Methodology for Inspection of Collector Systems

ZUBAIR AHMED AND THOMAS D. WHITE

Edge drains are a vital component of pavement drainage systems. In Indiana, performance problems exist with the types of drains used. A study was initiated to inspect and evaluate existing and retrofitted subdrainage collector systems through external visual inspection in combination with a probe for internal inspection. Distresses and deficiencies observed in construction are listed and have been compiled on video. A methodology for inspection is presented that can be used by highway agencies in monitoring the condition, need for maintenance, and performance of collector systems.

The concept of positive drainage for highway pavements is not new. It involves reducing the amount, duration, and extent of moisture present in a roadway base, subbase, and subgrade. In the absence of an effective subdrainage system, moisture-related damage reduces the performance of both flexible and rigid pavements.

In flexible pavements, the continued presence of moisture in conjunction with heavy vehicle loads may result in stripping of asphalt from aggregate, potholes, and alligator cracking. In concrete pavements, moisture may result in loss of support, degradation of the base material, and concrete deterioration.

If pavements are provided with a means for efficient internal drainage, water-related damage is significantly reduced. Internal drainage not only increases the life of the pavement, but also minimizes the cost of maintenance and rehabilitation.

A number of research studies have been conducted to improve the material properties associated with drainage of base and subbase layers (*1,2*). These studies have resulted in the development of permeable open-graded drainage layers having a low percentage of fines. Mathis (*3*) has compiled a list of the gradations and permeabilities of open-graded base courses used by different highway agencies.

One facet of the drainage system that has not been emphasized is the collector system, which receives water from the base or subbase layers and discharges it outside the pavement system through outlet pipes. Cedergren and O'Brien (*4*) and Moulton (*5*) have prepared guidelines and procedures for the design and construction of collector systems. But, literature on inspection procedures, cleaning, and maintenance of edge drains is limited. Dempsey et al. (*6*) have described a system for jet cleaning conventional pipe edge drains. California (*7*) has standard plans incorporated into the specifications for cleaning and inspection of edge drains.

Z. Ahmed, Civil Engineering Department, NED University of Engineering and Technology, Karachi, Pakistan. T. D. White, School of Civil Engineering, Purdue University, West Lafayette, Ind. 47907.

To maintain subdrainage effectiveness, edge drains should be inspected inside and outside. This research focuses on the inspection of existing subdrainage collector systems.

PURPOSE AND SCOPE

This portion of a larger study on subdrainage is aimed at observing and recording the distresses around and within the existing subdrainage collector systems. Results of the study will help the Indiana Department of Transportation (INDOT) better plan the construction and maintenance of edge drains.

Objectives

The objectives of the study included

1. Inspecting existing types of edge drains in Indiana in regard to performance and operation,
2. Monitoring the conditions inside edge drains by means of a video probe, and
3. Developing a methodology for inspection of edge drains.

Basis

For the study, a comprehensive field survey was initiated to locate sections with the two basic types of subdrainage collector systems used in the state. These are the perforated pipe edge drains and prefabricated edge drains or fin drains. To achieve a comparative evaluation of the performance of the drains, drains 10 years and older and those placed for newly built road sections less than 4 years old were incorporated into the study.

A total of 70 pipe and fin drains were inspected through the outlet pipes, and visual and camera observations were recorded. This paper summarizes the findings of the inspections and gives a detailed step-by-step procedure used for this purpose. An edited video of significant observations made during the inspection was prepared as part of the study.

INSPECTION OF EXISTING SUBDRAINAGE SYSTEMS

Site Information

Before inspection of the edge drains, site specific information was needed for the pavement subdrainage sites selected for investigation. This was achieved through project log records and construction plans. The log records provided information on the highway classification, route number, county and district in which the section was located, project and contract numbers, and project location.

The construction plans helped determine the location of the edge drain in the pavement section and type and size of edge drain used. Edge drain design, placement, and construction practice vary. A typical pipe edge drain design used in Indiana for both old and new construction projects is shown in Figure 1. This consists of a trench 350 mm wide × 600 mm deep. A perforated edge drain pipe is placed at the bottom of the trench to a required depth and the trench backfilled with open-graded aggregate. Lining the trench or wrapping the pipe with geotextile is not practiced. For retrofit and overlay projects, a geocomposite fin drain is used and connected to the outside by a 100-mm diameter plastic outlet pipe (Figure 2). The pipe edge drains are located either at the edge of the pavement under the shoulder or at any intermediate point under the shoulder, whereas fin drains are next to the pavement at the pavement-shoulder joint. Location of the drain helps determine in advance the length of the outlet pipe that the inspection probe has to traverse before making a bend into the collector pipe.

