MLR 8510

Underseal Evaluation Project

Poweshiek County I-80
near milepost 189.5, Eastbound Roadway

July 1985

Highway Division
Iowa Department of Transportation

UNDERSEAL EVALUATION PROJECT

PREPARED BY:

OFFICE OF MAINTENANCE: DWIGHT M. RORHOLM - MAINTENANCE OPERATIONS ENGINEER

OFFICE OF MATERIALS: O.J. LANE - PORTLAND CEMENT CONCRETE ENGINEER

OFFICE OF ROAD DESIGN: KERMIT L. DIRKS - SOILS GEOLOGIST

OFFICE OF CONSTRUCTION: THOMAS E. CACKLER-PORTLAND CEMENT CONCRETE FIELD ENGINEER

FEDERAL HIGHWAY ADMINISTRATION-IOWA DIVISION: MARTHA J. NEVAI

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FOREWORD

This project was developed to answer several questions in regard to undersealing of Portland Cement Concrete pavements. Equipment was recently purchased by the Department to replace old "mud pump" units. These units are designed to pump a cement - flyash grout to fill voids under the pavement created by traffic action and erosion. This work is very similar to contract undersealing work which is beginning to be utilized in conjunction with other concrete pavement repair work.

The purpose of the project was to determine an optimal hole pattern, and to also determine if it is practical to underseal a pavement with existing longitudinal subdrains without plugging the subdrain system.

The conclusions represented in this report are the opinions of the authors and do not necessarily represent the official views of the Iowa Department of Transportation-Highway Division. This report does not constitute a standard, specification or regulation.

PURPOSE

The purpose of this project was to determine the optimum hole pattern needed for undersealing work, and to also determine if it is feasible to underseal a roadway with existing longitudinal subdrains without plugging the subdrain system.

SITE SELECTION AND DESCRIPTION

To determine the optimum hole pattern for pavement undersealing, it would be necessary to overturn or lift out panels adjacent to the joints or cracks after undersealing was accomplished. With this in mind, we selected a section of pavement on I-80 which was under contract for removal and replacement (PCC inlay Project No. IR-80-6(106)191--12-79, Poweshiek County - eastbound roadway).

EXISTING PAVEMENT DETAILS

- 10" PCC with mesh reinforcing
- Joint spacing - 76' 6" with load transfer assemblies
- 4" granular subbase (24'-8" trench installation)
- Paving completed and open to traffic in October 1964
- Longitudinal drains were installed by retrofit in the fall of 1978 (6" perforated corrugated polyethylene tubing with porous backfill)

The existing joints in the area selected were faulted 0.25", measured at mid-lane.

Subdrains in this area were installed in the shoulder along the outside pavement edge in 1978. Depth of installation was 24", measured from the surface elevation of the edge of pavement. Subdrains were to be removed on the 1985 inlay project and replaced with subdrains installed to a 48" design depth. Deeper subdrains were needed to accommodate the 1985 inlay pavement structure.

CEMENT - FLYASH GROUT INJECTION

The roadway was undersealed in the driving lane only. Four hole patterns were utilized (see figure 1). Undersealing was accomplished on June 3, 1985.

The driving lane of the roadway was closed to traffic.

One-inch diameter injection holes were drilled 10" to 11" in depth. Holes were redrilled to 12" in depth after pumping pressure of 100 PSI at hole "D" was encountered. Monitoring holes, 8" depth, were drilled in the shoulder over the center of the subdrain installation. The purpose of these holes was to monitor possible grout flow, if any, into the porous backfill and to also provide pressure relief. Grout was mixed and injected by a CHEMGROUT CG-625 trailer mounted grout plant. Mixing was done by a colloidal mixer and injected with a progressing cavity pump.

GROUT COMPOSITION AND FLUIDITY

One part Portland Cement (by volume) - 94 lbs. per sack
Three parts class C, Council Bluffs flyash (by volume)-76 lbs. per sack
1/4 sack double strength mortar color - #4 red - 23 lbs. x 1/4

Water was added to achieve required fluidity (measured by the Corp of Engineers flow cone method CRD-C611-80). Ten (10) to 20 seconds was selected as the starting target value for efflux time.

