleaning of all edgedrains to cleaning one-seventh of the edgedrains each year. The Illinois maintenance program requires inspection every 3 years; cleaning debris, silt, and vegetation and flushing as often as necessary. Several agencies indicated the desire to incorporate their video cameras into their preventive maintenance programs.

Pavement management systems provide a very effective tool for obtaining an inventory of edgedrain usage and determining the cost effectiveness of drainage systems. Although five agencies (Illinois, Montana, Nebraska, Oregon, and Virginia) reported that maintenance is tied into their pavement management systems, only Illinois and Virginia indicated that edgedrain performance was an indicator in their system. Illinois stated that performance indicators are developed from a condition rating survey performed every 2 years. Virginia is correlating pavement distress to edgedrain performance (i.e., pumping, alligator cracks, etc.)

PREVENTATIVE MAINTENANCE PROGRAMS

The components of a preventative maintenance program include inventory, inspection survey, and scheduling. Six agencies reported having a preventative maintenance program, but only two agencies (Indiana and Oklahoma) reported having a complete program. Five agencies reported that inventories were performed and five agencies reported that inspection surveys were performed, but only two agencies indicated that these activities were routinely scheduled.

Edgedrain Surveys

Systematic inspection using appropriate performance indicators provides one of the most effective means of ensuring the performance of drains and is one of the essential elements of a preventative maintenance program. Only seven agencies reportedly perform some form of edgedrain surveys. Several agencies indicated that their surveys were performed in conjunction with routine roadway surveys. However, very few states have an inspection survey form or instructions. One state reported that windshield inspections are performed. Inspection frequency was also inconsistent, ranging from annually to intermittent (when manpower is available). As previously indicated, Illinois has a formal policy requiring inspection every 3 years. Several districts in Arkansas rely on the county maintenance office to report drainage problems. One agency reported that it had performed a survey and found numerous problems, but that it did nothing to correct any of the deficiencies. Several district offices from one agency with a formal inspection policy indicated that inspection surveys were not performed.

Video Surveys

Probably the most significant development in edgedrain inspection has been the use of small-diameter, optical tube video cameras with closed-circuit video systems. Video cameras allow the inside of the edgedrain system to be logged and expose the weaknesses in construction and inspection procedures (Figure 6). Iowa was one of the first states to effectively use video inspection (Steffes et al. 1991). In 1989, with over 4.3 million m (14 million ft) of edgedrain installed, a proposal was presented to the Iowa Highway Research Advisory Board to evaluate the performance of state edgedrains. Random inspection exposed many problems including:

- Rodent nests in the drain,
- Varied sag from mainline to outlet,
- Polyethylene tubing and connector failures,
- Break from stretch or puncture, and
- Geocomposite drain J-buckling.

The information obtained in Iowa by use of video inspection of subsurface drainage has led to changes in processes that will improve lifetime performance.

A significant effort to evaluate the use of video cameras as an inspection tool and demonstrate the technology was undertaken by the FHWA under the "Video Inspection of Highway Edgedrains" contract. Demonstrations have been performed in 29 states (Daleiden 1998). As reported by Baumgardner (1998), the number and severity of problems were astonishing (see Figure 7). Problems similar to those found in the Iowa study were prevalent throughout the states surveyed. In an evaluation of 269 outlet pipes, 35 percent of the laterals could not be inspected because they were crushed or clogged and the condition of the mainline could not be investigated. Of the mainlines that were evaluated, 17 percent were blocked or clogged. These findings clearly indicated that there were serious inadequacies

a)

b)

c)

FIGURE 6 Video camera photos of edgedrain problems (courtesy of Iowa DOT from 1990 video): *(a)* ineffective rodent screen; *(b)* clogged pipe; *(c)* aggregate in pipe.

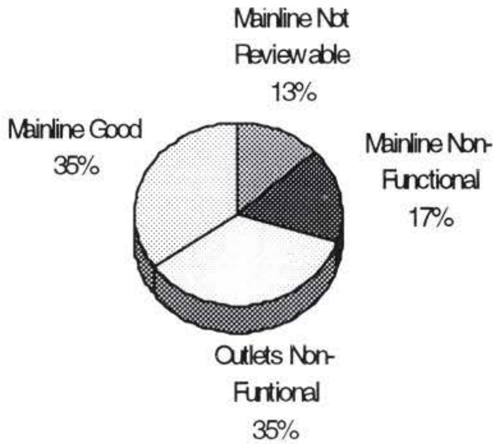
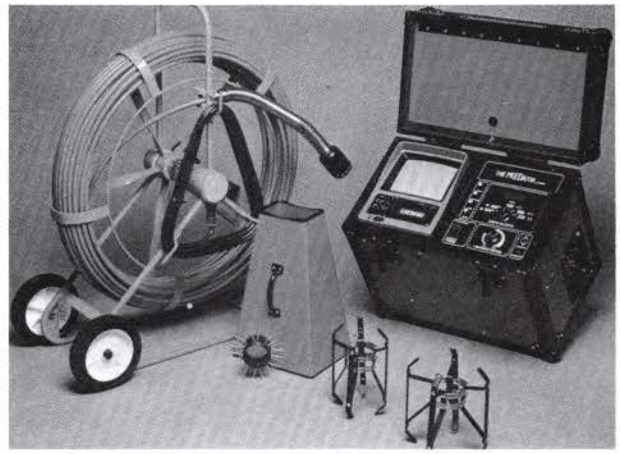


FIGURE 7 Results of video camera inspection (after Daleiden 1998).

in the edgedrain design, construction, and maintenance practices. The study also showed that video inspection of edgedrains was a viable tool for determining the existing condition of edgedrains and had a definite role in providing construction quality assurance.

The FHWA program to promote this technology appears to have had a significant impact. More than 17 states reported having used a video camera. Many agencies own their own video camera(s), whereas the others have access to a camera through a consultant. Unfortunately, most of the agencies do not use cameras routinely as part of their edgedrain survey, and 10 maintenance groups indicated that they did not use their camera at all. (As reported by several agencies, in some of these cases these cameras are being used for construction acceptance.) In one agency that reportedly owned a video camera, many of the district maintenance groups were unaware of its existence. One state indicated that its camera is only used when a problem develops, which is obviously too late as damage to the pavement system has already occurred. Several states however use their cameras extensively, both for construction acceptance and for edgedrain surveys.

Arkansas reported that investigations using cameras found that almost all outlet pipes are crushed either right behind the headwall or at the connection with the edgedrain. Ohio video inspected 18 sites ranging in age from 1 to 13 years in age and noted numerous problems. Indiana and Mississippi have plans to perform video surveys as part of their preventive maintenance program. Working with the Indiana Department of Transportation (DOT), Ahmed and White (1993) proposed a system of inspection for transportation agencies that includes visual and video camera inspection techniques. Arkansas and Virginia have developed standards for inspection of underdrains and edgedrains using video cameras and/or visual methods, a copy of which is included in Appendix D.



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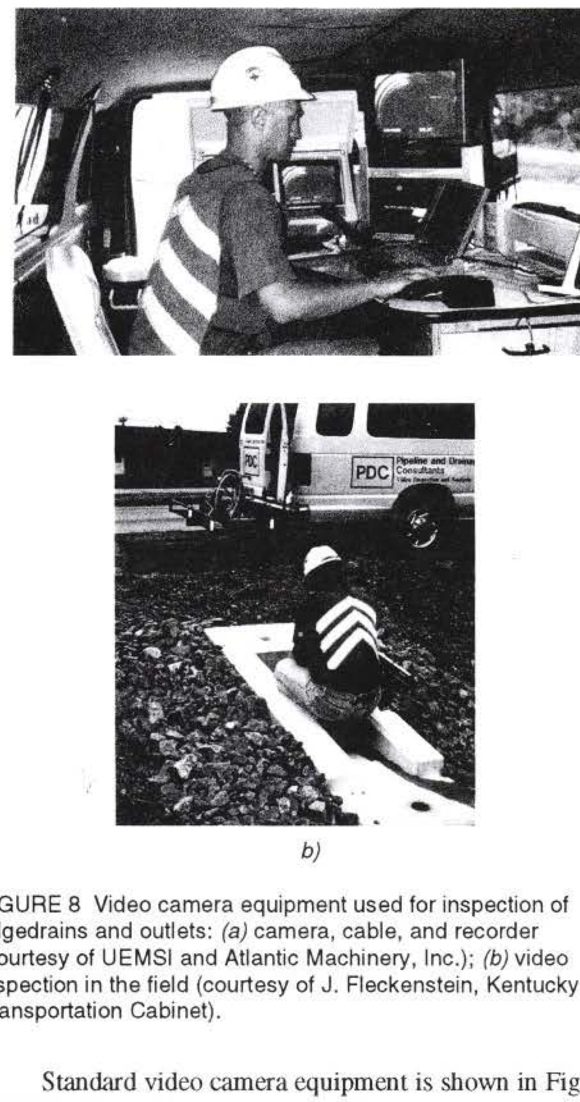


b)

FIGURE 8 Video camera equipment used for inspection of edgedrains and outlets: *(a)* camera, cable, and recorder (courtesy of UEMSI and Atlantic Machinery, Inc.); *(b)* video inspection in the field (courtesy of J. Fleckenstein, Kentucky Transportation Cabinet).

Standard video camera equipment is shown in Figure 8. Table 1 provides a summary of equipment owned by seven of the agencies along with some of the problems they have experienced. As shown in Table 1, the cost of a video system ranges from $13,000 to $40,000 depending on the type and extent of the equipment purchased. Apparently the cost has been reduced significantly over the past

TABLE 1
VIDEO EQUIPMENT SURVEY RESULTS

Agency	Type of Equipment and Estimated Cost	Reported Performance
Arkansas	1. Cues ($?). 2. Pearpoint ($32,000)—new model being purchased at $15,000.	1. Requires significant maintenance. 2. Overall performed well.
Iowa	1. Pearpoint, 500 ft, B&W, 2 in. dia., 1992. 2. Cues, 300 ft, B&W, 2½ in. dia., 1989. 3. Welch Allyn, 50 ft, color, 1/2 in. dia., 1989.	1. Some light bulb contact problems. 2. Modified cable supplemental. 3. Cable stiffener often added.
Maryland	Cues Mini-Scout Video Inspection System with VCR and generator ($14,000).	No comments.
Michigan	1. Pearpoint Model P270 ($40,000). 2. Cues Mini-Scout ($20,000), 1998.	1. Expensive to buy and maintain—cannot see well under water. 2. Limited range (cannot go around bends).
North Carolina	Cues ProScout ($13,000).	Push rod is not stiff enough to push the camera past obstacles.
South Carolina	Cues, ProScout, tractor, crawler, camera, VCR, still picture adapter.	Not enough ground clearance, tractor gets stuck in sand. Crawler: not enough ground clearance; gets stuck easily.
Virginia	1. UEMSI Predator Color Mini-Camera (nine units at $15,000 each), 1999. 2. Flexible Video Borescope IV8C6-50, 5 m long and 8 mm diameter used to inspect geocomposite edgedrains (one unit at $38,025), 1999.	New purchases—functioning well after 1 year of service.

several years. Although there were some reported problems as noted in Table 1, overall these systems have performed well. The high cost of maintenance appears to be a significant issue.

Only one state agency (New York) indicated that they had data on the cost effectiveness of drainage surveys. Although the New York survey did not give specific cost data, the effectiveness was apparent. The New York survey gave excellent feedback on the effectiveness of its existing drainage system for both new and retrofit construction, what specific components were being used, and what problems had been encountered with those components. It also allowed their districts to determine and address specific problems.

Maintenance Practices for Edgedrains

Standard maintenance for edgedrains includes flushing the system, cleaning the outlets, and replacing the outlets when damaged. Scheduled periodic flushing and outlet cleaning provide an effective tool for preventive maintenance. Flushing is best performed with a high-pressure rodding system. For example, Oklahoma uses a system generating 21,000 kPa (3,000 psi) of pressure at a rate of 19 L/min (5 gal/min) from a trailer-mounted water pump (Sawyer 1998). Its system uses 90 m (300 ft) of high-pressure hose and a series of interchangeable thruster heads. They have found that the most effective thruster head has one forward stream, which cuts through roots and sediment with four reverse thruster streams to propel the hose through the pipe and force the debris toward the outlet opening.

Figure 9 shows the responses from 30 agencies that were asked whether standard maintenance practices were performed on a scheduled basis (i.e., always, sometimes, or never). Unfortunately, most agencies do not follow a consistent scheduled maintenance practice. Only three agencies indicated that they flush their drains on a routine basis. A majority of the respondents (60 percent) indicated that they flush sometimes, usually when specific problems are identified. The remaining 40 percent indicated that they never flush their systems. Most of the respondents do clean the outlets and six agencies do it on a routine basis. Finally, seven agencies never replace their outlets. Explanations for the absence of maintenance were again related to lack of manpower and resources. Two agencies indicated that these activities are only performed during roadway widening, overlaying, or rehabilitation.

When asked which headwall system used by its agency requires the least maintenance or is the easiest to maintain, 50 percent of the respondents preferred precast headwall units. Several agencies endorse cast-in-place units. Two agencies preferred concrete or asphalt pads and two agencies favored flared-end with riprap. However, three agencies clearly identified the easiest system to maintain as one with no outlets (i.e., outletting into another drainage structure such as a catch basin, drop inlet, manhole, or cross pipe).

EDGEDRAIN PROBLEMS AND SOLUTIONS

The survey found that precipitates (e.g., chemical, silt, and debris), clogging, and mowing damage were the most

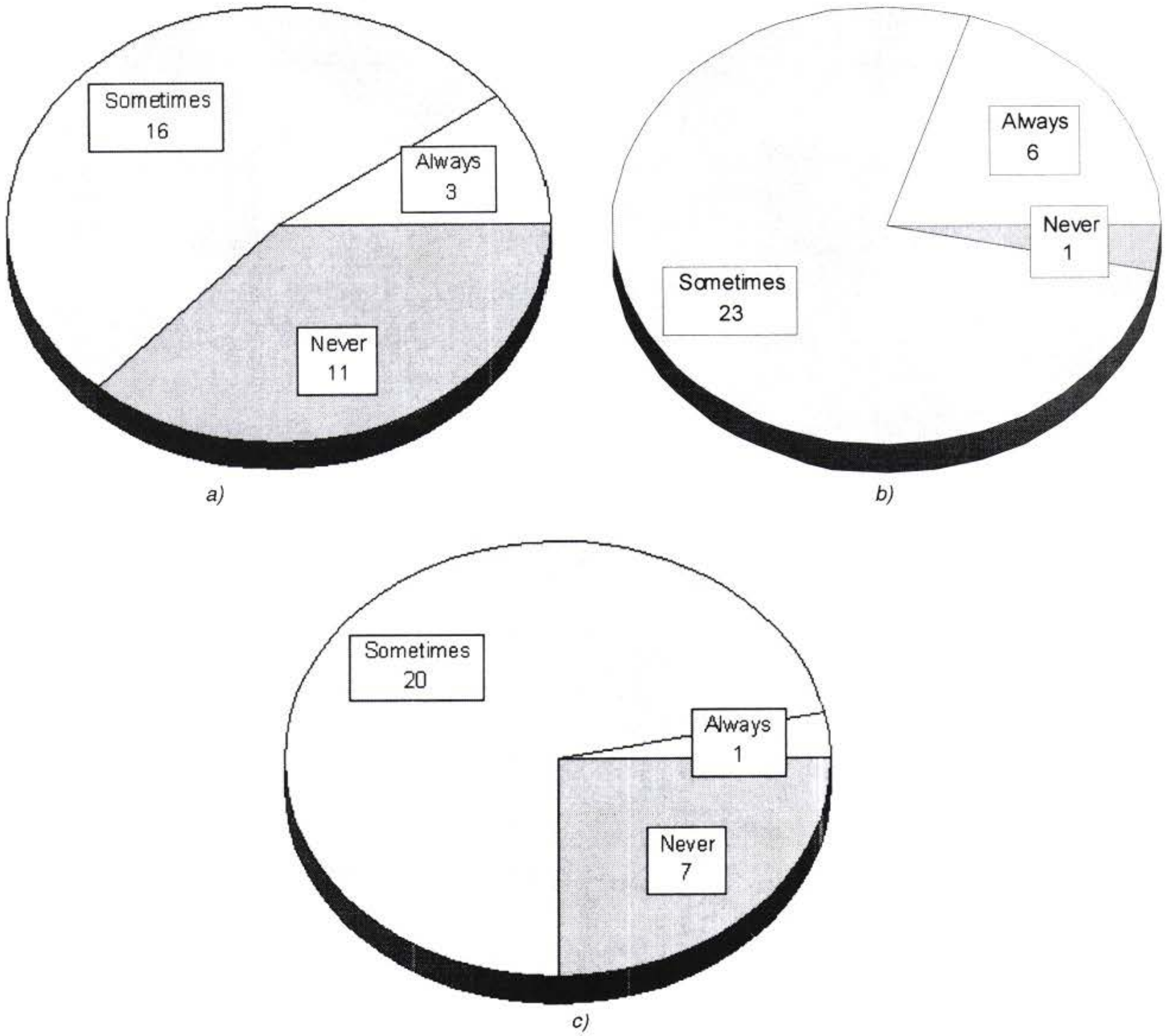


FIGURE 9 Reported frequency of maintenance activities: *(a)* flush edgedrain system; *(b)* clean outlets; *(c)* replace edgedrain components.

prevalent problems with edgedrains, with frequent occurrence noted by many (10 or more) agencies. Precipitates especially have been identified as a problem with crushed concrete base (e.g., recycled concrete, rubblizing, or crack-and-seat) as reported in the literature (Snyder and Bruinsma 1996; Holtz et al. 1998), reviewed in *NCHRP Synthesis 239*, and noted by the respondents to this study (Figure 10a). Several solutions for drainage design in these situations are also reviewed in *NCHRP Synthesis 239*. Use of very open permeable-base-type material, from the recycled material to the drain with geotextile filters placed around the outside of the drain (as shown in Figure 3), appears to be reasonably effective in preventing clogging. One agency (Iowa) noted that they had replaced rodent screens with steel fingers to reduce the potential for plugging from chemical precipitates in these situations. Others (e.g., Michigan) have simply stopped using crushed concrete for base aggregate and subbase. For other types of precipitates, such as siltation, many agencies reported that flushing and cleaning programs have helped reduce or eliminate this problem. For example, Arkansas reported that they recently purchased a flushing trailer to clean the drains and it has been valuable on at least one-half of the projects. Several agencies reported that since they began using geotextile filters, precipitates and clogging problems have greatly diminished.

Clogging was in many cases associated with crushed outlet pipes and was reported to be usually construction related (Figure 10b). Several agencies (Arkansas, Delaware, Indiana, Idaho, Iowa, Kentucky, Michigan, and Virginia) reported the use of video cameras to help solve this problem. Virginia now uses a video camera to negotiate edgedrain replacement with the contractor before signing off on projects. Indiana and Mississippi have plans to start this process. Since 1997 Kentucky has made contractors responsible for inspecting all edgedrain outlets and the mainline within 46 m (150 ft) of the outlet (i.e., limited by

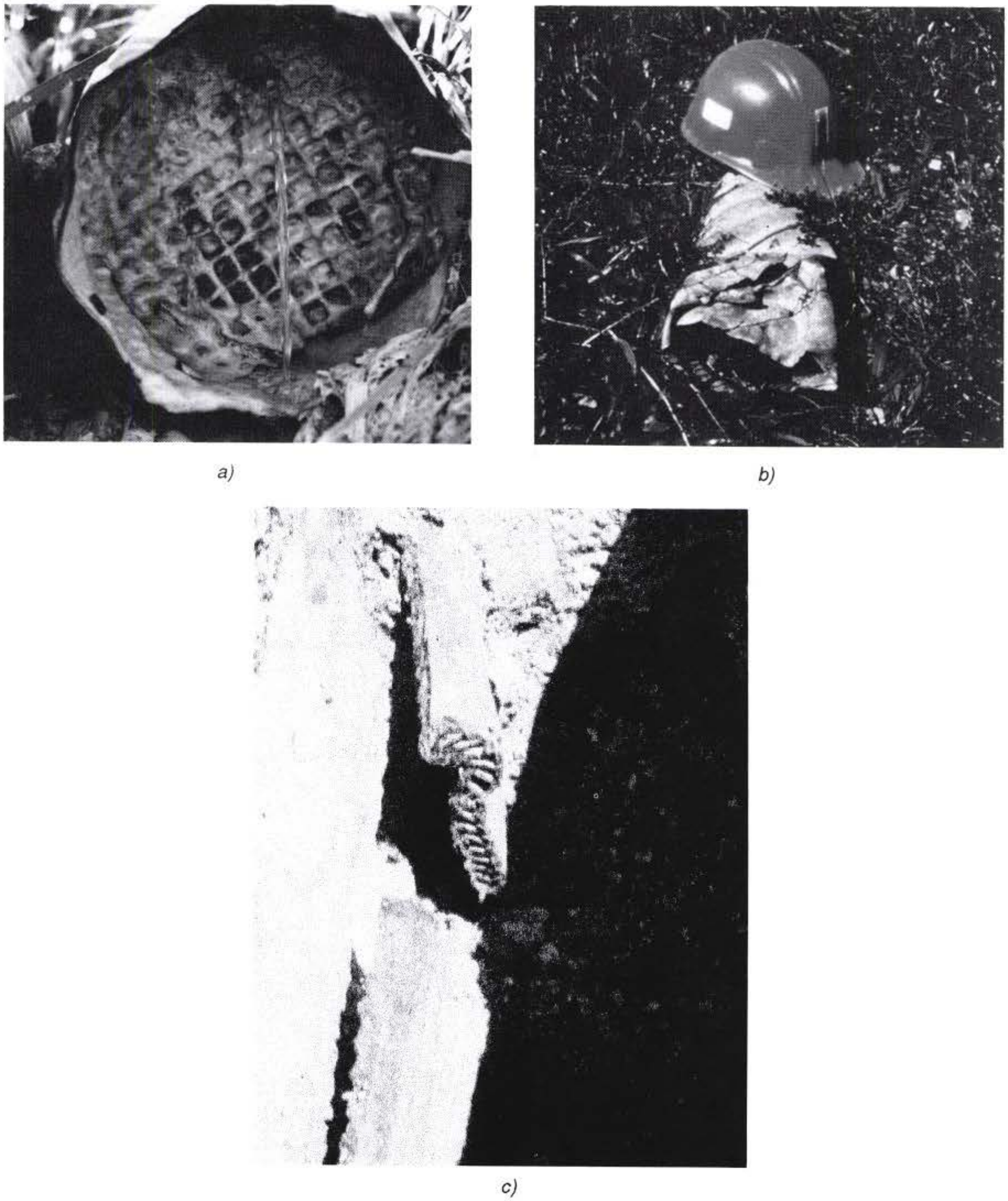


FIGURE 10 Photos of PGED edgedrain and outlet end problems: *(a)* rodent screen clogged by precipitates (note water flow out of puncture hole); *(b)* crushed outlet pipe; *(c)* PGED buckling problem.

the push length of the video camera) and repairing their own work (Fleckenstein and Allen 1999).