Condition Evaluation

Inspection of edge drains was preceded by an evaluation of pavement conditions of surveyed sites. The objective was to quantify the extent of deficiencies affected by the presence of moisture and imperfect functioning of existing drainage facilities. Evidence of distresses, such as pumping, alligator cracking, and joint cracking, could be related to drainage.

Pavement condition surveys were performed using the distress identification procedure developed by Shahin and Kohn (*8*). Generally, condition surveys were not conducted on newly constructed or overlaid sections. However, water stains from pumping and bleeding of water from overlaid concrete pavement sections were noted at sites where edge drain outlets were buried or clogged.

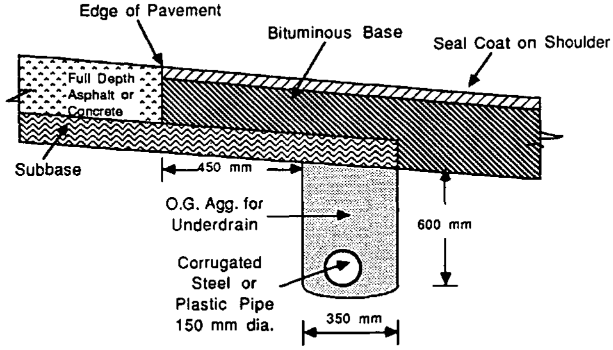

FIGURE 1 Cross section of pipe edge drain used in Indiana.

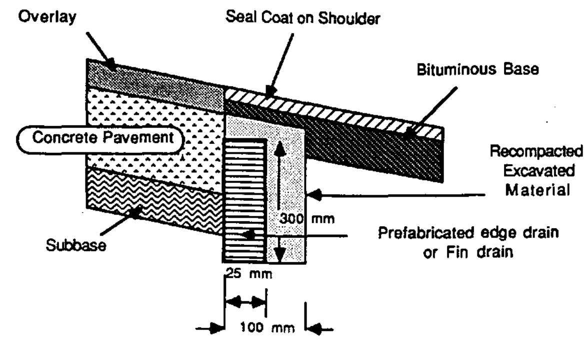

FIGURE 2 Cross section of fin drain used in Indiana.

Equipment for Inspection

Borehole Camera System

Internal inspection of collector systems is conducted with a videoimagescope or borehole camera. For this project, a market survey was made to find a camera system that would allow effective inspection of either 100- or 150-mm diameter edge drains or outlet pipes, or both. Four systems were considered.

Two Olympus camera systems were evaluated. The first system consists of a 20-mm diameter videoimagescope pushed inside a pipe edge drain through the outlet pipe to a working length of 22 m. It has an interior 100 degree field of view that can be recorded on video.

The second Olympus system allows a single-lens reflex camera to be attached to a rigid borescope. This system can be used to pierce the fabric of the prefabricated edge drain and record an interior view of the drain.

The PLS system uses a compact television probe 76 mm long with an outside diameter of 40 mm. It comes with 46 m of camera cable, camera guide skids, push rod and reel, and a control unit that includes a 230-mm color television monitor/recorder. The system comes with two light heads, which are interchangeable. A view of the system is shown in Figure 3.

The final system considered (Cues) has a black-and-white camera system with a built-in, field replaceable lighting system. The camera is 70 mm in diameter tapering to 21 mm at the ends and is mounted on a skid assembly. This system also comes with 46 m of push cable mounted on a rotating drum and has to be connected to an external video recorder to record the image seen from the television housed in the control unit.

A decision to purchase the PLS system was based on the length of the cable available, the color image capability, and the provision of the push rod and reel, which would help the probe manually through the pipe in the absence of a motorized unit. For inspection of fin drains, an Olympus borescope by Monsanto (Figure 4) was used for inspection of fin drains. Monsanto participated in the inspection of its fin drain product.