GROUT HOLES	WATER(GALLONS)	EFFLUX TIME(SECONDS)
A-E	17	16
F-J	19	19
M-V	27	15
W-FF	28	time not measured

Note: 1-1/2 batches were mixed and wasted after the injection at hole "J" was completed. The full batch wasted contained 22 gallons of water with an efflux time of 20 seconds.

INJECTION PROCEDURE

The packer was inserted into the holes and grout was injected into the void area under the pavement. Pumping was terminated when grout became visible at the joints or cracks or other injection holes, or when slab raise was detected. Vertical lift of the panels was monitored by the pump operator by placing his hand across a joint while maintaining contact with the panel being injected. The adjacent panel or the (paved) shoulder was used as a "stable" reference. Jacking of the panels did not occur, although minor uplift at some joints was noted.

Pumping pressure of 20 - 25 PSI was used, although pressures of 100 PSI were evident at some hole locations (D, F and G). These locations were later found to be unsuccessfully undersealed, except for a small cone at the underside of the slab. The quantity of grout injected into each hole was not measured.

Upon completion of the undersealing work, the holes were plugged with a dry cement-sand mixture. A 2-hour minimum cure was provided prior to removing the traffic control devices.

LIFT OUT OBSERVATIONS

The undersealed panels were removed for inspection July 10, 1985. "Lift out" consisted of tipping up the panels about centerline with an end loader. This method was unsatisfactory in the sense we were unable to walk under all the tipped up panels. We would have preferred to have the panels tipped onto the adjacent passing lane, but this method was unsatisfactory since this would have inhibited other project work.

SUBDRAIN CONDITION

Existing 24" deep, 6" diameter slotted subdrain tubing was examined during removal to determine the effect of pavement undersealing. Removal was accomplished by cutting a 10" wide trench through the asphaltic concrete shoulder and then lifting the tubing through the surrounding aggregate backfill (see Appendix A).

The undersealing grout infiltrated the subdrain system at three locations. The drainage system, however, appeared to be fully functional. It appeared that some damage to the drain tubing may have occurred during initial construction. An area located approximately 12' west of joint 3 contained a pipe splice failure which had resulted in a 4" separation. The drain pipe was also collapsed for about 4' adjacent to crack 12, possibly from excess "stretching" during installation. Water was flowing through the system at the time of drain removal and had apparently been flowing during the time of grout injection. The fact that this drain was continuing to function normally speaks very well for the porous backfill system.

Considerable grout was injected into the drainage trench. The grout caused backfill cementation at the base of the drain pipe between joints 2 and 3, and through an area extending 15' either side of joint 5. Grout had filled the subdrain trench to a depth of approximately 10" through the area where the drain pipe collapsed at crack 12. Approximately 14' of pipe was encased by grout. At this location, hardened grout had entered the drain tubing and filled the corrugations in the flowline of the pipe. Some of the grout may have been removed from the tubing by flowing water while the grout was fluid. Joint 3, which contained 5 injection points, did not show any evidence of grout under the slab. The same situation was true with the approach panel of joint 11. Apparently the drainage system accepted nearly the total amount of grout placed at these locations with little harm. Heavy concentration of grout was present on the panel edge in these areas, but no grout appeared in the relief holes drilled over the subdrain. Through the entire trial section, the upper portion of the drainage trench was free of grout.

UNDERSEALING OBSERVATIONS

Seven joints and two mid-panel cracks were undersealed to evaluate the effectiveness of various injection hole patterns. Figure 1 shows the approximate grout spread at each location.

JOINT 1:

Two injection points were located 3' from the outside edges of the approach panel. Grout spread consisted of a 4" to 8" diameter cone centered on each injection point. This was the first test pattern tried and demonstrates the problems associated with a "thick" grout consistency.

JOINT 2:

One injection hole was located in the approach panel, 3' from the shoulder and 1.5' from the joint. This location contained the cone effect noted at joint 1. A definite unfilled void was present near this location.

Two injection holes were located in the leave panel adjacent to a 4" foam filled pressure relief joint. Cemented base material, 5" thick, adhered to the slab adjacent to the pressure relief joint. This material tapered to an approximate 3" thickness over a 12' long area adjacent to centerline and a 3' long area 30" from the shoulder. There was no cementation in a 30" band adjacent to the shoulder. No grout projected across the pressure relief joint.