In addition to using a video camera, Michigan indicated that they had simplified design to enhance construction to avoid errors. They have also reduced their outlet spacing (i.e., increased the number of outlets) and changed the connector from a wye to a radius bend to facilitate flow and reduce the buildup of sediment. These changes have also been found to facilitate inspection and flushing *(NCHRP Synthesis 239)*.

Corrugated outlet pipe was noted to be highly susceptible to crushing. Several states reported having started placing sleeves around existing corrugated outlet pipe, whereas others are replacing existing corrugated outlet pipe with stiff, smooth-walled polyvinyl chloride (PVC) pipe. At least one district in Kentucky has significantly reduced crushing failures by backfilling around outlet pipes with flowable fill, a wet mix of sand, fly ash, and cement (Fleckenstein and Allen 1999).

Sediment in the ditch line has also contributed to clogging. Iowa has reduced the depth of the edgedrain trench from 1.22 m to 1.07 m (4 ft to 3.5 ft) to allow the outlet exit to be higher and above the ditch sediment. Clogging was also attributed to not using a geotextile filter and, in at least one case, to using a geotextile filter. Although the use of a geotextile filter has been debated by some (Sawyer 1998), a preponderance of performance information shows that geotextile filters have a much better performance history than well-graded granular filters (e.g., Koerner et al. 1994; Holtz et al. 1998). In either case, project-specific design of the filter material with respect to the soils to be filtered is recommended (Holtz et al. 1998).

Several agencies have limited the use of PGEDs due to a potential for sediment infiltration and subsequent clogging. Crushing and bending (also known as "J" buckling) of the panels, as shown in Figure 10, have also been observed by some agencies (e.g., Illinois, Iowa, and Pennsylvania). Others have modified the design and construction procedures for PGEDs similar to those recommended in *NCHRP Report 367* (Koerner et al. 1994) and have reported good performance (e.g., Kentucky and Virginia). The inability to video inspect many of the PGEDs has also been reported as a problem (Fleckenstein and Allen 1999) and should be a consideration in the selection of the type of product.

Mowing damage appears to be a reality with outlets. The precast concrete outlets help, but still may become damaged (as does the mower). Optimum headwalls to reduce the potential for damage will be reviewed in chapter 5. Possibly the best approach, as suggested by Maryland, is to try to outlet all edgedrains into other drainage structures to prevent damage to the outlet.

Other problems that were sometimes observed included rodent problems (e.g., ineffective rodent guards) and downstream erosion. Most agencies now use rodent screens to prevent rodent problems. The downstream erosion problem has generally been solved by placing small riprap rock (in some cases underlain by a geotextile filter) at downstream ends of outlets. Erosion upstream was reported to be much less of a problem, except for sediment in the ditch line as previously indicated. Sags in outlet were noted as more of a problem than sags in mainline. As with crushing, most of the outlet sag problems were with corrugated pipe, and the use of stiff, smooth-walled PVC pipe for the outlets was reported to have significantly reduced the occurrence of this problem.

Several agencies indicated that they were not able to address any of their maintenance problems due to lack of funds. However, on the positive side, one agency (Kansas) helped address its maintenance problems by making presentations to construction inspectors and maintenance workers showing them the problems encountered and the effects of poor construction and lack of maintenance.

Cost Effectiveness of Maintenance Programs

The reported number of person-hours expended by each state per year for edgedrain maintenance varied considerably, ranging from 0 to 15,000 h/year (independent of the miles of edgedrain installed). Although most of the agencies did not know the number of hours, five answered "zero" and several others answered "very few" (e.g., 30 or less). These low numbers appear to be reflective of the short-term trend to cut budgets without evaluating the long-term consequences. At least some agencies are aware of the return on investment produced by good maintenance programs (see chapter 6), with two agencies reporting 500 to 800 h/year and two others indicating a very extensive program at 12,000 and 15,000 h/year. Most agencies indicated that maintenance is performed by in-house personnel, whereas two agencies stated that they out-source these services and four noted that they use both. Training provided to edgedrain maintenance personnel goes hand-in-hand with the hours expended (i.e., if you do not spend any hours maintaining, why train). Those agencies that have person-hour budgets provide a variety of training, including training on use of video cameras, flushing, cleaning of outlets, marking of outlets, and visual examination. In several cases, formal instruction is provided either by in-house personnel or through the National Highway Institute. Videotape is also used by several organizations for training. As mentioned in the previous section, Kansas uses presentations at group meetings for both training and awareness programs. Several states indicated the use of on-the-job-training. Unfortunately, none of the respondents had information on the actual cost-effectiveness of their agency's maintenance practices. An analysis of the cost-effectiveness of maintenance is provided in chapter 6.

CHAPTER FOUR

FUNCTIONAL INTERACTION

INTRODUCTION

The team approach, in which all functional groups are involved in the design, construction, and maintenance decision process, was introduced in *NCHRP Synthesis 239* as a method to fully evaluate and establish the most appropriate subsurface drainage strategy. The team approach requires the development of formalized lines of communications to get the necessary (key) information to decision makers before the design has been completed. This works if changes are continuously fed back into the system as they occur. It is difficult for the decision maker to delay the project and recycle the information back through the process if the importance of the effect of the change is not evident.

In this chapter, the relationship between maintenance and design, as well as between maintenance and construction, will be discussed. Information from the survey on feedback systems used by various agencies for communication between functional groups will be presented. Good design and construction practices that have been found to reduce or facilitate edgedrain maintenance will also be identified.

MAINTENANCE AND DESIGN

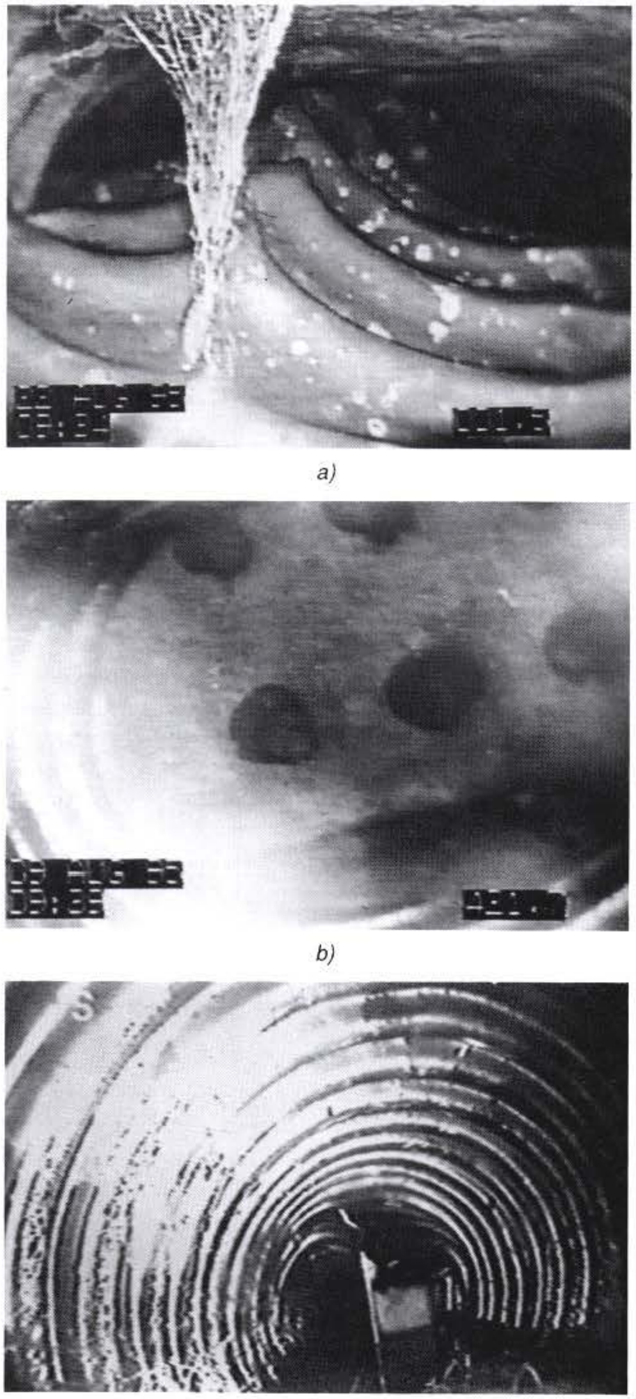
The survey for this study found that many of the maintenance groups work closely with design and construction. More than one-half (19) of the 35 agencies responding to this question indicated that the maintenance group is involved in design decisions, at least from a review capacity. In one state, the designers and central office maintenance personnel indicated that maintenance staff is involved in design, although many of the districts did not believe that this was the case. The input ranged from sometimes reviewing (e.g., informally, on an as-need basis), to reviewing at the final design stage (i.e., 80 to 90 percent), to complete review at all stages (scoping, 25 percent, 60 percent, 90 percent, and final plans and specifications and in some cases construction review). Several groups reported using the team approach, which range from a partnering team (e.g., Arizona), giving advice with little involvement in scoping the project, to a full-team approach (e.g., Connecticut and Washington), with the designer distributing the plans to all groups involved (maintenance, construction, and specialized design units such as soils and hydraulics) at the different stages of design including scoping. In Virginia, the maintenance representative is involved in the establishment of drainage standards. Unfortunately, the other half of the maintenance groups indicated that they have no input in the design (other than to fix the problems they create, as remarked by one respondent).

To facilitate communication and improve the design for future projects, there needs to be a routine feedback loop from the maintenance staff to the designer. The advantage of a formal system is obvious: recurring events can be documented such that they receive special attention. Unfortunately, a number of the responding agencies (21 of 43) indicated that they do not have a feedback system established between maintenance and design units. Most of those reporting a feedback system indicated that it is informal and usually verbal. Several agencies do have formal feedback systems between maintenance and design units to report on maintenance issues. Two agencies (Illinois and Michigan) indicated that feedback is through a committee, with Michigan having a stand-alone edgedrain outlet committee to provide feedback for standard plans.

It was interesting to note that only those agencies reporting having a feedback system were also able to identify design changes that they had implemented to reduce and/or facilitate edgedrain maintenance. This response appears to verify the statement in *NCHRP Synthesis 239* that "improvements are only achieved through feedback to design and construction." Improvements noted by several agencies included a change in outlet pipe from corrugate to smooth-wall, stiff plastic pipe to reduce sag and crushing problems. A change to precast concrete headwalls was also an improvement cited by several agencies. Iowa noted that the radius at outlets had been increased and, as previously indicated, that the (edgedrain) trench depth was reduced to 1.07 m (3.5 ft) to allow drainage to the ditch. Massachusetts indicated that the use of geotextile filters around their drains has reduced siltation and clogging.

Kentucky has recently (1998/1999) used a team process and experience with video inspection to implement several design changes (Fleckenstein and Allen 1999). These design changes include:

- New headwall and outlet design using a loop-type edgedrain system with outlets on both the upstream and downstream ends to facilitate flushing and video inspection,
- Flowable fill (a wet mix of sand, fly ash, and cement) for the outlet pipe,



a)

b)

c)

FIGURE 11 Video camera photos of edgedrains damaged during construction (Daleiden and Peirce 1997): *(a)* crushed edgedrain; *(b)* brick inside of pipe; *(c)* post driven through pipe.

- Ditchline collector system and inspection ports for the ditchline collector pipe and the edgedrain loop, and
- Channel lining in the ditches along the cuts to decrease erosion and maintenance.

These and other design modifications will be discussed in more detail in chapter 6.

Several agencies provided suggestions for improvements that should be implemented to facilitate edgedrain maintenance of their specific systems, the most noteworthy of which was to establish communication between maintenance crews and design teams. Other recommended improvements included increased efforts in ditch cleaning (cited by two agencies), standardized marking systems, and additional manpower and resources.

MAINTENANCE AND CONSTRUCTION

Involvement of maintenance staff with construction was not as encouraging as the involvement of maintenance staff with design; only three states (all of which use the team approach) indicated that maintenance staff is involved in decisions on inspection requirements. Many of the agencies do have special inspection or testing of subsurface drain systems performed before construction acceptance, but a large majority (approximately 22 of 30) do not. Most of those agencies that have acceptance procedures (seven of nine) use a video camera for construction inspection. From the PIARC survey the transportation agencies in Denmark, Germany, and Switzerland are also using video surveys on a routine basis before accepting subdrainage works (Hoppe 1998). Agencies are often surprised at the problems they find, including poor grades, crushing, and obstructions. Several examples of problems uncovered by video inspection are shown in Figure 11.

Delaware reported that the use of video is mandatory and Virginia noted that it is routinely used. As previously indicated, Kentucky requires the contractor to inspect edgedrains using a video camera and to repair any mistakes. A quality assurance program in which the agency reviews the contractor's process and performs additional video inspection is also in place. Kentucky's experience, as shown in Figure 12, clearly demonstrates the significant impact that video inspection can have on reducing failures and the corresponding impact of this process on maintenance (i.e., reducing problems handed off to maintenance groups). They have reduced outlet pipe construction failures from over 20 percent prior to the introduction of their current inspection process to less than 5 percent, and the contractor is now responsible for those repairs. Currently, only 2 percent of the mainline pipes that are inspected statewide (with one-third of the entire mainline system being inspected) were found to be damaged (Fleckenstein and Allen 1999).

Most of the other agencies reported that video inspection is optional, usually up to the resident construction engineer and, as indicated by two of those agencies, seldom used. Some agencies reported using only visual inspection (e.g., Illinois and New York), with Minnesota augmenting visual inspection with a probe inserted up and through the

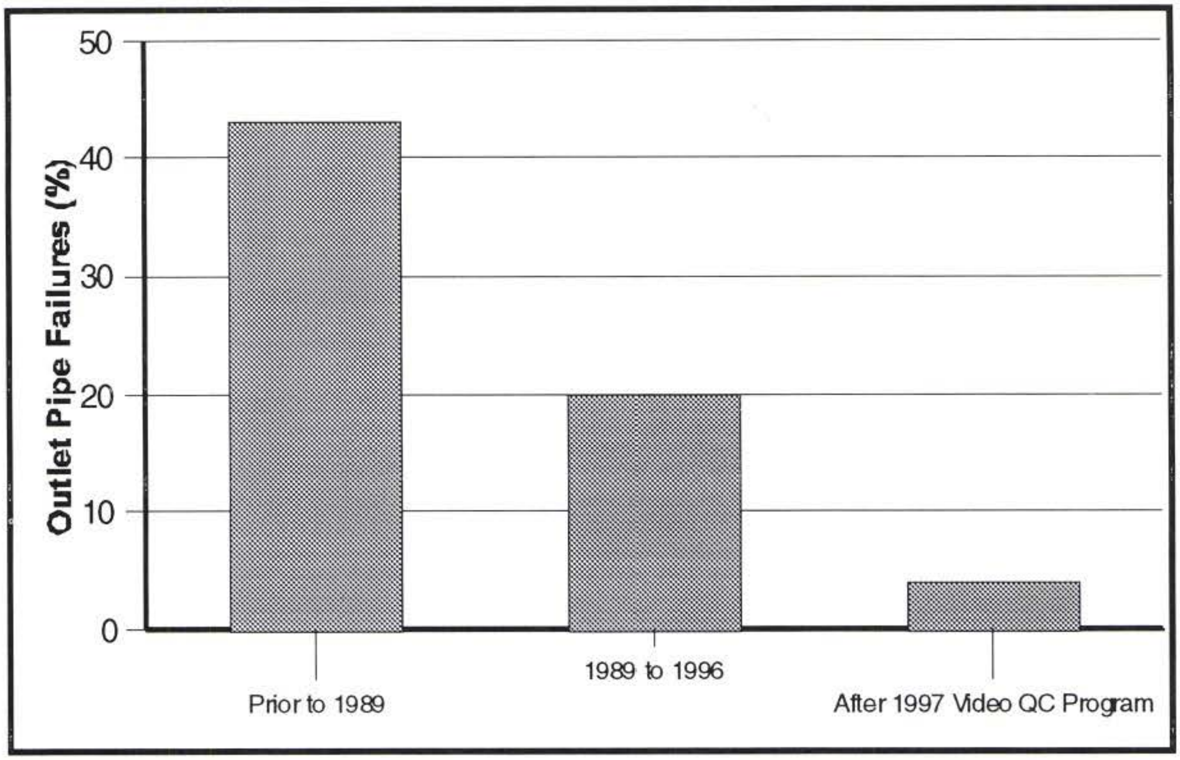


FIGURE 12 Kentucky's experience with edgedrain outlet pipe failures before and after video construction inspection (Fleckenstein and Allen 1999).

outlet pipe and the bend into the edgedrain to check for obstructions. It should be noted that visual inspection was the procedure used by Kentucky from 1989 to 1996 (see Figure 12), but that this inspection procedure was not nearly as effective as the current video inspection program.

There does appear to be feedback between maintenance and construction units, with 17 of 31 states reporting that methods exist to report maintenance issues with construction practices. However, most of the feedback, as with design, was reported to be informal. New York has plans to start using video as an inspection tool, having recently issued a video inspection specification. Delaware has a formal system in which issues are relayed back and forth between construction and maintenance units through the central office. Kansas indicated that their field maintenance unit performs an annual "listening" tour. New York has a formal process where feedback is through a "Premature Failure Study." One state agency reported a formal "problem statements" process, which unfortunately takes several years. Another state has a simple process: both the Maintenance and Construction Assistant Division Engineers work for the Division Engineer.

The states that have good feedback have been productive in making construction changes that reduce and/or facilitate edgedrain maintenance (see comments in Appendix B). Improvements in the inspection process through the use of video cameras were cited by several agencies as reducing built-in maintenance problems. Iowa, Indiana, and Virginia indicated that most changes have been incorporated in edgedrain design and construction standards. A request for quality assurance during construction was offered by one agency as a recommended improvement. Another would like to see more attention paid to protection for the outlet pipe during the construction process. Trench fill gradation and placement quality was also noted by one agency as an area where improvement is needed. Several agencies noted that less construction care is often given to the outlet than to the mainline resulting in many of the observed outlet problems. This is one of the reasons Kentucky has started using flowable fill around the outlet pipe.

CHAPTER FIVE

EFFECTIVENESS OF CURRENT MAINTENANCE PRACTICES: AN OVERVIEW OF SYNTHESIS RESULTS

As previously indicated in chapter 3, the FHWA, through their "Video Inspection of Highway Edgedrains" program, found a number of edgedrain failures. Many state agencies supported those findings with their own video inspection studies, with a number of problems reported in chapter 3. The agencies were queried as to the primary cause of these premature failures of edgedrain systems. The majority of the respondents to the survey indicated that most of the premature failures are due to inadequate maintenance and inadequate construction of the edgedrains and outlets. Nine agencies indicated that failures could always be traced to these issues, with practically all of the other respondents indicating that failures frequently relate to one of these two issues. Only two (of 29) respondents did not feel that failures were related to either maintenance or construction issues. The majority of respondents (26 of 30) believe that inappropriate design, especially in relation to unrecognized site conditions was sometimes a cause of premature failure. Most of the respondents did not feel that the absence of paved shoulders or failure of the shoulder made a significant contribution to edgedrain failures, although several respondents did indicate that they currently always use paved shoulders. Education and research are often means of improving the performance of systems. Most of the agencies (17 of 29) agreed that more education was needed. Especially noted were teaching all individuals involved with pavement systems the importance of correct edgedrain installation and the benefits of properly maintaining it. Although several respondents specifically indicated that additional research was not needed, 35 percent felt that it could provide some improvement. Specific research needs that were noted by the respondents include correlation of pavement performance to edgedrain, measured performance of existing systems, and different types of systems. Other suggestions related to:

- Design improvements
  - The need to consider alternate designs for varying soil types,
  - Establish better design details,
  - Include maintainability in design criteria, and
  - Spend money on building high-quality edgedrains without taking shortcuts.
- Construction improvements
  - Contractors and inspectors need to personally inspect the outlet pipe,
  - Improve construction inspection such as the use of end-result video inspection,
  - Document proper installation practices (e.g., read the construction section of the Demo 87 course manual and *NCHRP Synthesis 239*),
  - Hold preconstruction meetings, and
  - Arrange training for contract administrators on requirements.
- Maintenance improvements
  - Improve maintenance access options for cleaning and
  - Improve maintenance inspection.
- Management improvements
  - Establish basic policy on edgedrain maintenance with strong administrative support.

Although numerous research studies have confirmed improved performance through the use of edgedrains (as reviewed in *NCHRP Synthesis 239*), very few agencies have documented their own experience and developed confirming correlations. This information is important to develop performance indicators and determine the life-cycle cost benefit of using edgedrains. Illinois, Kansas, Washington, and Ontario all indicated developing correlations showing that pavement systems with drainage require less maintenance than pavement systems without drainage. Unfortunately, all of these correlations were qualitative (i.e., not supported by data). Illinois indicated that its correlation was not in relation to improved performance, but rather it was with the poor performance where there are no drains. As stated by one of its districts, "you take care of the subsurface drainage, you eliminate most of your problems and pavement lasts longer." Iowa indicated that its experience generally confirms that subdrains can extend the life of new pavement or overlays from 25 percent to as much as 50 percent. Virginia noted that its correlation was on a case-by-case basis (i.e., "when we make field diagnosis of failures related to poor drainage, the maintenance group develops a better appreciation for edgedrains"). Ontario also indicated that although it does not have documentation, its maintenance group, together with its pavement/geotechnical group, has informally developed a correlation relating improved performance and a decrease in roadway maintenance to the use of edgedrains. Arizona indicated that research is ongoing on this topic, and Nebraska noted that its Pavement Management group has plans to develop such correlation.

Data showing poor pavement performance in relation to edgedrain problems were also not available. Again, several agencies did have qualitative information (see Figure 13).