A trial run was made in the laboratory with a T-type pipe joint before field application. This step was taken to develop techniques for camera operation, insertion, and extraction. Two problems were encountered. One problem was that the guide attached to the camera head could not be easily ma-

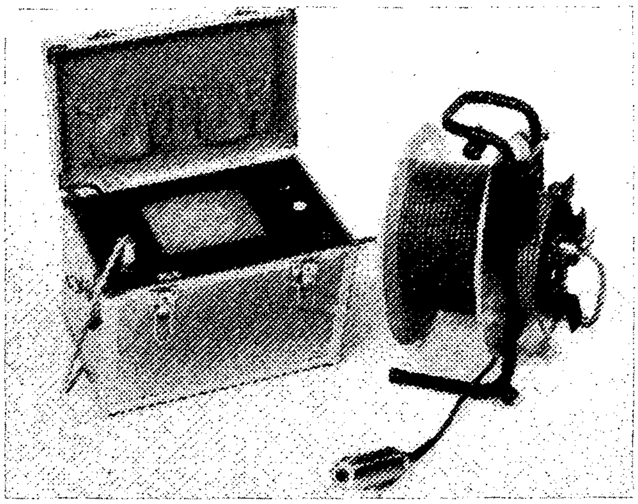

FIGURE 3 Inspection system for pipe edge drains (PLS Corporation).

neuvered through the 90 degree bend. The guide with attached camera was forced through the bend, but could not be extracted. The second problem was that the guide, because of its smaller diameter, "walked" up the sides of the pipe wall while being pushed. Another problem was that, for corrugated pipes, the probe would not ride smoothly over the corrugations, which resulted in a distorted image. Modifications were subsequently made to the guides that are shown in Figure 5.

Auxiliary Equipment

Equipment used for field inspection, in addition to the camera system, was a generator, weed eater, metal detector, and miscellaneous tools and equipments (shovels, crow bars, tapes, etc.). To operate the camera with both types of light heads, a portable generator with a minimum 750 W rating is required. For this study, a Honda generator with a maximum 1000 W output was used. The unit is compact, quiet, and easy to transport.

A weed eater can be effective in clearing the area around the outlet pipe. For most of the drains inspected, tall grass

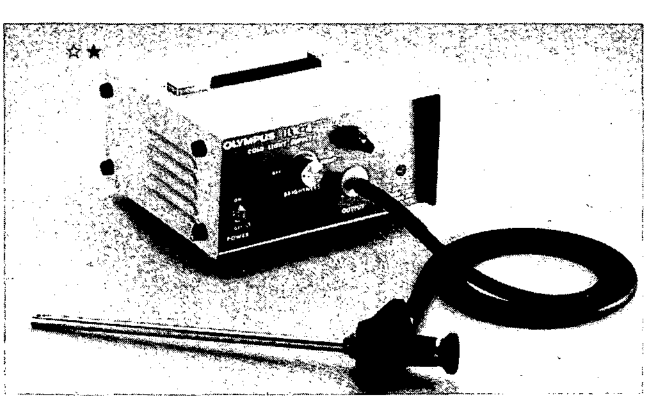

FIGURE 4 Inspection system for fin drains (Olympus Corporation).

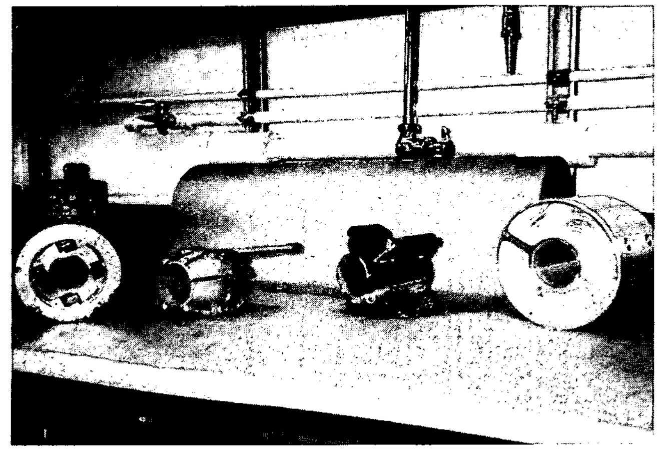

FIGURE 5 Types of guide sleeves used.

and vegetation were encountered, which not only obstructed the flow of water but also made it difficult to inspect the outlet.