JOINT 3:

Five injection holes were located adjacent to this joint. Two holes were located 1.5' from the joint on the approach panel, and two holes were located 3' from the joint on the leave panel. A third hole was located 6' from joint 3 and 3' from the shoulder.

There was no indication of cemented base in this area. A very thin grout stain was present on the underside of the slab. The subbase was moist over an area which extended approximately 5' on either side of the joint. There was some question as to the injection hole depth at this location. The two holes located in the approach panel were visible as small cones of grout.

CRACK 4:

Undersealing was not done at this location.

JOINT 5:

Two injection holes were located in the leave panel. The holes were located 3' from the joint and 2' from the edge of the panel. A patch was located in the passing lane, and a 2' wide surface spall was present near the centerline.

Approximately 4" of base was cemented to the leave panel, extending 5' from the joint. Grout did not migrate across the joint. There was definite evidence of "fines" removal from the interior portion of the approach panel. Considerable deterioration of the joint had occurred. Approximately 4" of dowel bar was exposed at the joint, with deterioration tapering towards the underside of the slab at an approximate 45 degree angle. The "void" left by the spalling was filled with fine rubble. Grout did not penetrate the rubble or fill the voids at the joint.

CRACKS 6 & 7:

Undersealing was not done at these locations.

JOINT 8:

This was a repeat of the joint 5 hole pattern.

Flow characteristics were adjusted to new target values of 12 - 16 seconds at this point. Subbase was cemented to the slab, covering an area which extended for 3' under the approach panel to 7' under the leave panel. This joint also exhibited extreme deterioration, with bottom spalling extending 6" on each side of the joint. The hole closest to centerline apparently did not penetrate the slab and all undersealing was accomplished from the hole located near the shoulder. As at all other locations, the outer 30" of the subbase appears to be choked with lime fines which the grout did not penetrate. There is evidence that grout penetrated cracks in the subgrade soil in this area.

CRACKS 9 & 10:

Undersealing was not done at these locations.

JOINT 11:

Seven injection holes were located adjacent to this joint. Two holes were located in the approach panel approximately 1.5' from the joint and 3' from the panel edge. Three holes were located in the leave panel, 3' from the joint. The remaining two holes are adjacent to the shoulder 1.5' from the edge of the panel.

At centerline approximately 2" of subbase was cemented to the approach panel, extending for 9' from hole "0". This tapers to approximately a 5' width 24" from the shoulder. Grout was present around all of the load transfer dowels.

The leave panel had subbase cemented to an area near the center of the panel, beginning at about 5' from the joint. Approximately 1/2" of grout was deposited immediately under the joint.

CRACK 12:

This was a non - working crack. Seven injection holes were located in this area. This is a repeat of the hole pattern used at joint 11.

The approach panel had a uniform 6' triangular area of subbase cemented to the slab adjacent to centerline.

The leave panel had a 3" thick layer of cemented subbase extending uniformly from the crack to approximately 6' from the crack. No cemented subbase was present throughout an 18" area adjacent to the shoulder. The three injection holes adjacent to the shoulder resulted in a 12" wide, 4" thick, "bar" of cemented subbase adhering to the slab.

JOINT 13 & CRACK 14:

Two holes were located in the leave panel 3' from joint 13 and two additional holes were located 7' from the first set of holes. All four holes were located 3' from the edges of the panels. A non-working crack (crack 14) was located between these holes.

The approach panel of joint 13 had a thin grout covering on the subbase extending approximately 2' from the joint. Grout had intruded the joint and had filled the open areas around the dowel bars.

The leave panel of joint 13, extending for 18', had an approximate 2" thick, uniform layer of cemented subbase adhering to the slab. As at all other locations, the area adjacent to the shoulder did not contain grout.

The following remarks apply to all joints except joint 2. Existing load transfer devices were at best marginally operational. At all of these joints, concrete had deteriorated at the bottom of the pavement, exposing a portion of the dowels.

CONCLUSIONS

At this test site the hole pattern had little effect on the grout distribution. The hole pattern, to be effective, must locate existing voids. Holes must extend at least 2" below the underside of the pavement.

Void areas appeared at either side of the joint or crack. Voids under the approach panels were generally located very close to the joint or crack. The voids under the leave panels were more extensive, and extended greater distances from the joint or crack. These voids were most extensive along centerline and at mid portions of the panels adjacent to the joint or crack. The void zone began near the joint or crack and was more prominent approximately 3 ft. into the leave panel (see Figure 1, Appendix C.)