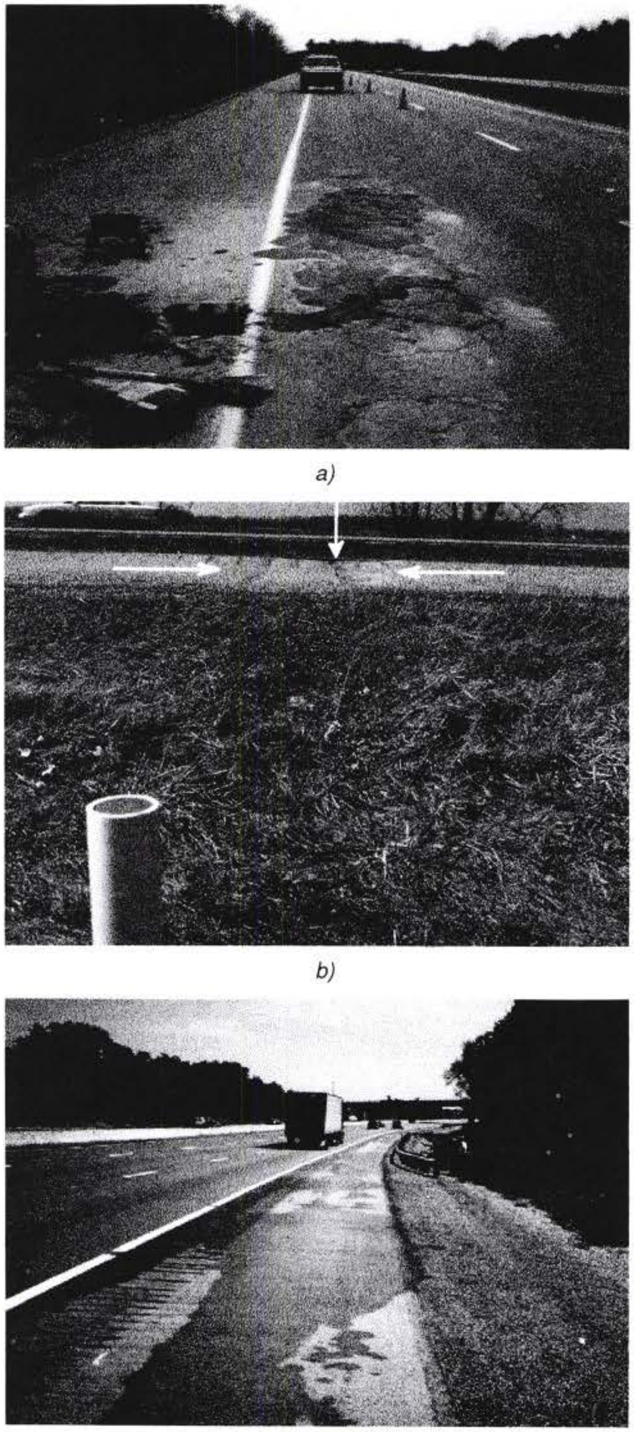


FIGURE 13 Pavement distress resulting from edgedrain problems: *(a)* pavement distress at clogged edgedrain section (Kentucky Transportation Cabinet); *(b)* sag across pavement shoulder due to poor compaction around edgedrain outlet pipe (Iowa DOT); *(c)* water from failed edgedrain trapped in pavement section.

Illinois again stated that their experience indicated poor pavement performance associated with poor subsurface drainage. Although Iowa and Oklahoma had no formal studies or documentation, they noted that frequently when there is a pavement problem there is a drain problem. One agency related this information to common sense stating "if pavement heaving occurs and subsurface water is prevalent, the edgedrain has failed."

Several case histories have documented pavement problems associated with edgedrain problems. The West Virginia DOT (Baldwin 1991) documented a pumping pavement problem on Interstate 77 that was directly related to problems with edgedrains constructed with both PGED systems and a fabric-wrapped trench. The edgedrains had been installed only 2 years earlier as part of a rehabilitation effort. It should be noted that the rehabilitation was necessary because of poor drainage. The pumping problems were primarily related to: (1) the very dense low-permeable base used to construct the shoulder of the road, (2) the location of the edgedrain 300 mm (12 in.) outside the edge of the pavement and out into this base course, and (3) the inability of the infiltration water to flow to the edgedrain. Some siltation and partial blocking of the edgedrain with what appeared to be backfill material was noted in one section. A study by the Pennsylvania DOT (Highlands et al. 1991) also documented pavement performance problems that were related to poor edgedrain performance. Subsidence of the PGED was observed in an experimental prefabricated geocomposite edgedrain section along 30 km (19 mi) of interstate highway, which was most likely a result of inadequate trench backfill compaction. Four years after construction, pumping problems were also observed in several areas. The problems were attributed to inadequate geotextile filter design on the edgedrain, which was compounded by a crushed outlet pipe, finer than normal subbase material, and harsh pavement pumping conditions. Both case histories illustrate the need for increased pavement maintenance that can occur when edgedrains do not perform properly. They also emphasize the importance of correct installation in relationship to problems inherited by maintenance units. Another relevant finding from the Pennsylvania DOT study was that cost over performance life rather than initial cost should be stressed the most in evaluating the type of pavement base drain system that should be installed. Maintenance and periodic replacement costs for nonfunctioning drains must be factored into the life-cycle cost analysis. The following chapter will explore the life-cycle cost of edgedrains along with alternate strategies that have been demonstrated to perform well.

CHAPTER SIX

MINIMIZING MAINTENANCE REQUIREMENTS

INTRODUCTION

In this section, strategies to reduce maintenance requirements will be presented from the survey and literature along with modern methods of increasing maintenance effectiveness. Unfortunately, as was reported in the previous two chapters, only a few agencies are implementing effective preventative maintenance programs. Most agencies are actually practicing worst-to-first maintenance, which has been proven to be the least cost-effective approach to maintenance (Geoffroy 1996). Understanding the current pressure on budgets and associated manpower, managers still need to receive information concerning the actual cost of poor maintenance practices. The alternative is to spend more up front to build a minimal maintenance system using strategies and alternatives reviewed in this chapter. Guidance is also provided for effective maintenance strategies, including inspection, and routine and preventive maintenance procedures. The best practices, as obtained from the survey, are highlighted in cases where there is consensus.

THE COST OF MAINTENANCE (OR MAINTENANCE IS FREE)

The reactive maintenance practices used by most of the agencies surveyed are extremely costly. In general, inspection, in conjunction with preventive maintenance programs, has proven to be many times more cost-effective (a $3 to $4 return on each $1 invested) than detection and repair programs, as reviewed in *NCHRP Synthesis 96* (Ridgeway 1982) and *NCHRP Synthesis 223* (Geoffroy 1996). However, many agencies claim they do not have that $1 to invest. What those agencies may not realize is that with edgedrains, maintenance is not an investment, but a necessary expense. Because the proper function of the road depends on adequate drainage, edgedrains are included in a design to mitigate the negative influence of water. Then, designers plan on the improvements provided by edgedrains to achieve the design performance period. For the road to achieve its anticipated design life the edgedrains must always function. If they do not, the agency will likely have to spend more dollars (e.g., $3 to $4) in repairing the pavement system over its anticipated performance period for every dollar not spent on edgedrain preventive maintenance.

The influence of edgedrain performance on the performance of the pavement system is somewhat predictable and can be evaluated using the drainage modifiers (m and C_d) from the AASHTO 1993 design guides, as discussed in chapter 2. High drainage modifiers may be used in the design when excellent to good drainage (i.e., the system drains within 2 to 24 hours following a rain event) is designed into the pavement system through the use of open-graded aggregate and edgedrains. However, as soon as the edgedrain ceases to function, the pavement section will be negatively impacted. The magnitude of the impact could be estimated by reducing the drainage modifiers to that of poor to very poor drainage conditions (i.e., the system takes a month of more to drain). This reduction (as much as 50 percent) in the drainage modifier will have a direct impact on the structural number and correspondingly the anticipated performance period for the pavement. The actual magnitude of performance period reduction will depend on many factors, such as the type of road (secondary or primary), the makeup of the structural section, the foundation conditions, and regional rainfall. However, in many cases, the reduction in performance period is significant (often on the order of 40 percent or greater, especially for flexible pavement with relatively thick base course layers). Therefore, when a designer includes an edgedrain in the design to obtain a 20-year performance period, for the case of a 40 percent reduction one could reason that a 12-year performance period would be anticipated if the edgedrain does not work. Likewise, if the road were to perform for 10 years before the edgedrain failed, then the road would last 16 years. However, this is not a worst case scenario, because the edgedrain itself could collect water, creating a bathtub effect and accelerating the deterioration of the road. If the pavement is saturated due to the bathtub effect, distress in the road is almost immediate. Figure 14 illustrates the potential effect of saturation on the design life of a pavement section, with the severity factor indicating the relative damage during wet versus dry periods anticipated for the type of road (Cedergren 1989). Assuming that the pavement will probably be saturated until it is repaired, significant damage will most likely already have occurred to the pavement section by that time.

In a worst-to-first maintenance program, pavement distress is often the first indication of an edgedrain problem. The cost of not having a preventive maintenance program is thus both the cost of repairing the drain and the road. This cost can be significant. In a study on the life-cycle cost benefits of using edgedrains in the rehabilitation of pavements, Fleckenstein and Allen (1999) found that edgedrains extended pavement life by approximately 7 years, resulting in a cost savings of approximately $150,000 per kilometer ($240,000 per mile) of roadway.

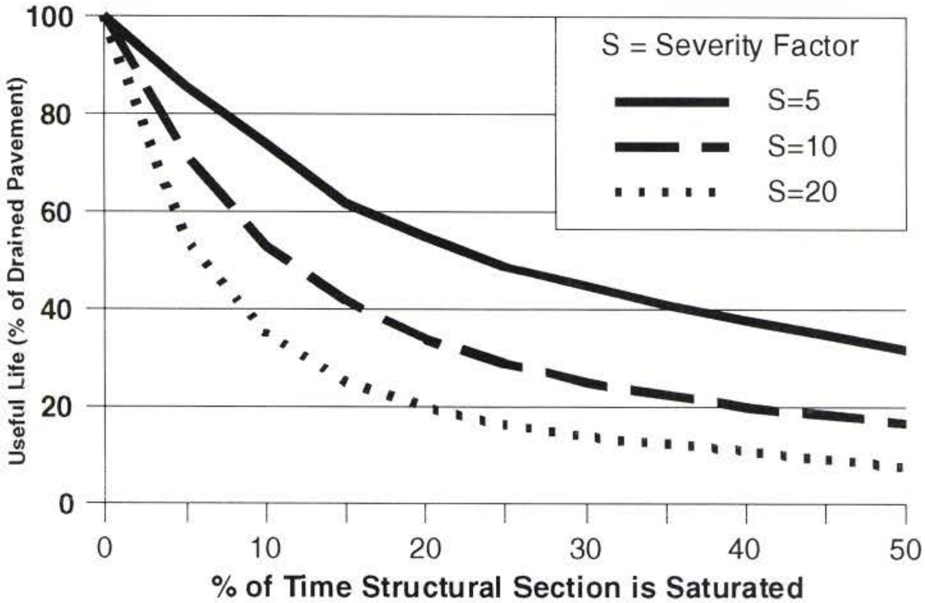


FIGURE 14 The influence of saturation on the design life of a pavement system (after Cedergren 1987)

TABLE 2
THE COST OF MAINTENANCE (INCLUDING MOBILIZATION AND REPORTING)

Maintenance Activity	Frequency	Time Required (h/km of road)	Annual Cost* (h/km of road)
Visual inspection (1-person crew)	Twice/year	2	4
Outlet and ditch line cleaning (3-person crew)	Once/7 years based on visual inspection	18	8
Video inspection (2-person crew)	Once/7 years	28	8
Flushing (2-person crew)	Once/7 years	18	5
Total			25

*Annual cost = colum 1 × colume 2 × column 3.

This money is lost if the edgedrains do not perform and would pay for a significant number of maintenance hours (on the order of 500 person-hours of maintenance per kilometer of pavement per year). The actual anticipated cost of edgedrain maintenance is shown in Table 2. From the table it can be seen that on the order of 25 hours of maintenance per kilometer per year (40 hours per mile) should be adequate to maintain the edgedrain system. In this case the return on investment could be as much as $20 for every dollar spent on maintenance. Unfortunately, many of the agencies that responded to the survey spend fewer than 40 hours per year on their entire edgedrain system. That equates to millions of dollars wasted on potentially avoidable pavement repairs.

DESIGN FOR MINIMUM MAINTENANCE

Although there is no such thing as a maintenance-free system, effective design with maintenance in mind can significantly reduce maintenance requirements, facilitate the remaining requirements, and significantly reduce long-term maintenance costs. The following suggestions for design of edgedrain system components represent the best experiences from agencies that have had a long-term maintenance program and advanced their designs with respect to maintenance requirements based on inspection surveys and monitoring.

- *Edgedrains*
  - The modern "French" drain with a geotextile filter lining the trench, open-graded aggregate, and a slotted longitudinal collection pipe still appear to be the best-performing edgedrain, according to both this synthesis and the PIARC survey. The geotextile should be selected based on the soils to be filtered following the guidelines from FHWA (Holtz et al. 1998). The stone should be 12 to 30 mm (0.5 to 1.2 in.) of open-graded aggregate. The pipe should be a

100-mm (4-in.) diameter slotted, stiff, smooth-walled PVC or high-density polyethylene (HDPE) pipe to reduce crushing and sags and facilitate flushing.
  - PGEDs may be used to facilitate installation on rehabilitation projects, but installation should consider the guidelines cited in *NCHRP Report 367* (Koerner et al. 1994) to reduce the potential for clogging and siltation. Product selection should consider an evaluation based on the test procedures outlined in *ASTM D 6244-98, Test Method for Vertical Compression of Geocomposite Pavement Panel Drains* (1998) and the ability to video inspect the core.
  - Careful compaction control is required during construction for either type of drain to avoid dips in shoulders due to densification of fill over time.

- *Outlet Pipe and Spacing*
  - The outlet pipe should be a 100-mm (4-in.) diameter stiff, nonperforated smooth-walled PVC or HDPE pipe with a minimum slope of 0.03 m/m (3 ft in 100 ft). Good compaction control of backfill below, around, and above the pipe is required to avoid transverse shoulder sags (see Figure 13b). Alternatively, flowable fill could be considered to facilitate backfill placement and eliminate sag problems.
  - Wide radius outlet connections are recommended to facilitate flushing and video inspection, as shown in Figure 15. Two 45° couplings could also be used to form a broad turn.
  - The outlet spacing should be close enough to allow self-flushing of the mainline and facilitate inspection and maintenance flushing. Based on the reported problems with wide spacing from the survey, the 75-m (250-ft) spacing recommended by the FHWA (FHWA 1992) appears to be most appropriate.

- *Headwalls*
  - Large, flat, ground-level precast or cast-in-place headwalls that allow mowers to pass over top without excessive maneuvering are recommended by most agencies. The headwall should be sufficiently large, or 20- to 75-mm (3/4- to 3-in.) graded stone could be placed around it to inhibit vegetation encroachment as recommended by Kentucky. The headwall should be balanced to provide a uniform pressure on the subgrade such that backward tilting is avoided. Several examples are shown in Figure 16.

- *Delineation Post Versus Pavement Markings*
  - One of the detriments to an effective subsurface drain system maintenance strategy is the inability to locate the outlets for visual inspection and maintenance. Delineator posts, although an effective means of marking, were reported to cause problems with mowing. Another option reported to work well by several agencies is the use of permanent (e.g., painted or stamped) pavement markings, as shown in Figure 17.

The edgedrain system with the least maintenance would be a system with minimal or no outlets (i.e., outletting into another drainage structure such as a catch basin, drop inlet, manhole, cross pipe, etc.). This can be accomplished by using a double-pipe system consisting of a large diameter collector pipe running below a perforated drainage pipe. The collector pipe can be placed in the same trench, in a parallel trench beneath the shoulder, or in the ditch line. These systems have been successfully used in California, Kentucky (Figure 18), and several European countries (e.g., see Figure 5). The increased cost of the double-pipe system will most likely be offset by the maintenance dollars saved. However, although the double-pipe systems are low maintenance, some maintenance may still be required. Siltation of pipes can still occur over time, especially if pipes are crushed or sags are built into the system. To avoid extensive maintenance, inspection ports should be included in the design to facilitate both end-of-construction inspection and flushing. Kentucky has developed a minimum manhole for their ditch line collector (Figure 18) that serves these functions.

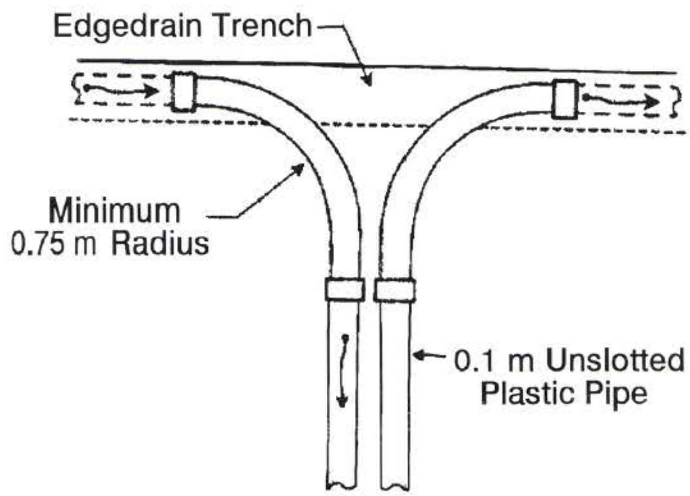
CONSTRUCTION REQUIREMENTS TO MINIMIZE MAINTENANCE

Inspection and traffic control during construction are the two primary items that can have the greatest impact on reducing maintenance requirements. Compaction control of backfill placement in the mainline and outlet trenches is essential to avoid sags in pipes and dips in shoulders due to densification of fill over time. Sequencing of construction activities is also important to minimize exposure of edgedrains to construction activities. Although sequencing is best left to the contractor, emphasis should be placed on backfilling trenches as soon as possible and restricting construction traffic within the vicinity of edgedrains. Outlet construction should receive as much care as the mainline construction.

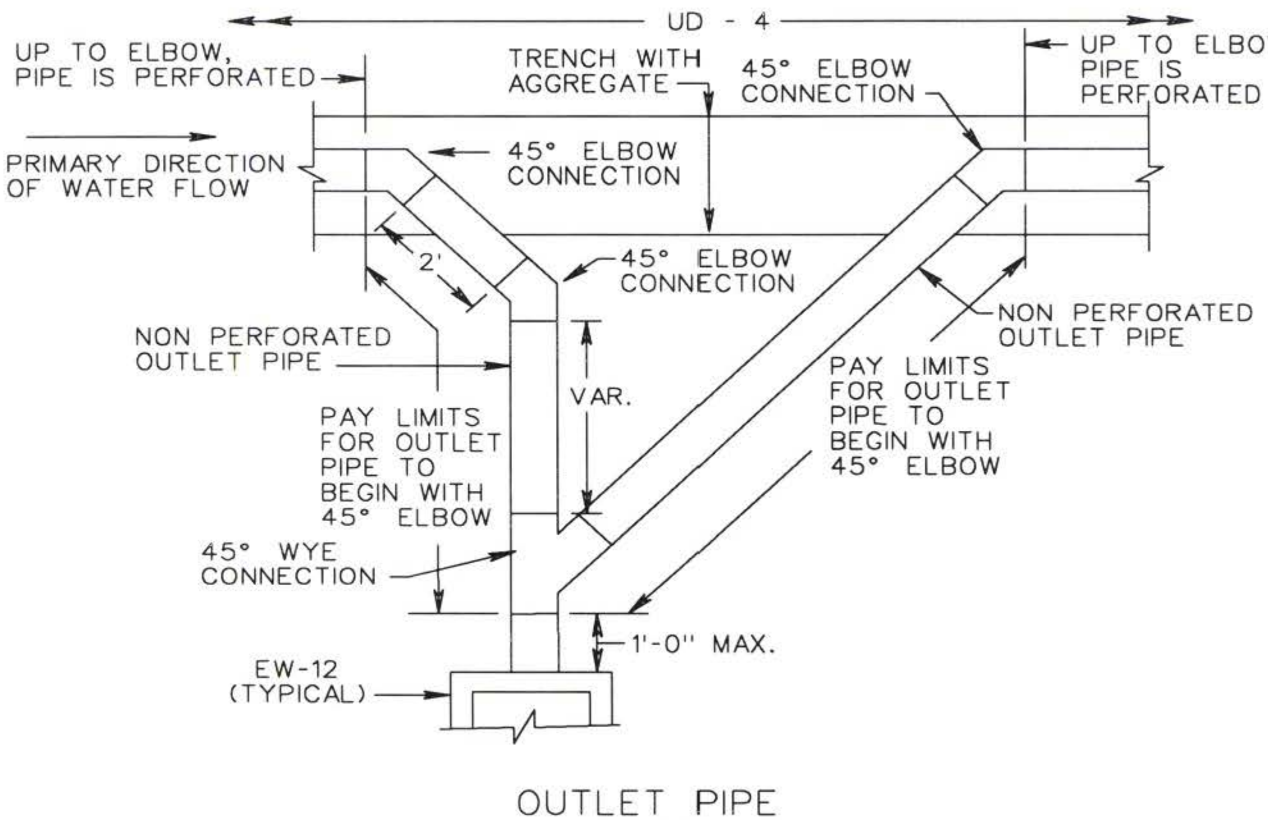
The inspection phase of maintenance actually starts during construction. Visual inspection of completed edgedrains alone will not provide adequate information to assure that the edgedrain has been properly constructed. Video inspection of the completed edgedrain is suggested for final acceptance of the project. Based on a review of those states that are currently performing video inspection, as reviewed in this synthesis, it is clear that most of the construction-related problems such as crushed pipe, contaminated edgedrains, and sags can be eliminated.