During the initial survey to locate edge drain outlets, considerable difficulty was encountered on highway sections in service for more than 10 years. In some cases, outlets were not marked and were not found at the stations listed on the construction plans. Outlets were found buried by landscaping of adjacent areas. To offset this problem, a metal detector was used successfully.

Visual Observations

Drain inspection was carried out through visual and camera observations. A visual observation of the condition of the outlet pipe opening and the surrounding area was made. A number of problems were encountered and are discussed.

Outlet Pipe Slope

A general check of outlet pipe slope was made by measuring the vertical depth of the outlet pipe from the pavement surface and checking this measurement with construction plans. In the case of flat terrain or longitudinal grades of less than 1 percent, the outlets were found to have a negative or reverse slope. For this condition, ponded water was observed through camera inspections.

Outlet Condition

A frequent condition found was that the pipes were exposed for some length (Figure 6) or the outlet was crushed (Figure 7). Crushed outlet pipes become clogged over time, rendering the drainage system ineffective. Crushing is associated with erosion of soil on flat slopes from around the outlet and subsequent operation of mowing equipment on the embankments.

Markers and Rodent Screens

In most cases, outlet markers were not present or were bent or lying beside the outlet pipes. Rodent screens on outlet

FIGURE 6 View of exposed and damaged outlet pipe.

FIGURE 8 Spear-type rodent screen.

pipes were present in most of the inspected highway sections. Three outlet screen designs were found. The most common was a mesh-type screen, followed by spiral and spear types. The spear-type screen (Figure 8) did not cover the outlet and could be easily lifted, allowing rodents and small animals access to the pipe.

Vegetation

A main difficulty in edge drain inspection is the growth of vegetation around the outlet pipe. Moisture is retained around the pipe, rendering placement of equipment for inspection difficult. The standing grass around the outlet creates a barrier for flow from the outlet pipe. Accumulation of sedimentation and vegetation growth progressively blocked the pipe from outside. When vegetation was removed, any water standing in the outlet pipe started flowing.

Headwall and Erosion Control Apron

The presence of a headwall and erosion control apron or riprap protection around outlet pipes was observed to have a positive effect on the water outflow. In the absence of this protection, the soil around the outlet pipe erodes (Figure 9), exposing the pipe. The connection between the outlet pipe and the headwall may also be broken. A headwall or lined ditch at the outlet was found to be effective in restricting vegetation growth.

Camera Observations

The second stage in the inspection process involved the use of the camera systems for internal observations of pipe edge drains and geocomposite fin drains and the corresponding outlet pipes. Pipe edge drains were inspected by means of the PLS camera system. The same system was used to inspect outlet pipes for fin drains. Different-colored plastic tape was tied to the camera cable and push rod at 3-m intervals to determine the length of probe travel. This helped ascertain the distance to distresses described later and to points at which resistance was met.

Prefabricated edge drains were inspected with the equipment and personnel provided by INDOT and Monsanto Company staff. First a section of shoulder about 380 mm^2 was excavated next to pavement-shoulder joint. The excavation was made to a depth just above the top of the drain, and manual excavation was then used to expose the top of the fin

FIGURE 7 View of crushed outlet pipe.

FIGURE 9 Erosion around newly constructed outlet pipe.

drain. The shaft of the Olympus borescope was inserted through the fabric into the core. Visual inspection was first made of the conditions inside the core, and a photographic record subsequently made with a reflex camera fitted to the borescope with an adapter. The condition and distresses observed for both types of drainage systems are described.

Joint Connections

Inspection of pipe interiors revealed the joint connections to be the most distressed part of the system. Specifications require the coupling to be flush with the pipe, but in some cases inspections revealed the absence of couplings and connections made by bending the pipe ends and forcing the bent end into the adjacent section. Plant roots were often observed penetrating such connections into the pipe.

Flow of Water

In newer sections (those built within the last 2 or 3 years), water was found to be flowing freely inside both the edge drain and the outlet pipes. In older sections, standing water with fine particles in suspension was observed where there was a sag in the pipe along its length or negative slopes for some outlet pipes. This could be attributed to either improper care during construction, as a result of settlement, or loads from vehicles or mowing equipment. Inspections made immediately after a rain showed water flowing with high velocity in sections having a positive slope for outlet pipes or at sag points along the highway. This helped flush out fine particles entering the drain through slots and openings.