EFFECTIVE MAINTENANCE STRATEGIES

The most effective maintenance programs include the following five phases:

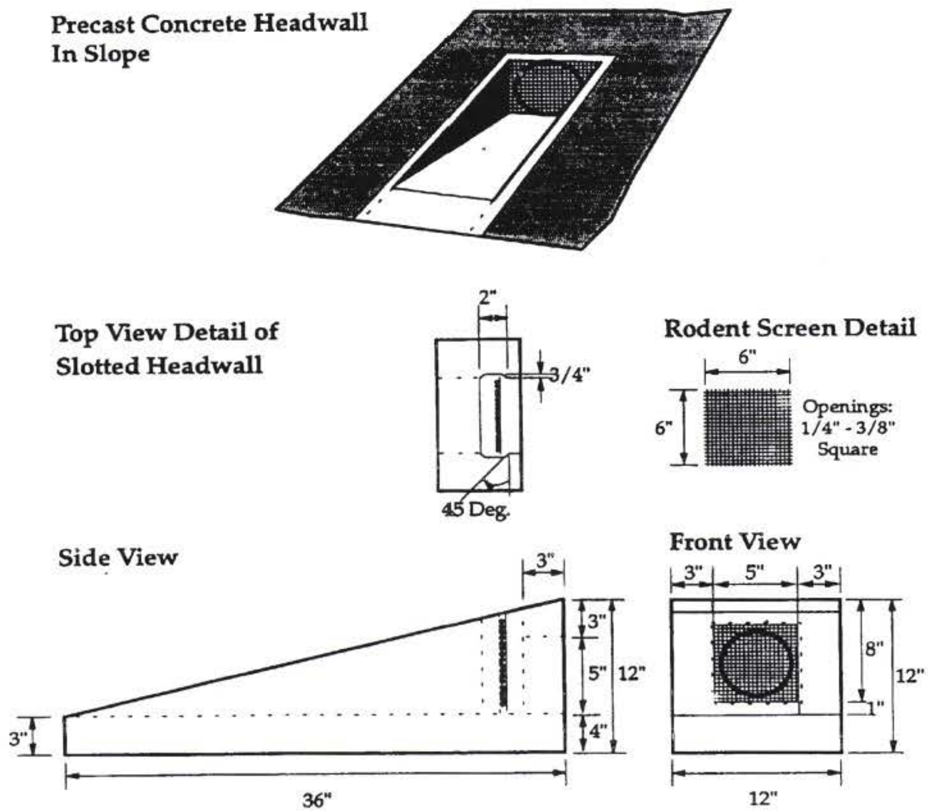


a)

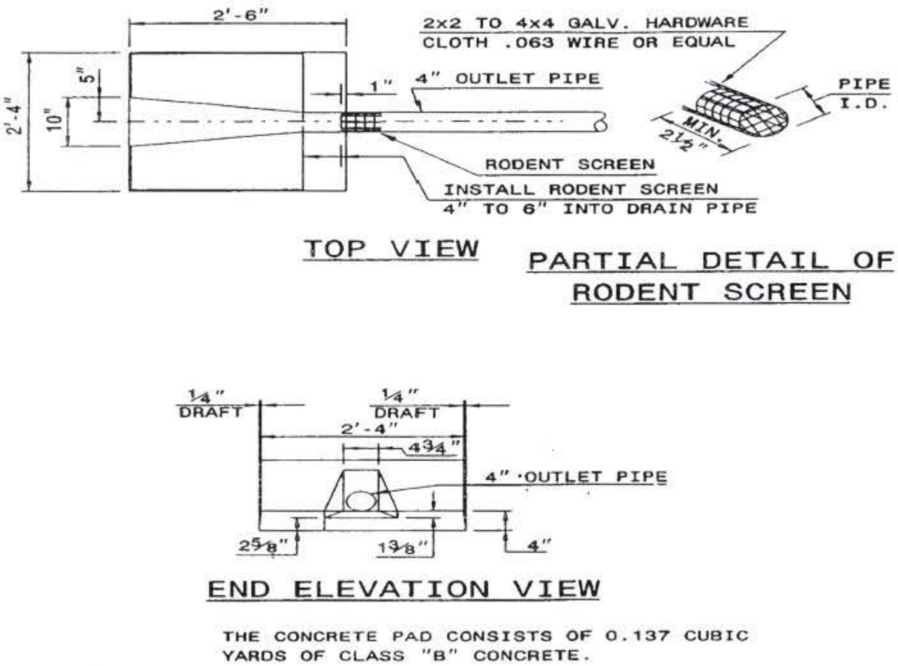


b)

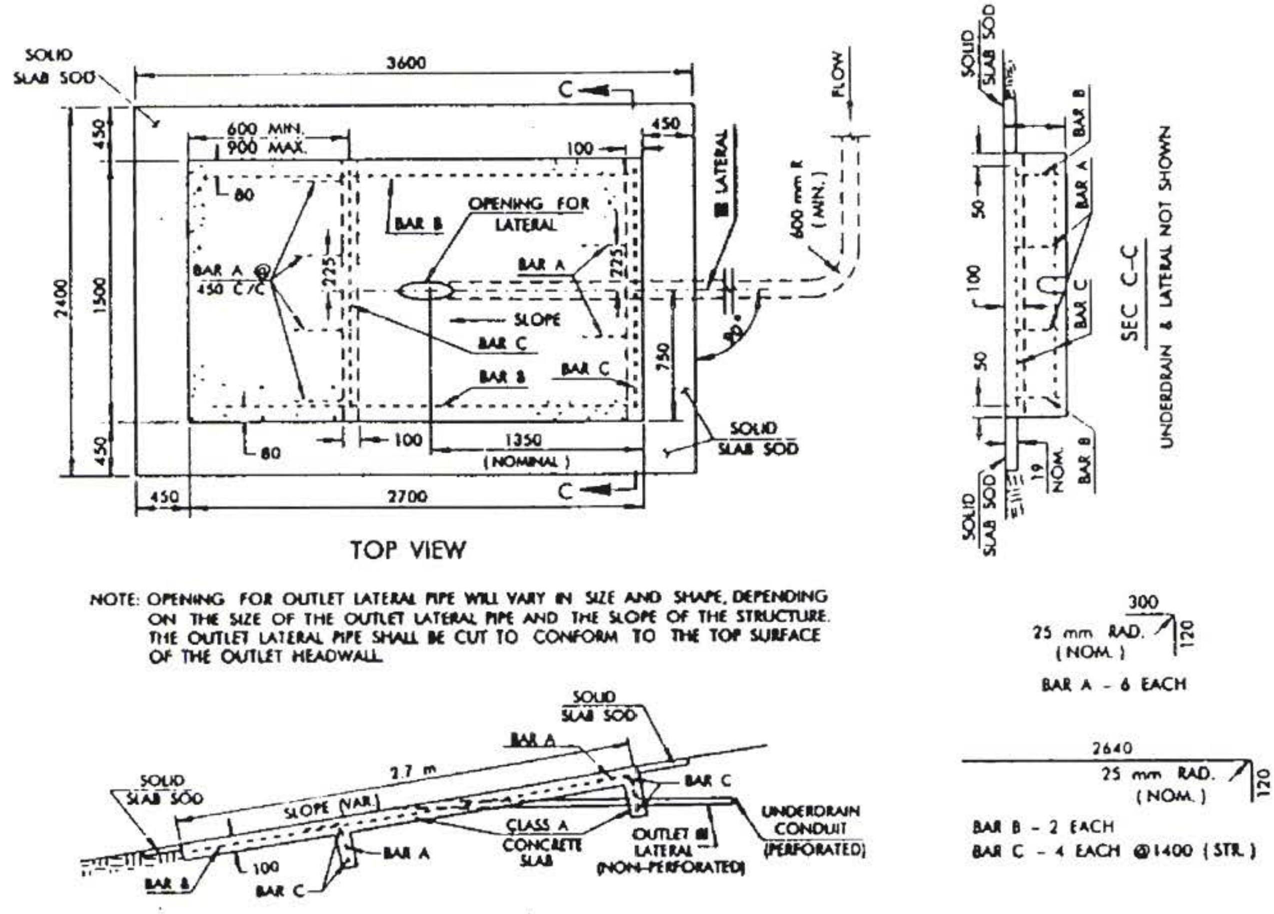
FIGURE 15 Outlet connection detail to facilitate video inspection and flushing: *(a)* FHWA recommended wide radius bend design (FHWA 1992); *(b)* angle couplings for broad turns plus upstream and downstream access (Virginia DOT).


Precast Concrete Headwall
In Slope
Top View Detail of
Slotted Headwall
2"
3/4"
45 Deg.
Rodent Screen Detail
6"
6"
Openings:
1/4" - 3/8"
Square
Side View
3"
3"
5"
12"
4"
3"
36"
Front View
3"
5"
3"
8"
12"
1"
12"

a)


2'-6"
2'-4"
5"
10"
1"
4" OUTLET PIPE
2x2 TO 4x4 GALV. HARDWARE
CLOTH .063 WIRE OR EQUAL
PIPE
I.D.
MIN.
2½"
RODENT SCREEN
INSTALL RODENT SCREEN
4" TO 6" INTO DRAIN PIPE
TOP VIEW
PARTIAL DETAIL OF
RODENT SCREEN
¼"
DRAFT
¼"
DRAFT
2'-4"
4¾"
4" OUTLET PIPE
2⅝"
1⅜"
4"
END ELEVATION VIEW
THE CONCRETE PAD CONSISTS OF 0.137 CUBIC
YARDS OF CLASS "B" CONCRETE.

b)



c)

FIGURE 16 Examples of headwall designs to facilitate maintenance: *(a)* FHWA recommended headwall design (FHWA 1992); *(b)* alternate flared headwall design (North Carolina DOT); *(c)* alternate large cast-in-place and design (Oklahoma DOT).

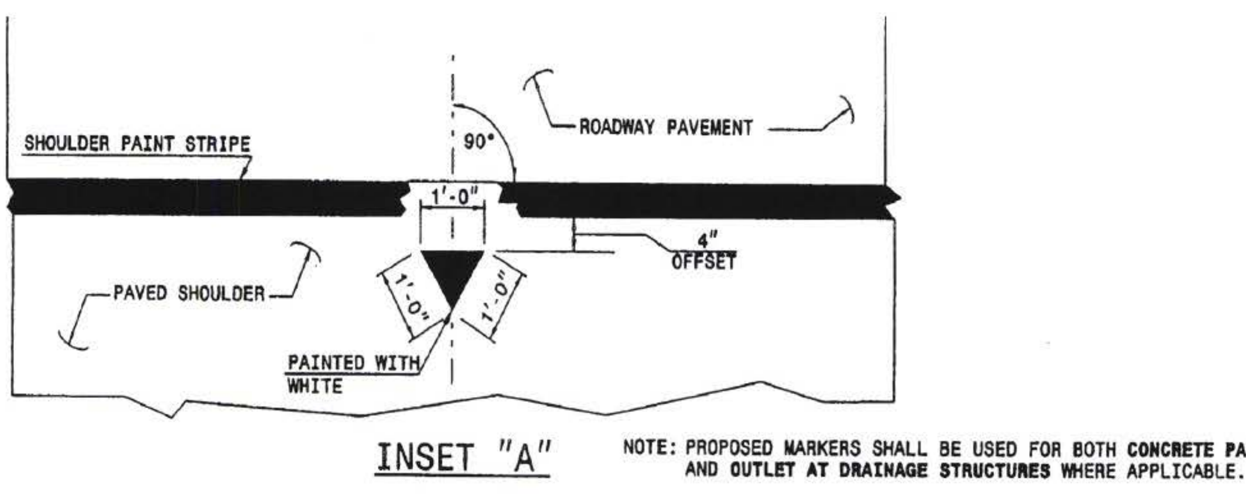


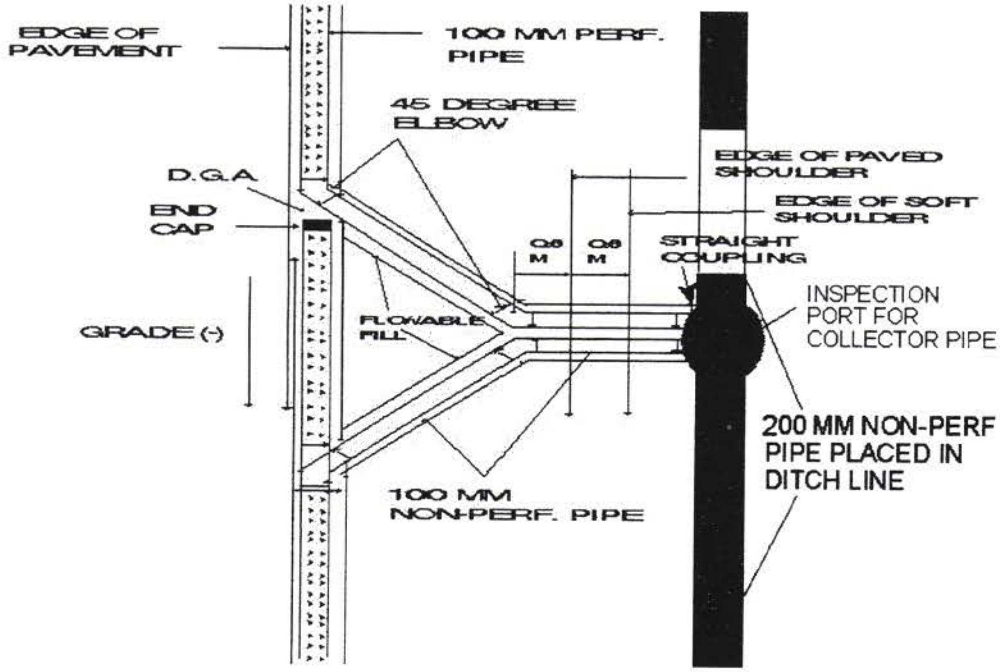
FIGURE 17 Pavement marking scheme (North Carolina DOT).

- Inspection and monitoring,
- Preventive maintenance,
- Detection,
- Repair, and
- Continued monitoring and feedback.

Each phase is reviewed in relation to edgedrain maintenance requirements in the following subsections.

Inspection and Monitoring

Continued inspection following construction provides important data on the effectiveness of drainage elements and the need for further maintenance. Inspection practices include visual inspection, video inspection, and effectiveness testing. Visual inspection consists of an inventory of outflow following storm events and of the outlet condition.



a)

b)

FIGURE 18 Low maintenance, dual pipe edgedrain with ditch line collector used in Kentucky: *(a)* loop edgedrain with ditch line collector; *(b)* inspection port (Fleckenstein and Allen 1999).

Inventories are generally qualitative for outflow assessment (e.g., high, moderate, low, and no flow). A typical visual inspection should examine (Sawyer 1998):

- Outlet conditions
  - Is the outlet opening at least 150 mm (6 in.) above the 10-year flow of the invert of the ditch?
  - Is the outlet open?
  - Is the headwall stable?
  - Is the rodent screen in place?
  - Is vegetation encroaching on the outlet opening?
  - Is the outlet pipe showing signs of deterioration?

- Roadway conditions
  - What is the condition of the roadway in the proximity to the outlet?
  - Are problems water related?
  - Has the roadway been patched since the installation?
  - Are there shoulder dips either along the edge of the road or in the proximity of the outlets?

In addition to the visual inspection, video inspection can be used to examine the interior of the edgedrain. Video inspection should be used to answer the following:

- Is the drainpipe crushed?
- Is there backfill in the pipe?
- Is sediment being deposited in the pipe?
- Is water standing in the pipe?
- Are the joint connections in satisfactory condition?
- Is there any deterioration of the pipe? (corrosion? abrasion?)
- Have vehicles damaged the pipe?

Inspection forms for both visual and video inspection are included in Appendixes D and E.

Effectiveness provides a more quantitative assessment of performance and consists of post-storm event monitoring with bucket sampling, tip buckets set up at strategic locations, or direct upstream inflow and downstream outflow measurements. Design should facilitate inspection and effectiveness testing by including pipe access at the "upstream" end of all drain lines.

Preventive Maintenance

Preventive maintenance actions from *NCHRP Synthesis 239* that help control the subsurface drainage system performance include (FHWA 1990):

- Clean and seal joints and cracks,
- Clean and verify grade of outlet ditches,
- Clean catch basins or other discharge points, and
- Clean outlet screen and area around headwalls.

A joint sealing policy should be implemented in conjunction with drainage of the pavement system to both reduce the water inflow and prevent wash in of particulate that can clog the drainage system [*NCHRP Synthesis 96* (Ridgeway 1982) and *NCHRP Synthesis 211* (McGhee 1995), respectively]. Guides for joint sealing are reviewed in *NCHRP Synthesis 211* (McGhee 1995) and detailed by the FHWA (1990), the American Concrete Pavement Association (1993), and the Strategic Highway Research Program (1993).

A common problem with edgedrains is blockage of the outlet due to sedimentation in the ditch (Sawyer 1998). Based on inspection and monitoring, ditches should be regraded to maintain their level well below the outlet opening [i.e., outlets should be at least 150 mm (6 in.) above the 10-year-flow level]. Vegetation that inhibits flow and collects sediments should also be removed near the outlet and regrowth controlled with herbicides or aggregate blankets.

Pipe flushing using high-pressure water jets on a regularly scheduled basis (e.g., once per year) is also an effective maintenance strategy (Figure 19). Access should be

a)

b)

FIGURE 19 Pipe flushing using high-pressure water jets (courtesy of FHWA): *(a)* high-pressure water jet with reverse thrusters; *(b)* flushing edgedrain.

provided to aid in inspection and flushing of subsurface drainage systems (Wells and Nokes 1993 and present survey results).

A routine outlet-cleaning program (e.g., on a biannual basis) could also be implemented based on the results of the outlet inspection program. With minimal training, mowing crews could be made responsible for checking and cleaning the outlets.

Repair

Once pavement damage from blocked subsurface drainage is visible, the damage is irreversible and the pavement life has been shortened (Ray and Christory 1989). Any problem(s) observed, no matter how minor in appearance, should be addressed immediately to confine it to a localized area. A damaged or nonfunctional outlet, clogged outlet, buried outlet, deposits at outlet, and water above outlet need prompt attention, as distress in the pavement is imminent. When blockage is apparent in the drain line, flushing may be performed. If flushing is not successful, the drain line may require replacement. Problem areas are often found in the last 6 m (20 ft) of an edgedrain or in the outlet (Sawyer 1998). Excavation of the outlet causes no serious problems to the roadway until the excavation reaches the shoulder. At that point extreme care must be taken to avoid undermining or disturbing the roadway support materials.

As indicated in *NCHRP Synthesis 239*, distress in the surface of the pavement or shoulder, seepage from cracks or joints, pumping, or frost heaves are signs that blockage of the drainage system has already occurred. When distress is visible it is often too late for maintenance to help and replacement of the pavement section is usually the only viable option.

Continued Monitoring and Feedback

Monitoring is a continuous improvement process, especially of sections that did not perform as intended. Again, field maintenance crews could provide this feedback on a continuous basis. Maintenance improvements are only achieved through feedback to design and construction. Maintenance staff should provide inspection results along with performance indicators to both design and construction units for their review. The information on performance of treatments and the cost to apply such treatments should also be fed into the DOT's pavement management system, maintenance management system, and cost accounting system. As previously indicated, video inspection provides an excellent inspection as well as a pavement management systems tool.

A training program for the maintenance staff on appropriate subsurface drainage strategies and their importance to the long-term pavement performance should also be a part of the feedback process.

CHAPTER SEVEN

CONCLUSIONS

Now that many of the interstate highways have been retrofitted with edgedrains, usage appears to have leveled off, and a decrease in the use of PGEDs has apparently occurred over the past several years. However, the annual edgedrain usage and the total amount of installed edgedrain are still significant. Unfortunately, most of those edgedrains are not well maintained, as most states indicate that they do not have an edgedrain maintenance program. Even for states that have a program, with few exceptions, the number of person hours per year would still indicate that more attention is needed. Lack of funding and human resources were the predominant reasons given for not having a program.

Several design issues were also noted. Most agencies have found corrugated plastic and metal pipe to be very susceptible to problems for outlets and have discontinued their use in favor of stiff, smooth-walled PVC or HDPE pipe. A relatively wide spacing (over twice the FHWA recommended spacing) is being used by most agencies. Also, most agencies are now using precast or cast-in-place headwalls, and many states still do not mark their outlets.

Those agencies that do have preventive maintenance programs have significantly improved their edgedrain performance. A team approach, in which all functional groups are involved in the design, construction, and maintenance decision process, has successfully been used by several agencies to gain these improvements. For example, in one case the agency improved from an edgedrain failure rate of 40 percent to a current failure rate of less than 5 percent. These improvements have been obtained through feedback between maintenance, design, and construction units that have resulted in more effective designs, improved construction monitoring and inspection, and continued improvement through periodic inspection, long-term monitoring, and surveys. Video cameras have proven to be a valuable tool for many of the agencies in identifying problems and exposing weaknesses in construction and inspection procedures. Many states currently do or will shortly require video inspection for construction acceptance. Scheduled periodic flushing and outlet cleaning have also been found to be very effective preventive maintenance tools. The majority of the agencies responding to the survey indicated that inadequate maintenance and inadequate construction caused most of the premature failures of edgedrains. Considering the relation between pavement performance and edgedrain performance, agencies that are incorporating the aforementioned preventive maintenance concepts are most likely saving significant taxpayer dollars in the form of reduced pavement repair cost; as high as $10 for each dollar spent on edgedrain maintenance. As stated by one agency, "you take care of the subsurface drainage, you eliminate most of your problems, and the pavement lasts longer."

A commitment to long-term maintenance will lead to optimum performance of the edgedrain and ultimately the pavement system. Several other significant conclusions have been found by this study, including:

- The cost of maintenance is far outweighed by the anticipated design life of the road that comes with edgedrains that perform.
- There is a significant cost in terms of poor performing pavements to agencies that use edgedrains and do not have an effective preventative maintenance program.
- Based on the results of *NCHRP Synthesis 239*, and confirmed by literature reviewed in this synthesis, there is a significant cost in terms of poor pavement performance to agencies that are not using edgedrains.
- Edgedrain failures have occurred where the water could not get out of the base fast enough (e.g., no pipe outlets, plugged outlets, crushed outlets, clogged filters, or clogged drains). Many drainage system failures are traced to poor construction and inspection.
- All maintenance personnel should be made aware that a plugged subsurface drainage system may be worse than no drainage system because the pavement system becomes permanently saturated.
- Maintenance efforts vary between good and nonexistent within a state and among different states.
- There is an apparent disconnect between maintenance, design, and construction in many state agencies.
- Long-term maintenance is essential to obtain the anticipated performance benefits of drainable pavement systems.
- Training of construction and inspection staff is important to improve drainable pavement performance.

This synthesis did not find that considerable additional research on edgedrains from a maintenance perspective was needed. Notably missing from the findings of this synthesis was the impact of "Superpave" on drainage requirements, which appears to also be missing from much of the literature on Superpave. The use of Superpave may make functional drainage systems even more important and could be evaluated in relation to the current edgedrain design and maintenance practices reviewed in this synthesis. Additional information on the cost-benefit ratio of drainage systems would also be useful to document the limited existing studies, e.g., more quantitative correlation between pavement performance and edgedrain performance. Most important, a significant effort could be directed toward the development of national and local training programs for all personnel involved with the pavement systems including administrative, design, construction, and maintenance staff on the importance of proper installation and maintenance of edgedrains.

REFERENCES

AASHTO Guide for Design of Pavement Structures, American Association of State Highway and Transportation Officials, Washington, D.C., 1993.

Ahmed, Z. and T.D. White, "Methodology for Inspection of Collector Systems," *Transportation Research Record 1426*, Transportation Research Board, National Research Council, Washington, D.C., 1993, pp. 37–44.

Annual Book of ASTM Standards, Section 4 Construction, Volume 0409 Soil and Rock (II): D 4943–latest: Geosynthetics, American Society for Testing and Materials, West Conshohocken, Pa., 1999.

Baldwin, J.S., "Evaluation of Pumping Pavement on Interstate 77," *Transportation Research Record 1329,* Transportation Research Board, National Research Council, Washington, D.C., 1991, pp. 36–41.

Baumgardner, R.H., "Video Inspection of Highway Edgedrains," *Proceedings of the International Symposium on Subdrainage in Roadway Pavements and Subgrades*, PIARC, Granada, Spain, Nov. 11–13, 1998.

Cedergren, H.R., *Seepage, Drainage and Flow Nets,* John Wiley and Sons, New York, N.Y., 1989.

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

Christopher, B.R., S.A. Hayden, and A. Zhao, "Roadway Base and Subgrade Geocomposite Drainage Layers," *Testing and Performance of Geosynthetics in Subsurface Drainage, ASTM STP 1390*, J.S. Baldwin and L.D. Suits, eds., American Society for Testing and Materials, West Conshohocken, Pa., 1999.

Christopher, B.R. and V.C. McGuffey, *NCHRP Synthesis of Highway Practice 239: Pavement Subsurface Drainage Systems,* Transportation Research Board, National Research Council, Washington, D.C., 1997.

Christory, J.-P., "Assessment of PIARC Recommendations on the Combating of Pumping in Concrete Pavements," *6th International Symposium on Concrete Roads*, PIARC, Madrid, Spain, 1990.

Concrete Pavement Joints, Technical Advisory 5040.30, Federal Highway Administration, U.S. Department of Transportation, Washington, D.C., 1990.

Daleiden, J.F. and L.L. Peirce, "Video Inspection of Subsurface Drainage Systems in Roadway Construction," Preprint No. 97-1319, Prepared for the 76th Annual Meeting of the Transportation Research Board, National Research Council, Washington, D.C., 1997.

Daleiden, J., "Video Inspection of Highway Edgedrain Systems," *Final Report to FHWA*, BrentRauhut Engineering, 1998.

Demonstration Project 87: Drainable Pavement Systems, Participant Notebook, Publication FHWA-SA-92-008, Federal Highway Administration, U.S. Department of Transportation, Washington, D.C., 1992.

FHWA Technical Guide Paper 90-01: Subsurface Pavement Drainage, Federal Highway Administration, Office of Engineering, Pavement Division, Washington, D.C., Oct. 1990.

Fleckenstein, L.J. and D.L. Allen, "Development of a Performance-Based Specification (QC/QA) for Highway Edge Drains in Kentucky," *Testing and Performance of Geosynthetics in Subsurface Drainage, ASTM STP 1390*, J.S. Baldwin and L.D. Suits, eds., American Society for Testing and Materials, West Conshohocken, Pa., 1999.

Forsyth, R.A., G.K. Wells, and J.H. Woodstrom, "The Economic Impact of Pavement Subsurface Drainage," *Transportation Research Record 1121*, Transportation Research Board, National Research Council, Washington, D.C., 1987, pp. 77–85.

Ghaffori, N. and S. Dutta, "Development of No-Fines Concrete Pavement Applications," *Journal of Transportation Engineering*, Vol. 121, No. 3, American Society of Civil Engineers, New York, N.Y., 1995, pp. 283–288.

Geoffroy, G.N., *Synthesis of Highway Practice 223: Cost-Effective Preventive Pavement Maintenance*, Transportation Research Board, National Research Council, Washington, D.C., 1996.

Hagen, M.G. and G.R. Cochran, "Comparison of Pavement Drainage Systems," *Transportation Research Record 1519,* Transportation Research Board, National Research Council, Washington, D.C., 1996, pp. 1–10.

Highlands, K.L., R. Turgeon, and G.L. Hoffman, "Prefabricated Pavement Base Drain," *Transportation Research Record 1329,* Transportation Research Board, National Research Council, Washington, D.C., 1991, pp. 42–48.

Holtz, R.D., B.R. Christopher, and R.R. Berg, *Geosynthetic Design and Construction Guidelines (Participant Notebook)*, NHI Course No. 13213, FHWA Publication HI-95-038, Federal Highway Administration, U.S. Department of Transportation, Washington, D.C., 1998.

Hoppe, E.J., "PIARC Committee C-12 International Survey on Roadway Subdrainage," *Proceedings of the International Symposium on Subdrainage in Roadway Pavements and Subgrades*, PIARC, Granada, Spain, Nov. 11–13, 1998.

Joint and Crack Sealing and Repair for Concrete Pavements, Report TB-012.0, American Concrete Pavement Association, Skokie, Ill., 1993.

Koerner, R.M., G.R. Koerner, A.K. Fahim, and R.F. Wilson-Fahmy, *NCHRP Report 367: Long-Term Performance of Geosynthetics in Drainage Applications*, Transportation Research Board, National Research Council, Washington, D.C., 1994.

McGhee, K.H., *NCHRP Synthesis of Highway Practice 211: Design, Construction, and Maintenance of PCC Pavement Joints,* Transportation Research Board, National Research Council, Washington, D.C., 1995.

"Materials and Procedures for the Repair of Joint Seals in Concrete Pavements," *Concrete Pavement Repair Manuals of Practice, SHRP-H-349*, Strategic Highway Research Program, National Research Council, Washington, D.C., 1993.

Moulton, L.K., *Highway Subdrainage Design*, Report FHWA-TS-80-224, Office of Research and Development, Federal Highway Administration, U.S. Department of Transportation, Washington, D.C., 1980.

Ray, M. and J.P. Christory, "Combating Concrete Pavement Slab Pumping State of the Art and Recommendations (in France)," *Proceedings of the 4th International Conference on Concrete Pavement Design and Rehabilitation*, PIARC Technical Committee on Concrete Roads, Purdue University, West Lafayette, Ind., 1989.

Raymond, G.P., R.J. Bathhurst, and J. Hajek, "Geosynthetics Use in Cold Climate Pavement Drainage," *Proceedings of the 49th Canadian Geotechnical Conference*, Canadian Geotechnical Society, St. John's, Newfoundland, 1996.

Raymond, G.P., R.J. Bathhurst, and J. Hajek, "Evaluation and Suggested Improvements to Highway Edgedrains Incorporating Geotextiles," *Geotextiles and Geomembranes*, Vol. 18, No. 1, Feb. 2000, pp. 23–45.

Raymond, G.P. and R.J. Bathurst, "Facilitating Cold Climate Pavement Drainage Using Geosynthetics," *Testing and Performance of Geosynthetics in Subsurface Drainage, ASTM STP 1390*, L.D. Suits, J.B. Goddard, and J.S. Baldwin, Eds., American Society of Testing and Materials, West Conshohocken, Pa., 2000.

Ridgeway, H.H., *NCHRP Synthesis of Highway Practice 96: Pavement Subsurface Drainage Systems*, Transportation Research Board, National Research Council, Washington, D.C., 1982.

Sawyer, S., "Design—Construction—Maintenance: A Synergistic Approach to Pavement Subdrainage Systems," *Proceedings of the International Symposium on Subdrainage in Roadway Pavements and Subgrades*, PIARC, Granada, Spain, Nov. 11–13, 1998.

Snyder, M.B. and J.E. Bruinsma, "A Summary of Field and Laboratory Studies of the Effects of Unbound Crushed Concrete Bases on PCC Pavement Drainage," *Transportation Research Record 1519*, Transportation Research Board, National Research Council, Washington, D.C., 1996, pp. 51–58.

Steffes, R.F., V.J. Marks, and K.L. Dirks, "Video Evaluation of Highway Drainage Systems," *Transportation Research Record 1329*, Transportation Research Board, National Research Council, Washington, D.C., 1991, pp. 27–35.

Test Methods for Vertical Compression of Geocomposite Pavement Panel Drains, ASTM D6244, American Society for Testing and Materials, West Conshohocken, Pa., 1998.

Wells, G.K. and W.A. Nokes, "Performance of Retrofit Edge Drain Projects," *Transportation Research Record 1425*, Transportation Research Board, National Research Council, Washington, D.C., 1993, pp. 11–17.

APPENDIX A

Survey Questionnaire

National Cooperative Highway Research Program

NCHRP Synthesis Topic 30-10

QUESTIONNAIRE

MAINTENANCE OF HIGHWAY EDGEDRAINS

PURPOSE OF THIS SURVEY

A previous survey on pavement subsurface drainage systems (NCHRP Synthesis 239) indicated that many respondents (mostly designers) have little information on maintenance activities within their agency. However, almost all respondents agreed that maintenance is the most important aspect that contributes to long-term performance of pavement subsurface drainage systems. The purpose of this nationwide survey is to identify practices and procedures for maintaining the edgedrain system (i.e., outlet, headwall, connection, longitudinal pipe). Equally important, this study is to identify design and construction procedures that will reduce and facilitate the maintenance of edgedrains.

The questionnaire is moderately extensive and will require patience and dedication from Maintenance, Construction, and Design respondents. Although this is time consuming, it is the only way to get a comprehensive national review of this issue. Please complete the following information:

Agency: ____________________
Address: ____________________
City: ____________ State: ____________ Zip: ____________

Questionnaire completed by: ____________________

Position Title: ____________
Date: ____________
Telephone: ____________
Fax: ____________
e-mail: ____________

RETURN QUESTIONNAIRE AND SUPPORTING DOCUMENTS BY: **June 5, 1999**

TO: Barry Christopher
210 Boxelder Lane
Roswell, GA 30076

For questions contact him by phone: 770-641-8696; fax: 770-645-1383; or e-mail: barryc325@aol.com

Note: For this survey the following definitions are used:

- Edgedrain: A subsurface drain usually located at the edge of the pavement (between pavement and shoulder) at an appropriate depth to intercept expected pavement section infiltration water.
- Prefabricated Geocomposite Edgedrain (PGED): An edgedrain consisting of an extruded plastic drainage core with a geotextile filter (a.k.a. panel drain, fin drain).
- Outlet: The point of discharge of an edgedrain. It may be the pipe, headwall, or a catch basin.
- Outlet pipe: The lateral connection from the edgedrain to the outlet. Usually a solid, strong pipe to prevent damage.
- Longitudinal pipe: A perforated pipe in drain required to carry the flow to the outlet pipe.
- Connection: Connector between the longitudinal pipe or PGED and the outlet pipe.
- Headwall: A protective structure at an edgedrain outlet.
- Underdrain: A deep subsurface drain located at a sufficient depth to intercept and lower the groundwater to a required design level. (Note: not part of this study.)

Section 1 Current Edgedrain Usage

1) About how much edgedrain is used per year for each type of shoulder? (Lane-kilometers or miles)

	Portland Cement Concrte Pavement			Asphalt Cement Pavement		
	Concrete Shoulder	Asphalt Shoulder	No Shoulder	Concrete Shoulder	Asphalt Shoulder	No Shoulder
New Road Construction						
Roadway Construction						
Retrofit Edgedrains						

2) What percent of edgedrain are:

	New Roadway Construction	Roadway Reconstruction	Retrofit Edgedrain
Graded aggregate around pipe			
Sand filter around pipe			
Geotextile wrapped aggregate with pipe			
Prefabricated geocomposite edgedrain			
Other (explain			
Total—100%			

Please provide standard details and specifications for each system used.

3) What percentage of edgedrain pipes are:

Type of Pipe	Longitudinal Mainline	Outlet Pipe
Stiff, smooth wall plastic HDPE or PVC		
Corrugated plastic HDPE or PVC		
Composite		
Metal		
Other		
Total—100%		

4) What type of connection is used between the longitudinal mainline pipe and the outlet pipe (e.g., tee, angled, wye, radius bend, other)? ______________________

Please provide standard details.

5) What is the typical outlet spacing(s)
with open graded, drainable base? ____________
with dense graded base? ____________

6) What is the percentage of use for each of the following types of outlet headwalls?

Prefabricated headwall ____________
Cast in place headwall ____________
No headwall (pipe only) ____________
Catch basin ____________
Other ____________
Total—100 %

Please provide standard details for each type used.

7) How are outlet locations identified (marked)? ____________

Please provide standard details.

Section 2 Edgedrain Maintenance Program

8) Does your agency have a formal edgedrain maintenance program?
❑ Yes ❑ No

If no, why not? ____________

If yes, please describe your program (e.g., worst to first, preventive by project, preventive by network, or other) and provide a copy of the maintenance policy.

Program type: ____________

Please describe: ____________

9) Is maintenance tied into your agency's pavement management system?
❑ Yes ❑ No ❑ the agency does not have a pavement management system

If yes, please describe the performance indicator (e.g., correlation of pavement distress with edgedrain performance):

Do you have data to support the performance indicator?
❑ Yes ❑ No

If yes, please send any supporting data (study results, reports, memoranda).

10) If you have a preventative maintenance program
a) do the components include: inventory ____________
inspection survey ____________
scheduling ____________
other ____________

b) are drainage surveys routinely performed?
❑ Yes ❑ No

If yes, please provide a copy of Survey Inspection/Maintenance forms.

What is the frequency? ________________

Please describe the survey procedures: ____
____
____

c) Does your agency own (or lease) a video camera?
❑ Yes ❑ No

If yes, is it used as part of the survey?
❑ Yes ❑ No

If yes, what is the frequency (e.g., every inspection)?
for the mainline ____________________
for the outlet ____________________

If a video camera is used, please provide details of equipment (manufacturer, model, components, cost):
____
____

Please note any limitations or problems you have experienced with this equipment:
____
____

11) Do you have any data on cost effectiveness of drainage surveys?
❑ Yes ❑ No

If yes, please send any supporting data (study results, reports, memoranda).

12) What types of maintenance are done on underdrains?
(3-always, 2-sometimes, 1-never)
Flush ________________
Clean outlet ________________
Replace ________________ Describe component(s) ________________________________
____

Other (name)____

Comments____
____

13) Which type of headwall system used by your agency (see question 5) requires the least maintenance or is the easiest to maintain? ____
____

14) Have you experienced any of the following problems with edgedrains or outlets and, if so, what is the extent of the problem?
❑ Yes ❑ No

	Yes/No	Frequency of Occurrence
Mowing damage	_____	____________________
Rodent problems (e.g., ineffective guards)	_____	____________________
Erosion - Upstream	_____	____________________
Erosion - Downstream	_____	____________________
Sags in mainline	_____	____________________
Sags in outlet pipe	_____	____________________
Clogging of edgedrain	_____	____________________
Others (please describe)	_____	____________________

Please describe any procedures that your agency has developed to mitigate the identified problems.

___

(use extra sheets if necessary)

15) Approximately how many man-hours are expended each year for edgedrain maintenance? ________man hours/year

Is maintenance performed by in-house or by contract personnel? ________

What types of training are provided to edgedrain maintenance personnel? ________

Please send any data on cost effectiveness of your agencies maintenance practices.

Section 3 Interaction of Maintenance with Design and Construction

16) Is the maintenance group involved in design decisions?
❑ Yes ❑ No

If yes, please describe the interaction mechanism (e.g., team approach, plans review at ____% stage, etc.):

___

17) Is there a feedback system between maintenance and design to report maintenance issues?
❑ Yes ❑ No

If yes, please describe and provide copies of any forms: ________

Please identify any design changes that your agency has (or should) implement(ed) that have reduced and/or facilitated edgedrain maintenance. ________

18) Are any special inspection or testing of subsurface drain systems performed before construction acceptance?
❑ Yes ❑ No

Please describe: ________

Is a video camera used for construction:
Inspection? ❑ Yes ❑ No
Acceptance? ❑ Yes ❑ No

Is the maintenance group involved in decisions on inspection requirements?
❑ Yes ❑ No

Comments ________

19) Is there a feedback system between maintenance and construction to report maintenance issues with construction practices?
❑ Yes ❑ No

If yes, please describe and provide copies of any forms: ________

Please identify any construction changes that your agency has (or should) implement(ed) that has reduced and/or facilitated edgedrain maintenance. ____

____

____

Section 4 Effectiveness

20) Which of the following do you believe are causes of premature failures of edgedrain systems?
(3-always, 2-sometimes, 1-never)

Inappropriate design? ____________
Absence of paved shoulders? ____________
Poor construction of edgedrains? ____________
Poor construction of outlets? ____________
Failure of paved shoulder? ____________
Inadequate maintenance? ____________
Unrecognizable site problems? ____________
Other? ____

21) Where do you think the greatest improvement in edgedrain systems would come from?
a) more basic research? ______________________________
b) more training? ______________________________

22) Has the maintenance group developed any correlation between improved pavement performance for paving systems with edgedrains (e.g., data showing pavement systems with drainage require less maintenance than pavement systems without drainage)?
❑ Yes ❑ No

Comments____

____

____

If yes, please send any supporting data (study results, reports, memoranda).

23) Has the maintenance group developed any correlation between pavement and edgedrain performance (e.g., data showing poor pavement performance in relation to edgedrain problems)?
❑ Yes ❑ No

Comments____

____

____

If yes, please send any supporting data (study results, reports, memoranda).

NOTE: Please remember to send the following information requested in the questions, if available, including:

- Standard edgedrain details and specifications
- Mainline pipe to outlet pipe connector details
- Standard headwall details
- Standard outlet marking details
- Maintenance policy
- Data supporting performance indicators
- Survey inspection/maintenance forms
- Video camera information
- Data supporting cost effectiveness of drainage surveys
- Description of special edgedrain maintenance problems
- Maintenance procedures to mitigate special problems
- Data supporting cost effectiveness of edgedrain maintenance
- Design/construction feedback forms
- Pavement performance data with and without edgedrains
- Pavement performance data in relation to edgedrain maintenance

Thank you in advance for your time and consideration!

APPENDIX B

Questionnaire: Summarized and Paraphrased Comments Received from Agencies

8) Does your agency have a formal edgedrain maintenance program? If no, why not?

1. Maintenance on an as-needed basis.
2. Maintenance handled by districts. Several districts attempt to clean outlets at least once a year.
3. Not established.
4. Feel it is not currently needed.
5. Limited quantity of edgedrain.
6. Each district handles edgedrain maintenance independently. Typically as part of annual routine spring maintenance.
7. Lack of manpower prevents active program.
8. Not a priority; lack of resources.
9. Can be referenced from as-built plans.
10. Done in conjunction with routine drain line maintenance.
11. Varies from district to district.
12. Not enough edgedrain in use long enough to establish procedures.
13. Very little installed at this time.
14. The pipe plus stone backfill provides a redundant system.
15. Not a priority with upper management.
16. Limited resources plus edgedrains are a relatively new feature for our state. Edgedrains are maintained as needed like any other feature in the system.
17. Insufficient amount.
18. Headquarters has asked that all be inspected.
19. The significant damage caused by poor drainage is not appreciated yet by maintenance officials. They want a maintenance-free system.
20. We do not have many edgedrains in our system.

If yes, please describe your program (e.g., worst-to-first, preventive by project, preventive by network, or other) and provide a copy of the maintenance policy.

1. Preventive by network: (a) inspect every 3 years; clear debris, silt, vegetation, and flush as often as necessary. (b) Clean once per year.
2. Outlet inspection: Outlet inspection only on a manpower available basis; video inspection program is being planned 4 to 5 years to implementation.
3. Preventive maintenance (by project): A minimal amount of edgedrain preventive maintenance is performed because of funding constraints.
4. If done, outlet cleaned yearly.
5. Clean 1/7th of system annually (standard).
6. Inspection and repair as needed.
7. Annual inspection: No formal policy; part of the annual drainage work.

9) Is maintenance tied into your agency's pavement management system?
If yes, please describe the performance indicator (e.g., correlation of pavement distress with edgedrain performance):

1. We use condition rating survey performed once every 2 years.
2. Field engineers check for clogged drains where pavement distress is noted.
3. Being developed.
4. Edgedrain performance is not a performance indicator in MDT's pavement management system.
5. Currently, the maintenance system "feeds" into the pavement management system, but we have no correlation between edgedrains and surface distress.
6. Edgedrains are not tied into their pavement management system.

7. Just started a new pavement management system and are correlating movement distress to edgedrain performance (i.e., pumping, alligator cracks, etc.).

10) If you have a preventative maintenance program (part b) are drainage surveys routinely performed?
Please describe the survey procedures.

1. Several districts have county maintenance office report if drainage (or lack of) becomes a problem on a pavement section. New outlets cut if there is a problem.
2. Yes, but the operation is rather loose and done when manpower is available.
3. Problem is addressed when detected.
4. Windshield inspections.
5. Surveys are done by field crews without a formalized form or instructions. Culverts are looked at to estimate remaining life and to correct those deficiencies noted.
6. Not specifically edgedrains, but all features are looked at during routine safety road patrols, especially during periods of high water or flooding.

12) What types of maintenance are done on underdrains?
Comments

1. Our policy is not followed very well due to lack of manpower.
2. Usually only performed when a roadway is widened, overlaid, or rehabilitated.
3. Maintenance is site-specific and completed under routine drain line maintenance.
4. There is no maintenance, but we may add an additional longitudinal drain and replace the outlets with a pavement project.
5. Flushing and cleaning done infrequently when specific problem is identified.
6. Edgedrain inspection is done before the completion of the project or within 10 working days from completion.
7. Few edgedrains.

13) Which type of headwall system used by your agency (see question 5) requires the least maintenance or is the easiest to maintain?

1. Concrete headwalls work well.
2. Use only concrete headwall with rodent screen. Working very well.
3. Riprap.
4. Precast headwall works well, but damaged by mower.
5. New design is a poured in-place flat concrete slab.
6. Prefabricated, 100-mm × 200-mm × 400-mm (4-in. × 8-in. × 16-in.) concrete block.
7. Prefab only. Easy to clean. No one does it.
8. Outletting into another drainage structure (drop inlet, manhole, cross pipe, etc.); functions with little or no maintenance.
9. Flared-end with riprap is easiest to maintain. Most subdrains outlet into existing surface drainage system catch basins.
10. Prefabricated headwall—currently piloting the use of several experimental headwalls to examine performance and maintenance characteristics.
11. Prefabricated concrete headwall.
12. Concrete pad.
13. Slope paving.
14. Catch basin.
15. Prefabricated headwall.
16. Any system with a concrete headwall is easier to maintain.
17. Cast-in-place.
18. EW-12.
19. Not known.
20. Only use one type in rural areas and catch basins in urban section. Catch basins are easier, simply because they are checked routinely (biannually) for other reasons.

14) Please describe any procedures that your agency has developed to mitigate the identified problems.