Pipe Corrosion

Most of the corrugated steel pipe edge drains viewed through the camera showed significant corrosion. This can be attributed to dissolved salts or other chemicals. This type of distress becomes more severe when there is standing water inside the pipe, because it allows time for the chemicals in water to react with the pipe metal. In some of the inspected pipes, the severity of the corrosion resulted in development of cavities and openings in the pipes. These openings allowed material to enter the pipe and, without flow for a period of time, the pipe system becomes plugged. In one of the inspected drains, gravel used in the embankment was being transported out of the pipe (Figure 10). Plastic pipes inspected were free from this form of distress.

FIGURE 10 Gravel from punctured outlet pipe.

Sedimentation in Fin Drains

Some of the fin drains inspected through the camera showed sedimentation at the bottom of the fabric. Typically the fin drains are 300 mm high. However in several cases the shaft of the borescope could not be pushed beyond a depth of 250 mm. This was because of sedimentation. A section of the fin drain was removed from along Interstate 65. The cut section of the drain, which had been in place for 4 years, showed sedimentation deposits to a depth of 75 mm (Figure 11). This section of I-65 has a dense-graded aggregate base. Fin drains installed along I-65, having bituminous stabilized subbases, showed less of this problem and water flowed freely immediately after rainfall events.

Fin Drain Buckling

Fin drain buckling was observed at most inspection sites. The cuspations of the drain core would appear to arch along the horizontal plane. This was more pronounced at transverse joints along concrete pavements. Sections exposed at the joint showed the width of the adjacent concrete slabs varying by 25 to 50 mm. Because the drain is placed immediately adjacent to the pavement-shoulder joint, projection of adjacent slabs causes the drain to bend in a horizontal plane (Figure 12). This in turn reduces the core flow capability of the drain.

A form of fin drain distress observed in the vertical plane is termed J-buckling (Figure 13). This is attributed to the design of the Monsanto fin drain. The drain core has a perforated base on one side with cuspations projecting from the base. The fabric is wrapped around the core. The cuspated side of the core is susceptible to buckling when loaded vertically. Such a vertical load is applied during trench backfilling

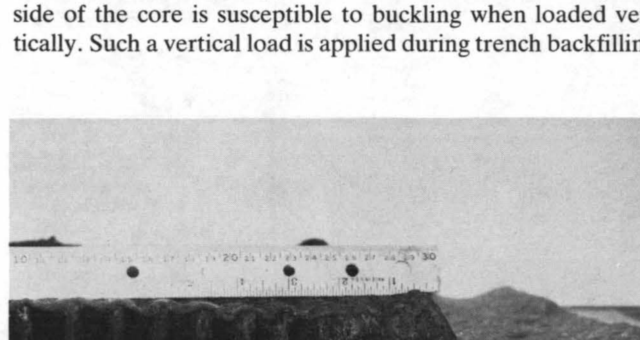

FIGURE 11 Sedimentation deposits in exposed fin drain.

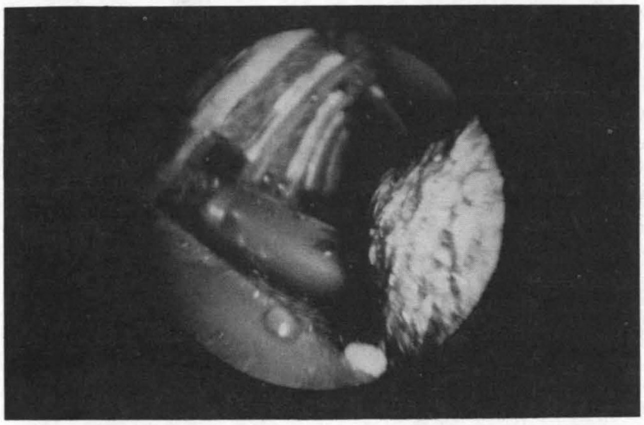

FIGURE 12 Fabric intrusion and roll over of fin drain.

and compacting. Also, outlet pipe connections are not made at the same time the drain is installed. Thus the trench has to be reexcavated at the point of joint connections to connect the outlet pipes. Backfilling and compaction result in the drain buckling along its bottom edge, especially at the joints. This was seen with the PLS camera system while checking the fin drain outlet pipes.