1. Investigations using our camera system have found that almost all outlet pipes are crushed either right behind the headwall or at the connection with the edgedrain. We now are using Schedule 40 PVC on the outlets. This problem has slowed down inspection considerably. If we go out to inspect, a backhoe and several feet of PVC are needed because outlets will have to be replaced. We recently purchased a flushing trailer to clean the drains. The flushing trailer has been valuable on one-half of the jobs.
2. We are requiring video inspection of the underdrain pipe prior to acceptance.
3. Sleeving outlet pipe or using higher strength PVC outlets. Require contractor to video inspect pipes prior to acceptance by agency. NOTE: We have used relatively thin-treated open-graded base 107 to 122 mm (0.35 to 0.4 ft) with continuous edgedrains. However, bulk of drainable base is on treated large diameter shotrock from 300 to 760 (12 to 30 in.) thick—OD reconstruction—intermittent edgedrains only. Where open-graded base is 180 mm (0.6 ft) or so thick, use continuous edgedrains. Deeper sections use none or only intermittent drains.
4. Procurement of screens to prevent rodent problems.
5. Finding the outlets can be a real challenge. We have developed a system where we paint a white triangle on the shoulder at each outlet location. This is better than a delineation post, which you would have to mow around. A uniform way of marking the outlets should be developed and then incorporated into the construction of the drainage system. You can't maintain it if you can't find it.
6. Put small riprap rock at downstream ends of outlets if erosion noted.
7. Clean outlet once each year or every several years when time and resources permit.
8. Recently changed design and will begin a program of videotaping.
9. Precipitates: none, chemical precipitates from recycled PCC base is source. Rodent guard: changed from wire mesh to fingers to reduce potential of plugging from chemical precipitates. Upstream erosion: fill above outlet is capped with crushed limestone. Edgedrain clogging: depth of drain trench was reduced from 1220 to 1070 mm (48 to 42 in.) to allow outlet exit to be higher and above ditch sediment.
10. Used a stiffer outlet pipe. Made presentations (education) to construction inspectors and maintenance workers showing them the problems encountered and the effects of poor construction and lack of maintenance.
11. Try to outlet all edgedrains into other drainage structures to prevent damage to outlet.
12. In years past, subdrain trench backfill material was limited to crushed stone. With the inclusion of geotextiles and other filter material, the problem of clogging has greatly diminished.
13. a. Random QC inspections are done immediately after construction.
    b. Stopped using crushed concrete for base aggregate and subbase.
    c. Using independent grades, when necessary, for drains and outlets.
    d. Implementing simplified design to enhance construction to avoid errors making inspection with video easier.
    e. Reduced outlet spacing from 150 to 90 m (490 to 300 ft).
    f. Changed connection from longitudinal pipe to outlet from wye to a radius bend.
14. Replacing metal outlet with concrete headwalls to reduce mower damage.
15. Considering the purchase of a video camera to inspect the edgedrains. Anticipate a preventative maintenance program to be developed around the use of the video camera.
16. Handcuffed by funding shortages.
17. Surveyed field offices and received numerous suggestions for improvement.
18. We have video inspected 18 sites. These sites range in age from 1 year to 13 years. They were all done after the projects were finalized. They were done with our equipment and by us. The problems noted were based on this information. No corrections were made.
19. a. We utilize a statewide nonencumbered contract for underdrain outlet repair.
    b. Edgedrain outlets are flushed periodically by state forces.
20. a. Precipitates rodents clogging—flush if problem noted.
    b. Mowing damage—install markers.
21. Use video camera and negotiate the replacement with the contractor before signing off on project.
22. No special procedures.
23. No longer allow PGED. Require rodent gates. Require stiff/rigid/smooth inside wall outlet pipe on/in granular trench. Are also looking at some form of quality assurance to ensure sags do not occur in outlet and that tee connectors are at the correct elevation.

15) What types of training are provided to edgedrain maintenance personnel?

1. No formal training except for camera and flushing trailer training.
2. Videotape—on-the-job-training.
3. Show videotape of internal drain problems.
4. Presentations at group meetings.
5. NHI training course.
6. Instructions are verbal—man-hours mainly involve cleaning of outlets, marking of end, and visual examination.
7. On-the-job-training.
8. On-the-job-training.
9. NHI classes, field visits, especially after severe pavement distress has occurred in the field.
10. On-the-job-training.
11. No training.

16) Is the maintenance group involved in design decisions?

If yes, please describe the interaction mechanism (e.g., team approach, plan review at _____ percent stage, etc.):

1. Member of partnering team. Minimum involvement in scoping of project.
2. Generally, the roadway designers seek district level input on all jobs in their area.
3. We have a team approach. The designer distributes the plans to all groups involved (Maintenance, Construction and Specialized Design units, such as Soils, Hydraulics, etc.) at the different stages of design.
4. Scope project and plan review.
5. Plan review (and in some cases, 80 percent complete construction review).
6. (Design): Yes for most retrofit projects (some input is obtained during field review). (Construction): Area maintenance engineer is present at project field exams for new projects and at subdrain review for retrofit projects.
7. Review design prior to them becoming standards.
8. Maintenance personnel are sometimes included in design approach and plan review.
9. Input in preliminary design stages—25 percent.
10. Region maintenance component conducts plan review at 50 percent stage and 90 percent stage.
11. Preliminary field review prior to designing the project.
12. "Plan-In-Hand" plan review.
13. Maintenance is in constant communication with designers, and can initiate projects based on need.
14. Preliminary plan review and advance plans review.
15. We include maintenance and hydraulic engineers in development of the edgedrain standards.
16. Try to be involved right at the scoping of projects as part of the team.
17. Plans are reviewed at final stage before finalizing standard.

17) Is there a feedback system between maintenance and design to report maintenance issues?
If yes, please describe and provide copies of any forms:

1. District coordination meetings and specifications committee.
2. Word of mouth.
3. (Design): Occasional, informal—nothing formal or scheduled.
4. Interoffice correspondence through the Chief Engineer on pertinent issues.
5. Edgedrain outlet committee established to provide feedback for standard plans.
6. Verbal communication between materials and maintenance personnel.
7. Telephone calls directly to design or construction contact, through Maintenance or District Engineer.
8. No forms; information is provided to district engineers from field crew then to design.
9. No forms, but feedback is provided informally (verbal and/or written memos) to the design team.
10. Nothing formal such as special forms.
11. Feedback during scheduling of rehabilitation priorities.

Please identify any design changes that your agency has (or should) implement(ed) that have reduced and/or facilitated edgedrain maintenance.

1. All designs reviewed by district.
2. Change to Schedule 40 PVC outlet pipes.
3. The specification was changed to require straight, smooth, stiff plastic pipe to outlet the system. This change is to eliminate sags in the outlet pipe.
4. Video inspection of installation should help.
5. Use of stronger outlet pipes, precast headwalls, and signing.
6. Our agency should implement a marking system on new projects. More thought should be put into headwall location to prevent erosion.
7. Eliminated filter fabric wrapping on pipe for a short time, but eventually returned to it.
8. Operations should do more ditch cleaning to provide a positive outlet at the edgedrain outlets; additional time and resources are needed though.
9. New design being implemented.
10. Radius at outlets increased; trench depth reduced to 1070 mm (42 in.) to allow drainage to ditch.
11. Geotextile filter fabric.
12. Ditch cleaning should be specified more often.
13. Concrete headwall and solid wall (TP) outlet pipes.
14. Communication between maintenance crews and design teams increased knowledge of the design team about maintenance practices and limitations for edgedrain maintenance.
15. Sometimes we get comments from inspectors or maintenance managers and usually we will make a field visit to solve the problem.
16. None.

18) Are any special inspections or tests of subsurface drain systems performed before construction acceptance? Please describe.

1. The main function of the camera system is for inspection of the contractor's edgedrain installation.
2. Must video.
3. Visual inspection by project implementation personnel only.
4. Seldom—at request of resident construction engineer (as needed).
5. Agency option to submit certain jobs for video inspection.
6. A probe is inserted up and through the outlet pipe and the bend into the edgedrain to ensure that there are no obstructions.
7. Drains are inspected to ensure conformance to specifications—pitch, diameter, compaction, etc.
8. Acceptance testing at the time of construction after installation. Testing done only if there are observed problems.
9. Yes and no. There are specifications for the use of the video camera, but it is left up to the resident construction engineers as to whether it is used or not (more often not).
10. Video camera.
11. Not known.

Is a video camera used for construction and is the maintenance group involved in decisions on inspection requirements?

1. Video camera inspection is left up to the resident construction engineers.
2. Video camera is used for maintenance inspection.
3. We have recently issued a video inspection specification and look forward to its use.
4. They are members of the design/inspection committee.

19) Is there a feedback system between maintenance and construction to report maintenance issues with construction practices? If yes, please describe and provide copies of any forms:

1. The districts have maintenance responsibility and construction responsibility.
2. The designer must respond to the review comments of each unit.
3. Through the central office of COMTECH issues are relayed back and forth between Construction and Maintenance.

4. District bureau coordination meetings and scoping field checks allow discussion/interaction on issues.
5. Word of mouth.
6. Subdrain review is done in field with design personnel for retrofit projects. Design participates with construction office in policy review.
7. Field maintenance engineer performs annual "listening" tour.
8. Interoffice correspondence through the Chief Engineer on pertinent issues.
9. Maintenance is involved through the input and evaluation of design/construction plans and proposals.
10. Informal verbal communication.
11. No forms; feedback is usually verbal.
12. We can report maintenance issues on "problem statements," which are an "after the fact" method of recording issues and take several years to go through the pipeline process.
13. Maintenance provides feedback in the form of the Premature Failure Study.
14. The Maintenance and Construction Assistant Division Engineers both work for the Division Engineer.
15. On occasion, maintenance personnel will raise concerns, if observed, with the construction project manager and/or inspectors.
16. During field reviews of similar projects.
17. Most of the time verbal communication or e-mail for the specific project they are involved with, especially when problems develop.
18. Feedback is informal.

Please identify any construction changes that your agency has (or should) implement(ed) that has reduced and/or facilitated edgedrain maintenance.

1. The inspection requirement of edgedrain installations has been implemented.
2. Video inspection to ensure that it was installed properly so as not to build a maintenance problem.
3. Again, implement a marking system on new projects. More thought should be put into headwall location to prevent erosion.
4. Should eliminate filter fabric pipe wrap and backfill with pea gravel, thereby helping to prevent shoulder heaving due to ice formation in trench.
5. Requiring CA-16 for backfill. Also, placing drain at minimum slope of 0.4 percent for pipe drains; our "General Note" requires placing open-graded trench plug on top of CA-16.
6. Most changes have been incorporated in design of plans/standards.
7. Outlet pipes need to be protected during construction process.
8. Clogging of edgedrains.
9. Changed backfill material to improve stability issue.
10. Large-scale downsizing and attrition have negated our ability to properly maintain roadways; lack of sweeping, litter pickup, and drain cleanout have led to clogged drains.
11. Revised edgedrain standards (attachment #1). Include all concerned parties, even the drainage office in FHWA (Mr. Bob Baumgardner).
12. Quality assurance should be implemented to ensure quality/working drainage system.

20) Which of the following do you believe are causes of premature failures of edgedrain systems? In addition to the causes of premature failures in question 20, agencies provided the following comments on other additional causes.

1. Construction damage.
2. Cross slope too flat and ditches too shallow.
3. We need more resources to provide maintenance of headwalls and outlet pipes.
4. Actually there are very few failures with our design.
5. Abuse by contractors, poor sequence of construction, poor inspection (inspectors do not know what to look for).
6. Pumpable subgrade conditions.

21) Where do you think the greatest improvement in edgedrain systems would come from? In addition to answering either more basic research or more training, the following comments were offered.

1. Teaching all people involved with this system the importance of the correct installation and the benefits of maintaining it.

2. Do not need more research, current design is adequate.
3. Include maintainability in design criteria.
4. Need to consider alternate designs for varying soil types.
5. Spend the money to build quality edgedrains without shortcuts. (Example: inexpensive geocomposites did not perform.)
6. Contractor and inspector need to bend over and look at the outlet pipe.
7. Better construction and maintenance inspection.
8. Better design details.
9. Continue use of end result video inspection.
10. Just need basic policy on edgedrain maintenance with strong administrative support.
11. a. More research on measured performance of existing systems.
    b. Proper installation practices should be documented.
12. More training stressing the importance of routine maintenance.
13. More research correlating pavement performance to edgedrain performance.
14. More training for inspectors and maintenance personnel.
15. Better maintenance access options for cleaning; need to train personnel.

22) Has the maintenance group developed any correlation between improved pavement performance for paving systems with edgedrains (e.g., data showing pavement systems with drainage require less maintenance than pavement systems without drainage)? Comments:

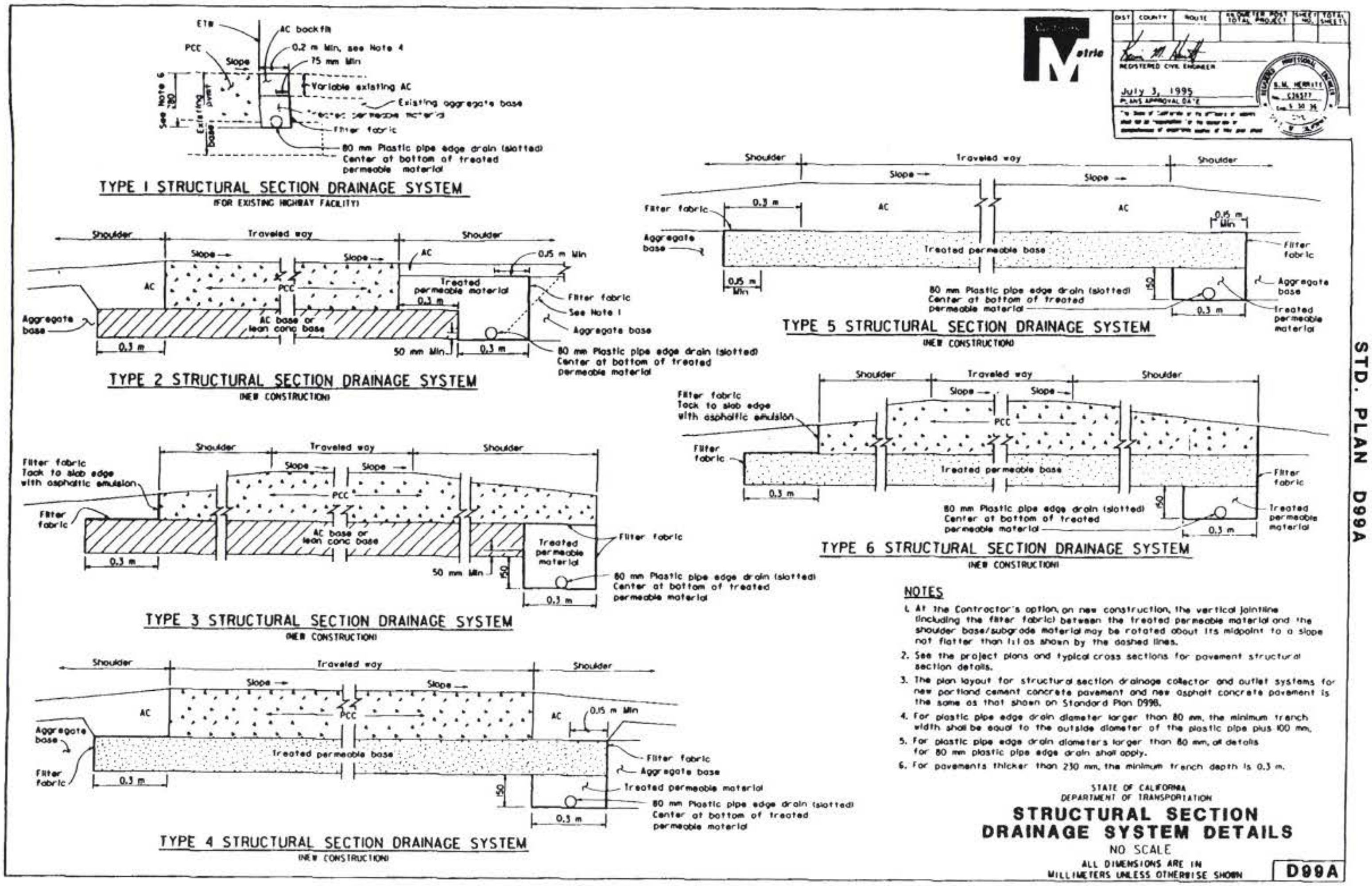
1. Research is ongoing on this topic.
2. Nothing to show better performance, rather it is the poor performance where there are no drains.
3. You take care of the subsurface drainage, you eliminate most of your problems and pavement lasts longer.
4. Less water under pavement.
5. General thinking is that subdrains can extend life of new pavement or on overlay by 25 percent to maybe 50 percent.
6. This is an area at which the Pavement Management group plans to look.
7. This is case by case (i.e., when we make field diagnosis of failures they then believe a correlation exists).
8. No documentation. Correlation informally developed with the pavement/geotechnical group.

23) Has the maintenance group developed any correlation between pavement and edgedrain performance (e.g., data showing poor pavement performance in relation to edgedrain problems)?

1. Research is ongoing on this topic.
2. Only visual; poor pavement associated with poor subsurface drainage.
3. Pavement has a longer life in areas with edgedrains.
4. No formal studies or documentation, but frequently when there is a pavement problem there may be a drain problem.
5. Common sense would dictate that if pavement heaving occurs, subsurface water is prevalent, and edgedrain has failed.
6. This is an area at which the Pavement Management group plans to look.
7. Failures in pavement where edgedrain does not perform.
8. Case by case.
9. Pavement/geotechnical group. Correlation informal, no documentation.

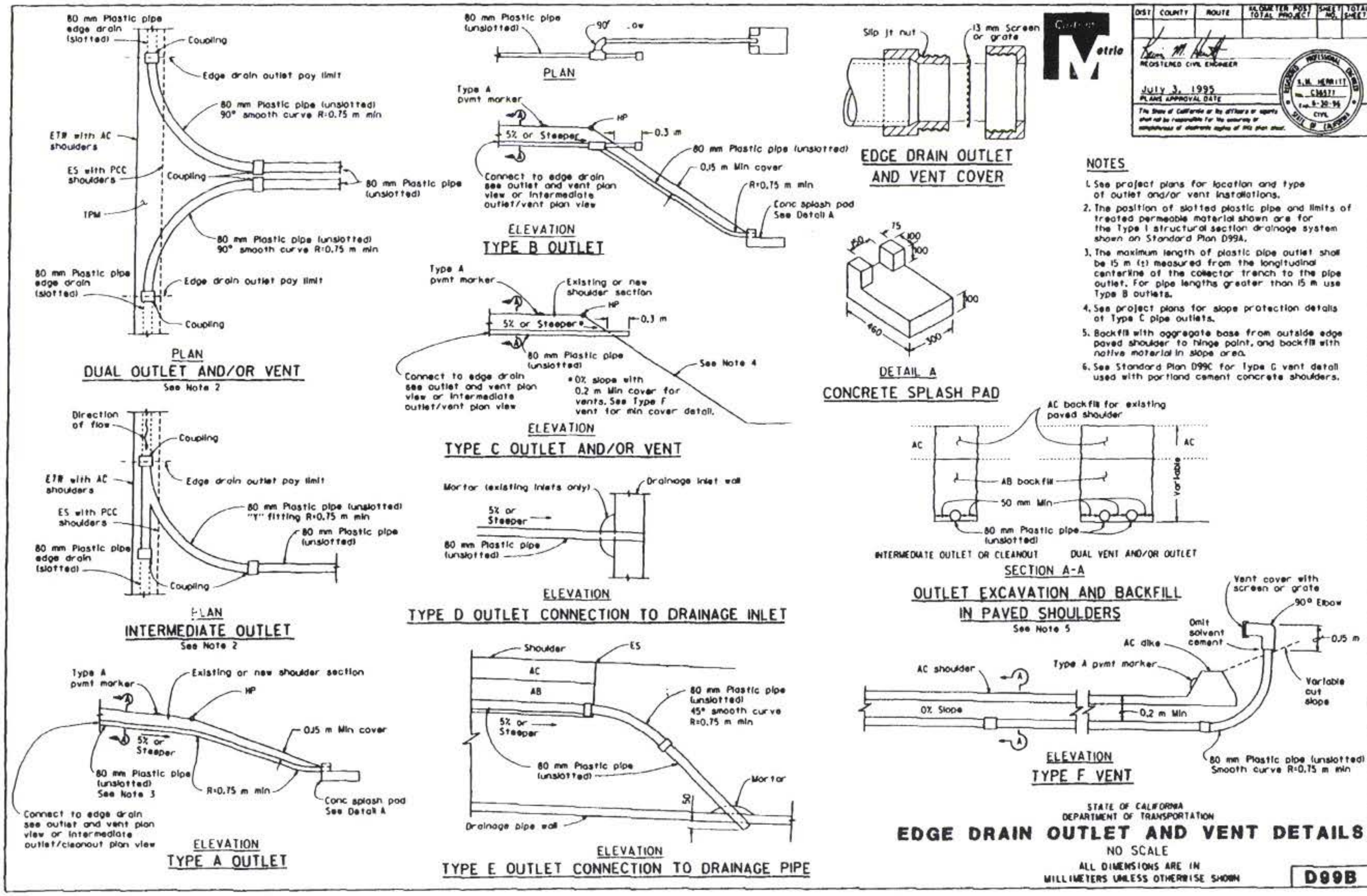
APPENDIX C

Representative Edgedrain Plans



STD. PLAN D99A

STD. PLAN D99B



DIST	COUNTY	ROUTE	KILOMETER POST TOTAL PROJECT	SHEET NO.	TOTAL SHEETS

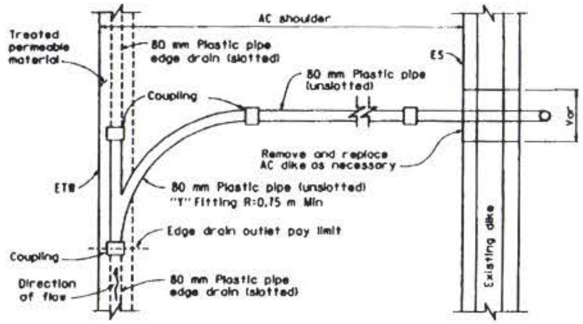
Metric

REGISTERED CIVIL ENGINEER

July 3, 1995

PLANS APPROVAL DATE

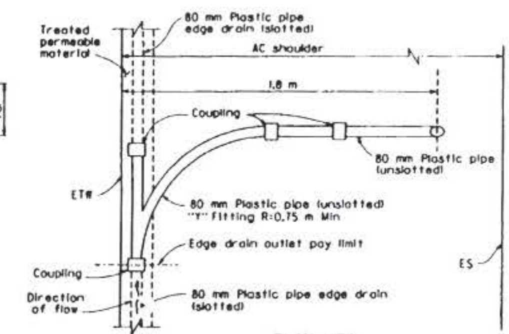
The State of California or its officers or agents shall not be responsible for the accuracy or completeness of electronic copies of this plan sheet.



PLAN VIEW

TYPE 1 CLEANOUT

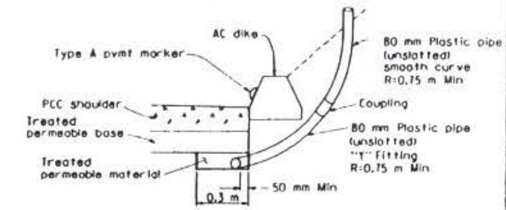
See Note 2



PLAN VIEW

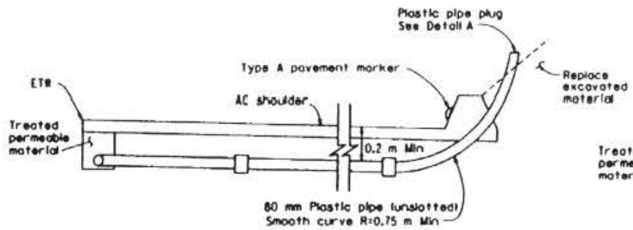
TYPE 2 CLEANOUT

See Note 2



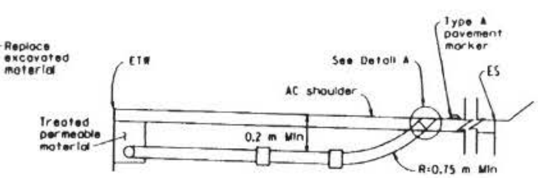
SECTION A-A

TYPE 3 CLEANOUT/TYPE G VENT



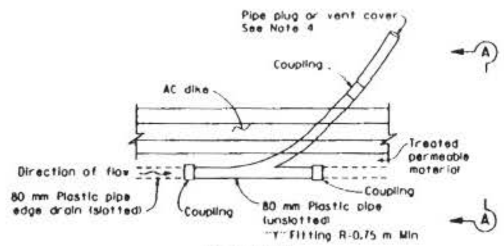
ELEVATION

TYPE 1 CLEANOUT



ELEVATION

TYPE 2 CLEANOUT



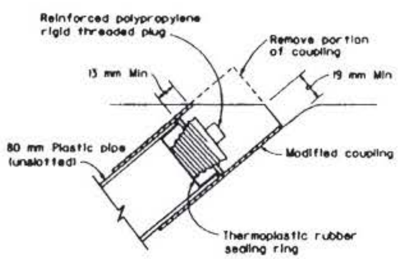
PLAN VIEW

TYPE 3 CLEANOUT/TYPE G VENT

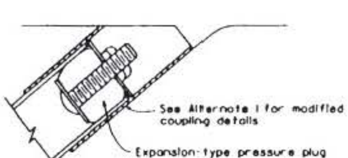
See Note 4

NOTES

1. See project plans for location and type of cleanout or vent installations.
2. The position of slotted plastic pipe and limits of treated permeable material shown are for the Type I structural section drainage system shown on Standard Plan D99A.
3. Other types of plugs may be substituted with the Engineer's approval.
4. The Type 3 cleanout and Type G vent is for use with portland cement concrete shoulders. The Type 6 structural section drainage system from Standard Plan D99A is shown. Use plastic pipe plug shown in Detail A with Type 3 cleanouts. Use vent cover shown on Standard Plan D99B with Type G vents.



ALTERNATIVE 1



ALTERNATIVE 2

PLASTIC PIPE PLUG

DETAIL A

See Note 3

STATE OF CALIFORNIA
DEPARTMENT OF TRANSPORTATION

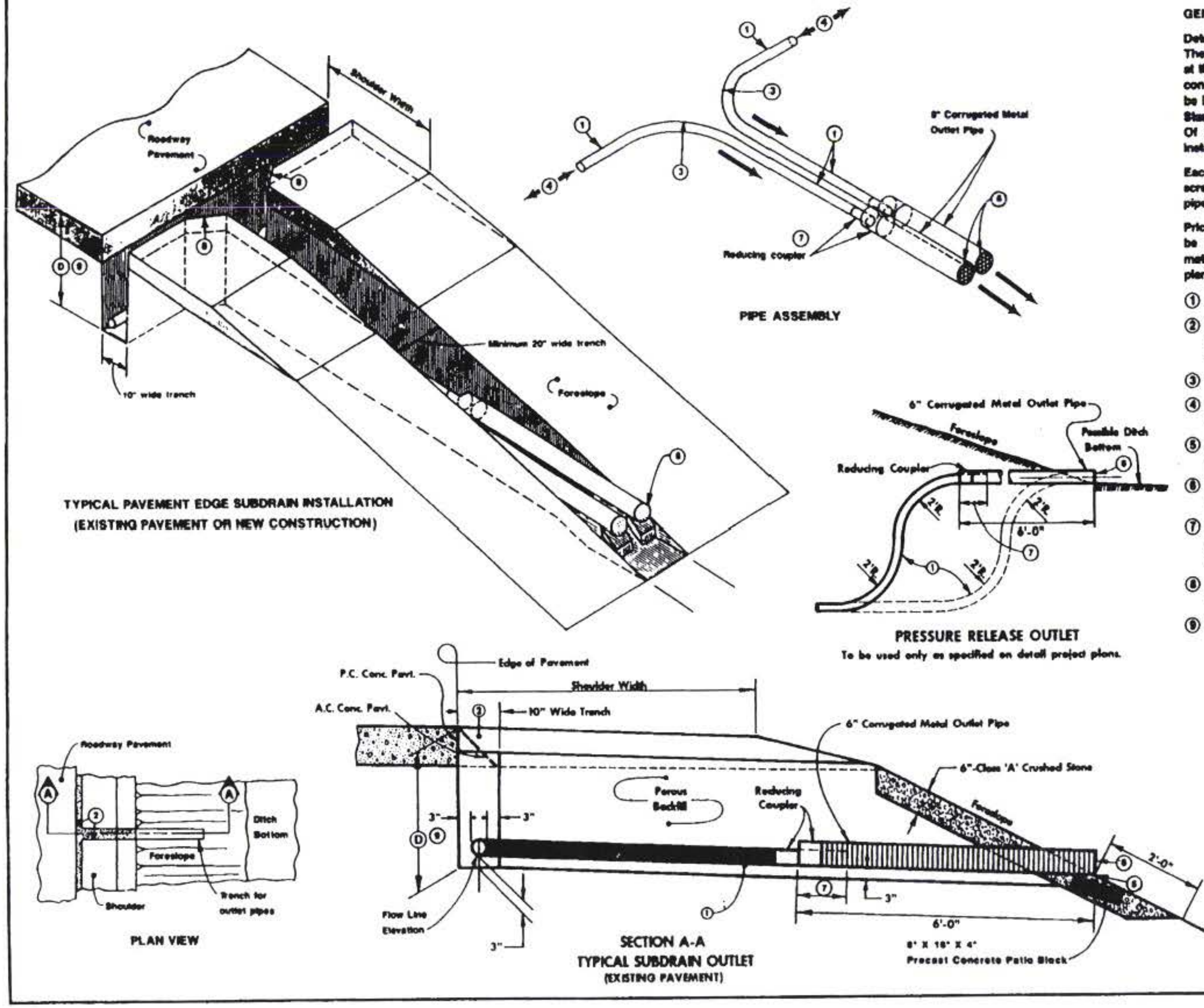
EDGE DRAIN CLEANOUT AND VENT DETAILS

NO SCALE

ALL DIMENSIONS ARE IN MILLIMETERS UNLESS OTHERWISE SHOWN

D99C

STD. PLAN D99C



GENERAL NOTES

Details indicated hereon are for the construction of subdrain outlets. The outlet assembly shall consist of a double outlet pipe (except at the end and beginning of the system) on downhill runs or sag conditions. All work and materials used in the installation shall be in conformance with applicable Standard Road Plans, current Standard and Supplemental Specifications. Refer to "Tabulation Of Longitudinal Subdrains" for details of individual subdrain installations.

Each outlet shall be covered with ½" mesh galvanized screen. The screen shall be securely fastened (but not permanently) to the outlet pipe end by means approved by the engineer.

Price bid for "Subdrain Outlet, C.M.P. 6-inch diameter" (No.) shall be considered full compensation for all installation work and materials necessary as detailed hereon, and as required by project plans. Double outlet is considered two outlets for payment count.

① 4" Perforated Subdrain (Polyethylene Corrugated Tubing).

② On projects where existing shoulder material is removed, the shoulder material shall be replaced as per Section 2502.05 of the Standard Specifications.

③ "Y" or "T" connection shall not be allowed. 1' minimum radius.

④ Direction of flow. Double outlets will be required at all locations, except where the subdrain system terminates.

⑤ 6" minimum drop in elevation between longitudinal subdrain and outlet.

⑥ ½" mesh galvanized screen fastened securely, but not permanently, to outlet pipe.

⑦ At the contractor's option, the 4" subdrain may be extended into the 6" C.M.P. a minimum of 1'-0" and the entire opening fully sealed with grout.

⑧ Trench shall be beveled to provide a minimum of 3" of porous backfill surrounding all portions of subdrain pipe.

⑨ Refer to "Tabulation of Longitudinal Subdrain," 104-9.

Iowa Department of Transportation
Highway Division

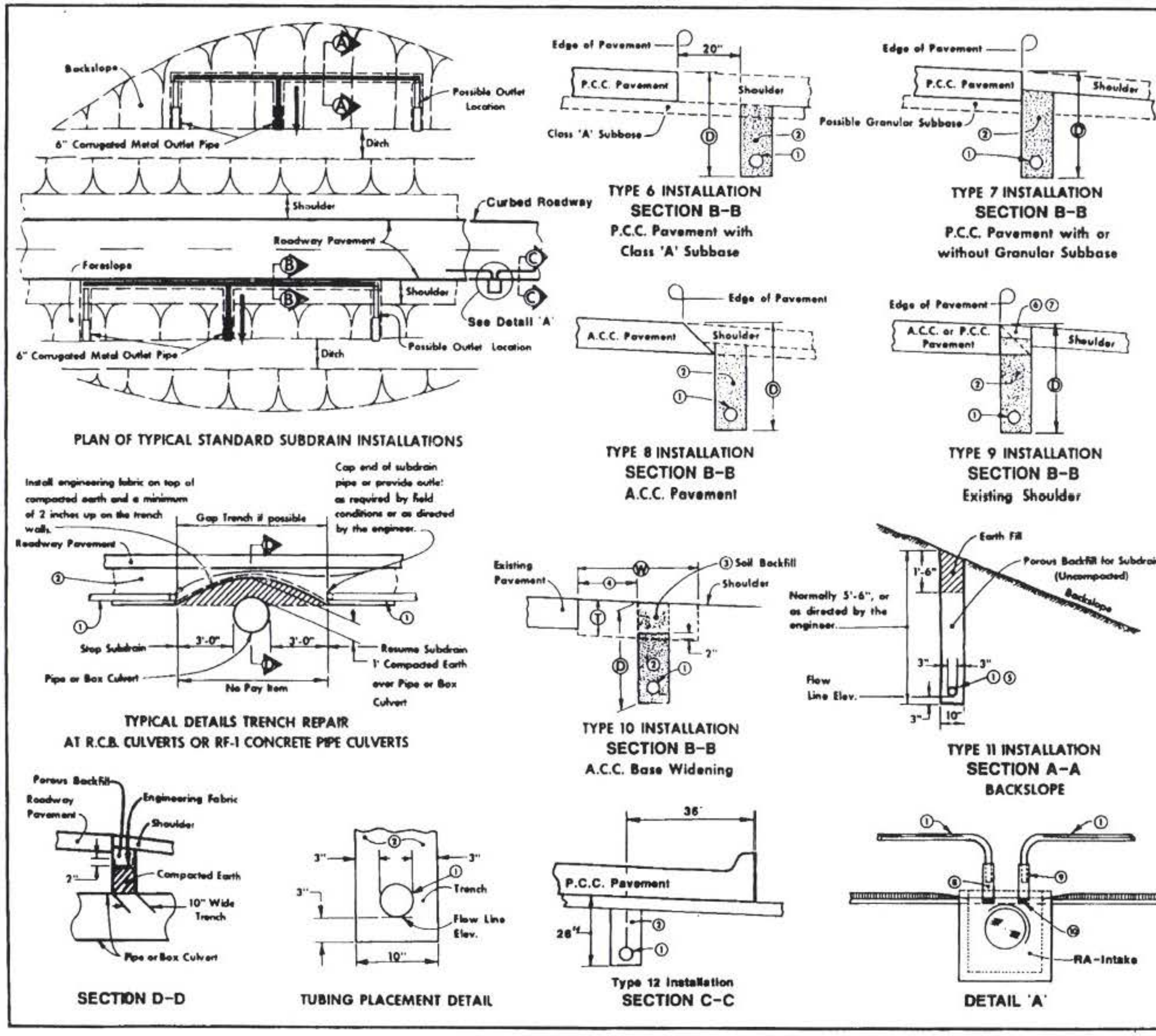
STANDARD ROAD PLAN RF-19E

RECOMMENDED BY ROAD DESIGN ENGINEER	05-23-90
APPROVED BY DEPUTY DIRECTOR DEVELOPMENT	05-23-90

REVISION: Revised general notes to require double outlet for all subdrain outlets.

SUBDRAIN (OUTLETS)

Standard road plan for subdrain outlets.



GENERAL NOTES:

Details indicated hereon are for the construction of longitudinal subdrains. All work and materials used in the installation shall be in conformance with applicable Standard Road Plans, current Standard and Supplemental Specifications. Refer to "Tabulation Of Longitudinal Subdrains" for details of individual subdrain installations.

Areas of shoulders in project limits not shown in tabulation of longitudinal subdrain and other areas conflicting with subdrain installation will not be trenched.

When RCB culverts or RF-1 concrete pipe culverts which are less than 1 foot below the trench bottom are encountered within a tabulated Subdrain, the trench shall stop 3 feet from the culvert and resume 3 feet beyond the culvert. If the trench is inadvertently carried over the culvert, the trench shall be repaired as detailed on this sheet. Care must be exercised so as not to destroy the tops of culverts with the trenching machine. If obstruction is 1 foot or more below normal trench bottom, carry subdrain line over in continuous alignment.

Subdrain trench shall be located adjacent to edge of roadway pavement. On new construction projects, the subdrain shall be placed after the mainline paving and prior to shoulder placement. On new projects with tied P.C.C. Shoulders, trench location shall be as determined by the enginer. On existing roadways, the trench shall be capped with material per current Standard and Supplemental Specifications.

Price bid for "Longitudinal Subdrain, (Shoulder)" or (Back Slope) (lin. ft.) and "outlets" each, shall be considered full compensation for all installation work and materials necessary as detailed hereon, and as required by project plans.

Porous backfill is considered incidental to "Longitudinal Subdrain".

(1) 4" Perforated Subdrain (Polyethylene corrugated tubing).
(2) Porous Backfill.
(3) Backfill of this area is not required if base widening is placed the same day of subdrain construction.
(4) Min. 8" to w/2.
(5) Subdrain is to be installed as cut proceeds.
(6) On existing Granular or Earth Shoulders replace with 4" minimum depth granular shoulder material.
(7) On Paved Shoulders refer to specification for finishing shoulder, see Section 2502.
(8) 6" CMP 2' long.
(9) Perforated P.E. fit into CMP minimum 12" if grout is used. At the contractor's option use reducing coupler or grout.
(10) Removable mesh cap ½" hardware cloth.

Iowa Department of Transportation
Highway Division

STANDARD ROAD PLAN **RF-19C**

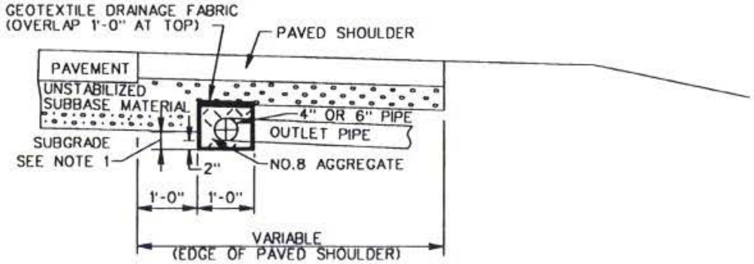
RECOMMENDED — ROAD DESIGN ENGINEER — 12/7/87 — DATE

APPROVED — DEPUTY DIRECTOR — DEVELOPMENT — 12/10/87 — DATE

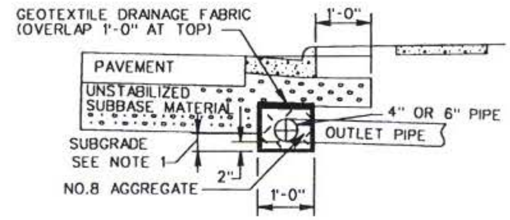
LONGITUDINAL SUBDRAINS

Standard road plan for longitudinal subdrains.

UD-4



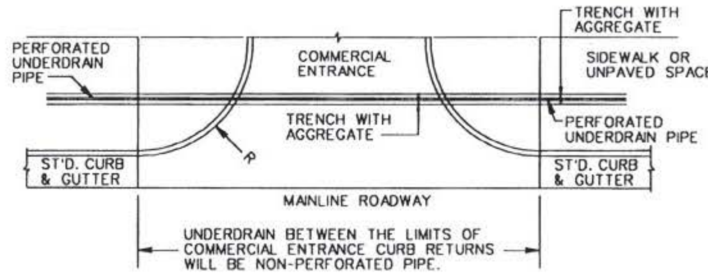
PAVED SHOULDER SECTION



CURB AND GUTTER SECTION

NOTES:

1. 4" MINIMUM, PROVIDED ATTANING MINIMUM 4" OF AGGREGATE ON TOP OF PIPE.
2. WHEN THE LONGITUDINAL PIPE CONNECTS DIRECTLY INTO A DRAINAGE STRUCTURE (DROP INLET, MANHOLE, ECT.), NON-PERFORATED OUTLET PIPES ARE NOT REQUIRED.
3. INVERT ELEVATION AT OUTLET END OF OUTLET PIPE TO BE A MINIMUM OF 1'-0" ABOVE INVERT ELEVATION OF RECEIVING DRAINAGE DITCH OR STRUCTURE.
4. ALL CONNECTIONS (ELBOWS, WYES, ETC.) WITHIN PAY LIMITS FOR OUTLET PIPE ARE TO BE OF THE SAME CRUSHING STRENGTH AS THE OUTLET PIPE.
5. OUTLET PIPES ARE TO BE INSTALLED ON 2 % MIN./3 % DESIRABLE GRADE AND LOCATED EVERY 350' MAXIMUM OR AS NOTED ON PLANS.
6. OUTLET PIPE TO BE SECURELY CONNECTED TO EW-12 OR OTHER DRAINAGE STRUCTURE.
7. WITHIN THE LIMITS OF A COMMERCIAL ENTRANCES, NON-PERFORATED PIPE SHALL BE UTILIZED LIEU OF PERFORATED PIPE.
8. THE LENGTH OF PIPE BETWEEN THE WYE CONNECTION AND THE EW-12 SHALL BE LIMITED TO NO MORE THAN 1" TO PERMIT CAMERA INSPECTION OF THE MAIN LINE IN EITHER DIRECTION.



LONGITUDINAL PERFORATED PIPE

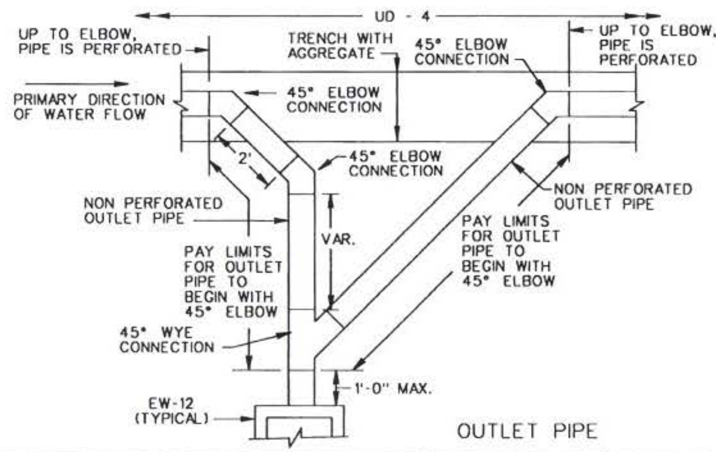
TYPE OF PIPE	CRUSHING STRENGTH			
	*W.T.	4" NOM. DIAMETER	*W.T.	6" NOM. DIAMETER
CORRUGATED ALUMINUM			0.48	
SMOOTH WALL PVC	.103		.153	
CORRUGATED PE		AASHTO M-252		AASHTO M-252

NON-PERFORATED OUTLET PIPE FOR USE UNDER COMMERCIAL ENTRANCES AND FOR OUTLETS

TYPE OF PIPE	CRUSHING STRENGTH			
	*W.T.	4" NOM. DIAMETER	*W.T.	6" NOM. DIAMETER
CORRUGATED ALUMINUM			0.48	
SMOOTH WALL PVC	.103		.153	
SMOOTH WALL PE		70 PSI ***		70 PSI ***

* WALL THICKNESS (MIN) - INCHES

*** TESTED ACCORDING TO ASTM D-2412 AT 5 % DEFLECTION.



OUTLET PIPE

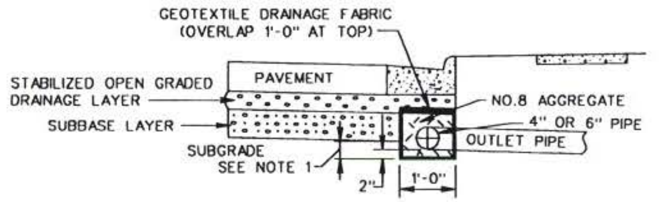
SHEET 1 OF 2

STANDARD PAVEMENT EDGEDRAIN

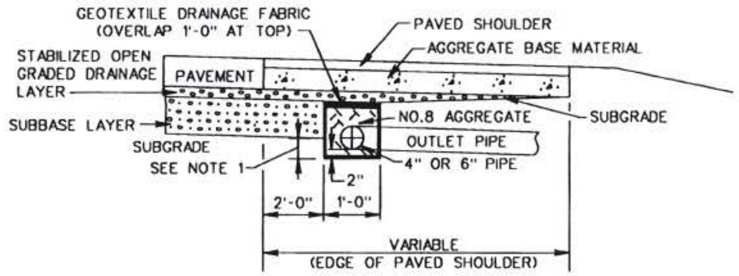
VIRGINIA DEPARTMENT OF TRANSPORTATION

108.06

SPECIFICATION REFERENCE
240
258
501
701



CURB AND GUTTER SECTION
(FOR USE WITH STABILIZED OPEN-GRADED DRAINAGE LAYER)



PAVED SHOULDER SECTION
(FOR USE WITH STABILIZED OPEN-GRADED DRAINAGE LAYER)

LONGITUDINAL PERFORATED PIPE

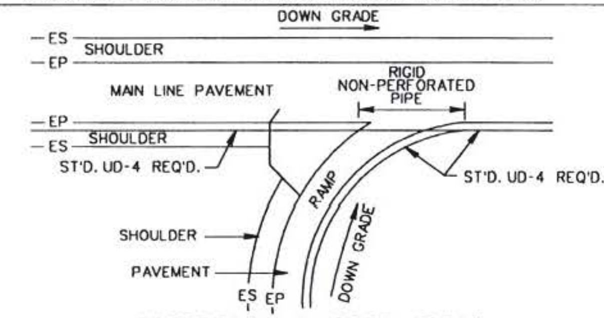
UD-4

TYPE OF PIPE	CRUSHING STRENGTH			
	* W.T.	4" NOM. DIAMETER	* W.T.	6" NOM. DIAMETER
CORRUGATED ALUMINUM			0.48	
SMOOTH WALL PVC	.103		.153	
CORRUGATED PE		AASHTO M-252		AASHTO M-252

NON-PERFORATED OUTLET PIPE FOR USE UNDER COMMERCIAL ENTRANCES AND FOR OUTLETS

TYPE OF PIPE	CRUSHING STRENGTH			
	* W.T.	4" NOM. DIAMETER	* W.T.	6" NOM. DIAMETER
CORRUGATED ALUMINUM			0.48	
SMOOTH WALL PVC	.103		.153	
SMOOTH WALL PE		70 PSI ***		70 PSI ***

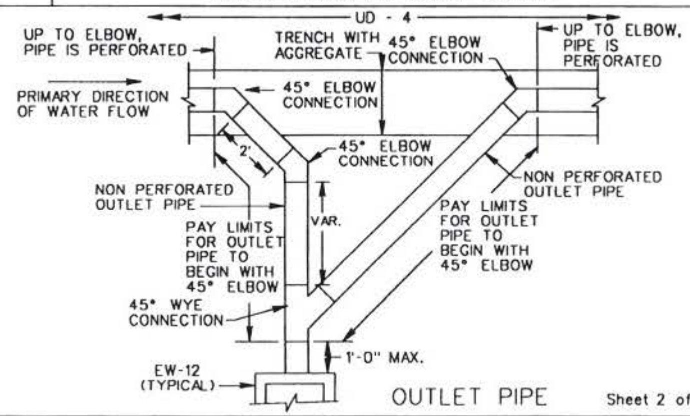
* WALL THICKNESS (MIN) - INCHES
*** TESTED ACCORDING TO ASTM D-2412 AT 5% DEFLECTION.