Connector Angle

The type of edge drain to outlet pipe connector will have a significant impact if future inspection, maintenance, and cleaning of the pipes are to be attempted. The connector angle has to be large enough not to restrict movement of the inspection camera probe. This is true as well for injection cleaning equipment, which may be used to clean the interior of the pipe through outlet pipes or clean-out ports. Evaluation of the existing drain connectors through the camera system has shown that the probe could be easily moved into a pipe edge drain through the outlet connector if a Y-connector is used instead of a T-connector. For new edge drains inspected, it was observed that connectors sweeping a 60 degree angle on a horizontal plane proved to be the most efficient for movement of the camera through the joint.

FIGURE 13 View of J-buckling in exposed fin drain.

EDGE DRAIN INSPECTION PROCESS

A detailed account of equipment and processes used to inspect pavement subdrain collector systems has been given. Various types of distresses and deficiencies in construction observed both visually and with the camera system have been described. A summary of the proposed inspection process will include

- Site information (inventory and as-built records),
- Condition evaluation of roadway,
- Visual and camera observations, and
- Information logging.

Site Information

Accurate site information is vital to the inspection procedure. Information on the route, location, direction, project and contract numbers, and year of construction can be obtained through inventory numbers, and year of construction can be obtained through inventory data maintained by the state highway agency. Construction plans help determine the exact locations of the outlets. This information is useful for periodic inspections of the same section.

Condition Evaluation

A general observation of the pavement condition before drainage inspection will give an indication of problems associated with trapped moisture. The observations will supplement those made by visual and camera observations.

Visual and Camera Observations

The features and geometrics of the outlet pipes are observed visually and noted, as well as any unusual feature that would help assess the effectiveness or problem areas associated with a collector system. Internal observations of the drains are made using an appropriate camera system.

Information Logging

For ease and convenience of recording information, a standard inspection report form has been developed. A completed sample form is shown in Figure 14. This form helps organize data. Supplemental information in the form of photographs also helps document deficiencies not listed or recorded. A final report should include the inspection report form, photographs, narrative descriptions, and other relevant information. This will provide a permanent record to be used for reference in periodic inspections of both existing and retrofitted drains.

CONCLUSIONS

A procedure for inspecting subdrainage collector systems has been described. Performance of existing and retrofitted subdrainage systems can be monitored effectively with a camera

COLLECTOR SYSTEM INSPECTION FORM

SITE INFORMATION

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

PROJECT No. I-64-2/34 8 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

FIGURE 14 Sample of completed inspection report form.

system. The information will lead to improved pavement maintenance, design, material specifications, construction specifications, and performance of subdrainage systems.

The camera system can serve as a valuable tool for inspection of newly built drains before the project is handed over by the contractor to the state agency. Damage or distress due to construction practices can be located. Modifications of the original camera equipment will result in a more efficient and trouble free operation.

Inspection of both old and new edge drain installations resulted in the following conclusions:

1. Edge drains are effective in removing infiltrated water if care is taken during construction regarding slope, backfill compaction, and outlet treatment.

2. Mesh-type screens are more effective than other designs in preventing rodents and small animals from getting into the outlet pipes and edge drains.

3. Treatment of the area around the outlet pipe contributes significantly to proper functioning of the collector system. Vegetation growth, sedimentation, and erosion around outlet openings are impediments to effectiveness of the system. Riprap protection or concrete pads around the outlet area will minimize this effect and protect the outlet pipe from damage caused by mowing equipment.

4. Edge drains on flat grades or at minimum slopes were observed to have the most problem with clogging. This can be remedied through the use of a clean-out assembly using high water pressure. For pipe edge drains, inspection and jet cleaning can be done through outlet pipes. For fin drains, a

vertical plastic or steel port placed halfway between outlets can be used to clean the drain core.

5. Smooth-walled plastic outlet pipes perform better than corrugated steel pipes because corrosion and sedimentation are more pronounced in the latter.

6. Care is required in backfilling and compacting trenches to avoid sags and collapse of pipe and fin drains.

7. The type of fin drain inspected in this study has a tendency to buckle, and the use of an improved product is recommended.

8. To facilitate inspection and cleaning of edge drains it is recommended that outlet pipes be connected with a 60 degree minimum angle for Y- or L-connections, and no T-connections should be allowed.

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