EDGEDRAINS IN GORE AREAS

NOTES:

1. 4" MINIMUM, PROVIDED ATTAINING MINIMUM 4" OF AGGREGATE ON TOP OF PIPE.
2. WHEN THE LONGITUDINAL PIPE CONNECTS DIRECTLY INTO A DRAINAGE STRUCTURE (DROP INLET, MANHOLE, ECT.), NON-PERFORATED OUTLET PIPES ARE NOT REQUIRED.
3. INVERT ELEVATION AT OUTLET END OF OUTLET PIPE TO BE A MINIMUM OF 1'-0" ABOVE INVERT ELEVATION OF RECEIVING DRAINAGE DITCH OR STRUCTURE.
4. ALL CONNECTIONS (ELBOWS, WYES, ETC.) WITHIN PAY LIMITS FOR OUTLET PIPE ARE TO BE OF THE SAME CRUSHING STRENGTH AS THE OUTLET PIPE.
5. OUTLET PIPES ARE TO BE INSTALLED ON 2% MIN./3% DESIRABLE GRADE AND LOCATED EVERY 350' MAXIMUM OR AS NOTED ON PLANS.
6. OUTLET PIPE TO BE SECURELY CONNECTED TO EW-12 OR OTHER DRAINAGE STRUCTURE.
7. WITHIN THE LIMITS OF A COMMERCIAL ENTRANCES, NON-PERFORATED PIPE SHALL BE UTILIZED LIEU OF PERFORATED PIPE.
8. THE LENGTH OF PIPE BETWEEN THE WYE CONNECTION AND THE EW-12 SHALL BE LIMITED TO NO MORE THAN 1' TO PERMIT CAMERA INSPECTION OF THE MAIN LINE IN EITHER DIRECTION.



OUTLET PIPE

Sheet 2 of 2

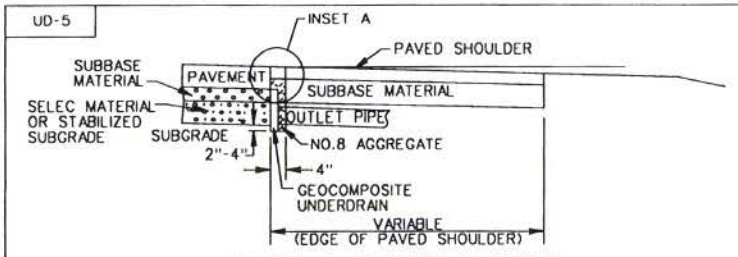
SPECIFICATION REFERENCE
240
258
501
701

STANDARD PAVEMENT EDGEDRAIN

VIRGINIA DEPARTMENT OF TRANSPORTATION

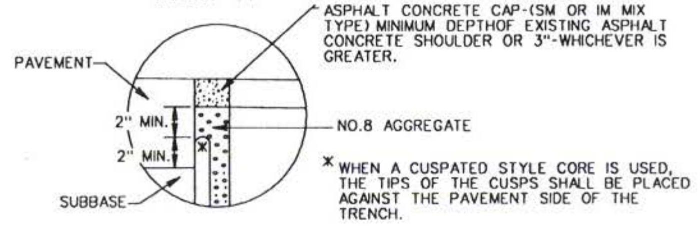
108.07

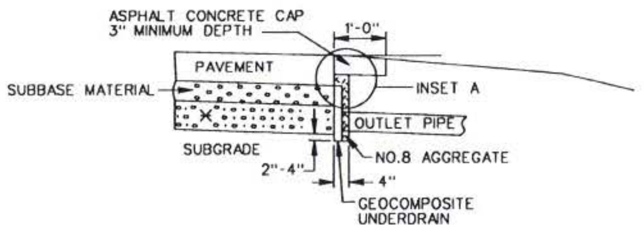
UD-5



PAVED SHOULDER SECTION

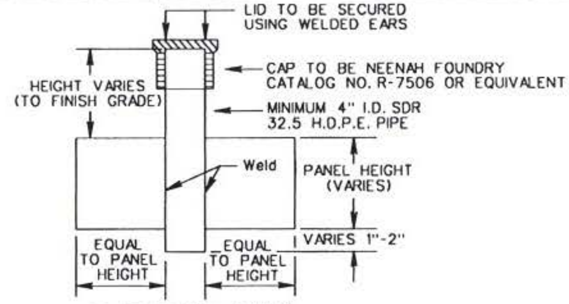
INSET A



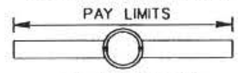


UNPAVED SHOULDER SECTION

* SELECT MATERIAL OR STABILIZED SUBGRADE MATERIAL

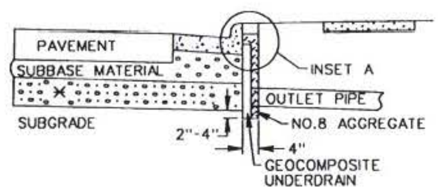


ELEVATION VIEW



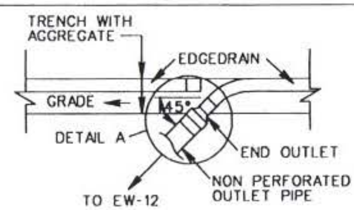
PLAN VIEW

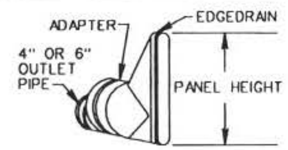
UD - 5
INSPECTION PORT



CURB AND GUTTER SECTION

* SELECT MATERIAL OR STABILIZED SUBGRADE MATERIAL





DETAIL A
END OUTLET

EDGEDRAIN CONNECTION TO OUTLET PIPE

NOTES:

1. INVERT ELEVATION AT OUTLET END OF OUTLET PIPE TO BE A MINIMUM OF 1'-0" ABOVE INVERT ELEVATION OF RECEIVING DRAINAGE DITCH OR STRUCTURE.
2. ALL CONNECTIONS (ELBOWS, WYES, ETC.) WITHIN PAY LIMITS FOR OUTLET PIPE ARE TO BE OF THE SAME CRUSHING STRENGTH AS THE OUTLET PIPE.
3. OUTLET PIPES ARE TO BE INSTALLED ON 2 % MIN./3 % DESIRABLE GRADE AND LOCATED EVERY 350' MAXIMUM OR AS NOTED ON PLANS.
4. OUTLET PIPE TO BE SECURELY CONNECTED TO EW-12 OR OTHER DRAINAGE STRUCTURE.
5. UD-5 INSPECTION PORTS ARE TO BE LOCATED WHERE SPECIFIED ON THE PLANS.

NON-PERFORATED OUTLET PIPE

TYPE OF PIPE	CRUSHING STRENGTH			
	* W.T.	4" NOM. DIAMETER	* W.T.	6" NOM. DIAMETER
CORRUGATED ALUMINUM			0.48	
SMOOTH WALL PVC	.103		.153	
SMOOTH WALL PE		70 PSI ***		70 PSI ***

* WALL THICKNESS (MIN) - INCHES
*** TESTED ACCORDING TO ASTM D-2412 AT 5 % DEFLECTION.

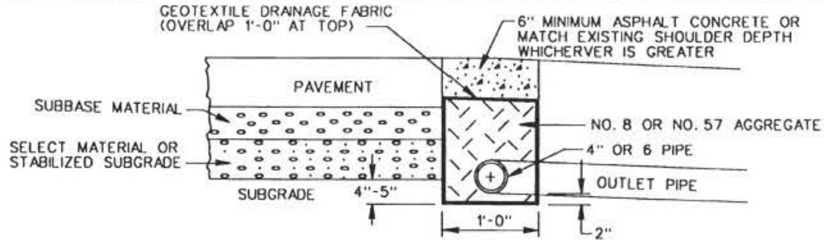
PREFABRICATED GEOCOMPOSITE RETROFIT PAVEMENT EDGEDRAIN

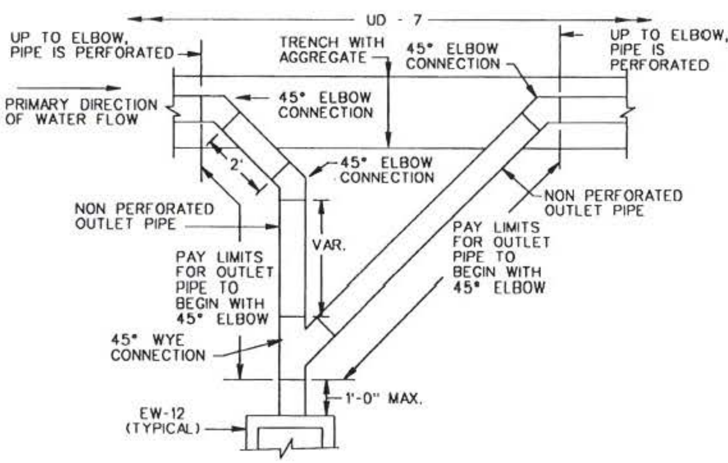
VIRGINIA DEPARTMENT OF TRANSPORTATION

SPECIFICATION REFERENCE
240
501
701

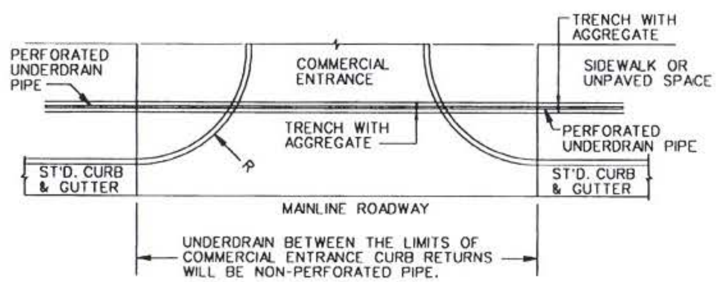
108.08

UD-7





OUTLET PIPE



NOTES:

1. WHEN THE LONGITUDINAL PIPE CONNECTS DIRECTLY INTO A DRAINAGE STRUCTURE (DROP INLET, MANHOLE, ECT.), NON-PERFORATED OUTLET PIPES ARE NOT REQUIRED.
2. INVERT ELEVATION AT OUTLET END OF OUTLET PIPE TO BE A MINIMUM OF 1'-0" ABOVE INVERT ELEVATION OF RECEIVING DRAINAGE DITCH OR STRUCTURE.
3. ALL CONNECTIONS (ELBOWS, WYES, ETC.) WITHIN PAY LIMITS FOR OUTLET PIPE ARE TO BE OF THE SAME CRUSHING STRENGTH AS THE OUTLET PIPE.
4. OUTLET PIPES ARE TO BE INSTALLED ON 2% MIN./3% DESIRABLE GRADE AND LOCATED EVERY 350' MAXIMUM OR AS NOTED ON PLANS.
5. OUTLET PIPE TO BE SECURELY CONNECTED TO EW-12 OR OTHER DRAINAGE STRUCTURE.
6. WITHIN THE LIMITS OF A COMMERCIAL ENTRANCES, NON-PERFORATED PIPE SHALL BE UTILIZED LIEU OF PERFORATED PIPE.
7. THE LENGTH OF PIPE BETWEEN THE WYE CONNECTION AND THE EW-12 SHALL BE LIMITED TO NO MORE THAN 1" TO PERMIT CAMERA INSPECTION OF THE MAIN LINE IN EITHER DIRECTION.
8. EXISTING ASPHALT SHOULDER TO BE SAWED TO ACHIEVE A SMOOTH JOINT.

LONGITUDINAL PERFORATED PIPE

TYPE OF PIPE	CRUSHING STRENGTH			
	*W.T.	4" NOM. DIAMETER	*W.T.	6" NOM. DIAMETER
CORRUGATED ALUMINUM			0.48	
SMOOTH WALL PVC	.103		.153	
CORRUGATED PE		AASHTO M-252		AASHTO M-252

NON-PERFORATED OUTLET PIPE FOR USE UNDER COMMERCIAL ENTRANCES AND FOR OUTLETS

TYPE OF PIPE	CRUSHING STRENGTH			
	*W.T.	4" NOM. DIAMETER	*W.T.	6" NOM. DIAMETER
CORRUGATED ALUMINUM			0.48	
SMOOTH WALL PVC	.103		.153	
SMOOTH WALL PE		70 PSI ***		70 PSI ***

* WALL THICKNESS (MIN) - INCHES

*** TESTED ACCORDING TO ASTM D-2412 AT 5% DEFLECTION.

SPECIFICATION REFERENCE

240
501
701

STANDARD RETROFIT EDGEDRAIN

VIRGINIA DEPARTMENT OF TRANSPORTATION

108.09

APPENDIX D

Sample Standards for Video Inspection of Edgedrains

Issued: 3/1/99

Virginia Test Method for Inspection of Pavement Underdrains/Edgedrains (PUD/PED)

VTM-108

1. Scope

This test method outlines the procedures for inspection of PUD/PED by video camera and/or visual methods.

2. Frequency of Inspection

Video camera inspection shall be conducted on all accessible outlet locations up to and including the mainline longitudinal connection. Additionally, a minimum of 10% of longitudinal pipe shall be inspected to assure that both installation procedures and protection measures have resulted in a functional drainage system.

The inspections should be performed prior to project completion, but after potentially damaging construction operations are completed.

Where an outlet location is inaccessible with the video camera, visual inspection shall include the following, as a minimum: slope of endwalls, pipe outfall, condition of the endwall, and the existence of rodent screens and outlet markers.

3. Procedures

Deficiencies to be found, during the inspection, shall include but not be limited to the following:

1. Crushed or collapsed pipe (including couplings or other pipe fittings) that prevents passage of the camera.
2. Pipe that is partially crushed or deformed (including splits or cracks) for a length of 12 inches (300 mm) or greater, but allows passage of the camera.
3. Any blockages or sediment buildup caused by rodent's nests, open connections, and cracks or splits in the pipe.
4. Sags in the longitudinal profile as evidenced by ponding of water for continuous lengths of 10 feet (3.0 m) or greater.
5. Endwalls and/or outlet pipes that are sloped with less than a uniform 2% positive slope toward the outlet.
6. Inadequate outfall of less than 6 inches (150 mm) from the pipe outlet to the bottom of the ditch.
7. Pipe that has been penetrated by guardrail posts, sign posts, delineator posts, etc.

Deficiencies shall be noted on the inspection report with their corresponding location on the project site, such as station numbers. If no deficiencies are noted or the deficiencies are not deemed detrimental to the drainage system, an ok entry shall be made under remarks for that particular outlet. Where deficiencies are noted and require corrective action, sufficient description shall be given on the report to indicate what corrective measures are needed.

Where deficiencies are noted that require corrective action, all efforts to locate and mark the location of the pipe shall be made using the locator purchased with the camera system. In addition, the length from the outlet to any deficiencies should be recorded on the test report using the footage counter furnished with the system.

Upon completion of corrective measures, the deficient locations shall be reinspected and satisfy the same criteria as a new PUD/PED system.

Adequate description should be given to each outlet inspected, including station number, direction of lane, location of outlet (median or shoulder), and size of pipe.

Where deficiencies are found, it is recommended that videotaping be used. Data should be entered using the titler/keyboard furnished with the camera system regarding the location and date of the inspection for incorporation into the videotape. The audio microphone should also be used to provide description of deficiencies.

Should the camera be inoperable, then the PUD/PED system may be inspected using a probe "plug" or mandrel equal in diameter to the camera (or other suitable means) to detect any major deficiencies.

4. Reports

The attached form is suggested to be used to report the inspection findings. As a minimum, copies of the inspection report shall be distributed to the Project Inspector, District Materials Inspection Engineer, and the State Materials Engineer.

APPENDIX E

Example of Edgedrain Inspection Form

Issued: 3/1/99

VIRGINIA DEPARTMENT OF TRANSPORTATION
________________ DISTRICT MATERIALS
UNDERDRAIN INSPECTION REPORT

CONTRACTOR: ________________

DATE: ________________

PROJECT NO.: ________________ **UPC NO.:** ____________

BY: ________________
(SIGNATURE)

TYPE UD: ________________ **MEASUREMENT UNITS:** ☐ METRIC ☐ IMPERIAL

OUTLET			LANE		TESTED LENGTHS			METHOD		INSP.	EW-12	
NO.	STATION	PIPE DIA.	DIR	SHLD	① DIR	OUTLET DIST.	TOTAL DIST.	CAMERA	PROBE	SATISF. Y / N	SATISF. Y / N	COMMENTS

① DIRECTION IN WHICH CAMERA IS LOOKING, WHICH MAY BE OPPOSITE THE LANE DIRECTION.

COLLECTOR SYSTEM INSPECTION FORM

SITE INFORMATION

DISTRICT VINCENNES COUNTY CRAWFORD HWY No. I-64 DIRECTION EB

PROJECT No. I-64-2(34)78 CONTRACT No. R-10230 CONTRACT LENGTH 4.6 (MILES)

PROJECT LOCATION FROM PERRY-CRAWFORD CO. LINE TO 1.5 MILES WEST OF SR-37

DATE OF INSPECTION 9/9/90 INSPECTED BY Z. AHMED & N. KHAN

DRAIN No. 2 DRAIN LOCATION 2nd DRAIN FROM PERRY CO LINE SIGN

DISTANCE FROM PREVIOUS DRAIN ______ (IN FEET) 0.2 (IN MILES)

OBSERVATIONAL INFORMATION

LOCATION OF COLLECTOR: (1.) END OF PAVEMENT 2. END OF SHOULDER 3. INTERMEDIATE POINT

TYPE OF COLLECTOR SYSTEM: [✓] UNDERDRAIN OR K-PIPE [ ] FIN OR X-DRAIN

TYPE OF UNDERDRAIN PIPE: (CIRCLE ONE) (1.) CORRUGATED STEEL 2. BITUMINOUS COATED CORRUGATED STEEL 3. PLASTIC CORRUGATED 4. CLAY 5. OTHER ______

TYPE OF OUTLET PIPE: (CIRCLE ONE) 1. CORRUGATED STEEL (2) BITUMINOUS COATED CORRUGATED STEEL 3. PLASTIC PLAIN 4. PVC CORRUGATED PLASTIC 5. OTHER ______

VERTICAL DEPTH OF OUTLET PIPE FROM PAVEMENT SURFACE 2.5 (FEET)

SIZE OF OUTLET PIPE: (6" DIA.) 4" DIA. OTHER ______

SLOPE OF OUTLET PIPE: FORWARD REVERSE (FLAT)

CONDITION OF OUTLET OPENING: (FULL SIZE) PARTIAL DAMAGED

SCREEN PRESENT: (YES) NO TYPE MESH

OUTLET MARKER PRESENT: (YES) NO CONDITION BENT

HEAD WALL PRESENT: YES (NO) CONDITION ______

EROSION CONTROL APRON PRESENT: (YES) NO TYPE LINED DITCH

CONDITION OF VEGETATION ON EMBANKMENT: (MOWED) NOT MOWED

MOVEMENT OF PROBE: FREE (PARTIAL) BLOCKED

WATER PRESENT INSIDE DRAIN: (YES) NO

IF YES: FREE FLOWING (STANDING)

DISTANCE TRAVERSED BY PROBE 54 (FEET)

CAMERA OBSERVATIONS: CORROSION OBSERVED ON SIDE WALLS; STANDING WATER AT SAG OF PIPE FROM 50 FT. ONWARDS. NO BLOCKAGE OBSERVED

ADDITIONAL OBSERVATIONS: SECTION AT START OF DOWNHILL SLOPE

DATE DUE

THE TRANSPORTATION RESEARCH BOARD is a unit of the National Research Council, a private, nonprofit institution that provides independent advice on scientific and technical issues under a congressional charter. The Research Council is the principal operating arm of the National Academy of Sciences and the National Academy of Engineering.

The mission of the Transportation Research Board is to promote innovation and progress in transportation by stimulating and conducting research, facilitating the dissemination of information, and encouraging the implementation of research findings. The Board's varied activities annually draw on approximately 4,000 engineers, scientists, and other transportation researchers and practitioners from the public and private sectors and academia, all of whom contribute their expertise in the public interest. The program is supported by state transportation departments, federal agencies including the component administrations of the U.S. Department of Transportation, and other organizations and individuals interested in the development of transportation.

The National Academy of Sciences is a nonprofit, self-perpetuating society of distinguished scholars engaged in scientific and engineering research, dedicated to the furtherance of science and technology and to their use for the general welfare. Upon the authority of the charter granted to it by the Congress in 1863, the Academy has a mandate that requires it to advise the federal government on scientific and technical matters. Dr. Bruce Alberts is president of the National Academy of Sciences.

The National Academy of Engineering was established in 1964, under the charter of the National Academy of Sciences, as a parallel organization of outstanding engineers. It is autonomous in its administration and in the selection of its members, sharing with the National Academy of Sciences the responsibility for advising the federal government. The National Academy of Engineering also sponsors engineering programs aimed at meeting national needs, encouraging education and research, and recognizes the superior achievements of engineers. Dr. William A.Wulf is president of the National Academy of Engineering.

The Institute of Medicine was established in 1970 by the National Academy of Sciences to secure the services of eminent members of appropriate professions in the examination of policy matters pertaining to the health of the public. The Institute acts under the responsibility given to the National Academy of Sciences, by its congressional charter to be an adviser to the federal government and, upon its own initiative, to identify issues of medical care, research, and education. Dr. Kenneth I. Shine is president of the Institute of Medicine.

The National Research Council was organized by the National Academy of Sciences in 1916 to associate the broad community of science and technology with the Academy's purposes of furthering knowledge and advising the federal government. Functioning in accordance with general policies determined by the Academy, the Council has become the principal operating agency of both the National Academy of Sciences and the National Academy of Engineering in providing services to the government, the public, and the scientific and engineering communities. The Council is administered jointly by both Academies and the Institute of Medicine. Dr. Bruce Alberts and Dr. William A. Wulf are chairman and vice chairman, respectively, of the National Research Council.

Transportation Research Board
National Research Council
2101 Constitution Avenue, N.W.
Washington, D.C. 20418

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