No voids were noted, nor was grout deposited, in an 18"-30" band adjacent to the shoulder. The subbase throughout this band contained a noticeable accumulation of fine limestone particles. These "fines" had not contaminated the porous backfill located in the subdrain trench. This band of redeposited fines is thought to have occurred due to the dewatering effects provided by the subdrain system.

Grout consistency was an important controlling factor. A grout with proper flow characteristics will fill voids encountered within a 6'-10' radius. Injection of grout with a high efflux time tends to cause coning resulting in points of localized support. This is contrary to the concept of undersealing, which is intended to re-establish uniform support.

It appears that pavements can be undersealed without significant damage to the existing subdrains. Special care is needed to assure that excess grout is not injected into the drainage system. To accomplish this, the number of injection holes should be held to a minimum and should be located at least 3' from the pavement edge. Inspection holes (relief holes) placed at the pavement edge are considered necessary to monitor grout entry into the subdrain system.

RECOMMENDATIONS

Based on this project the following recommendations are considered to be appropriate.

- The recommended hole pattern would consist of one hole in the approach panel. This hole would be placed 1.5' from the joint or crack and 4' to 8' from centerline. Two holes would be placed in the leave panel. These holes would be 3' from the joint or crack and 3' from the panel edges. The holes must extend at least 2" below the underside of the pavement. The holes would be 1" in diameter to minimize spalling at the bottom of the slab which could inhibit grout injection. When subdrains are present, monitoring holes (pressure relief hole) should be placed in the shoulder against the pavement edge. These holes should penetrate the porous backfill of the subdrain system.
- Grout efflux time should be within a range of 12 to 16 seconds.
- General practice to date has been to underseal prior to installing the subdrain system. Undersealing can be accomplished after subdrain installation; however, the risk of plugging the drainage system and associated damage to the pavement must be considered.
- There may be advantages to installing the subdrain system prior to undersealing. The primary advantage would be to provide a "stabilized", water-free base. Procedures for minimizing the risk of plugging the subdrains with grout may include:
  1) introducing positive water flow into the tubing while undersealing;
  2) opening a continuous trench over the subdrain to expose the pavement base; or
  3) place filter fabric adjacent to the pavement during initial drain installation.

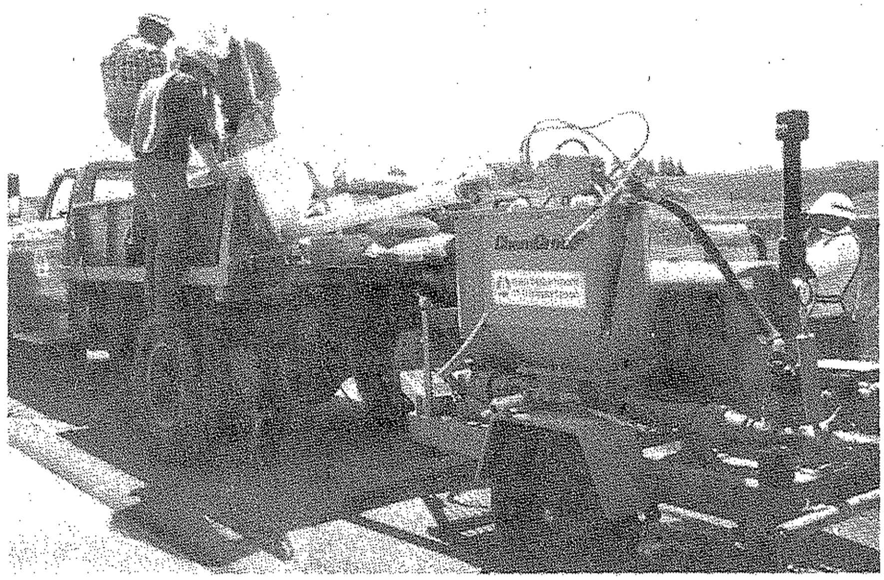
ADDITIONAL INVESTIGATION NEEDS

Investigation such as this needs to be undertaken on roadways with other base designs to determine if the recommended hole pattern would be appropriate.

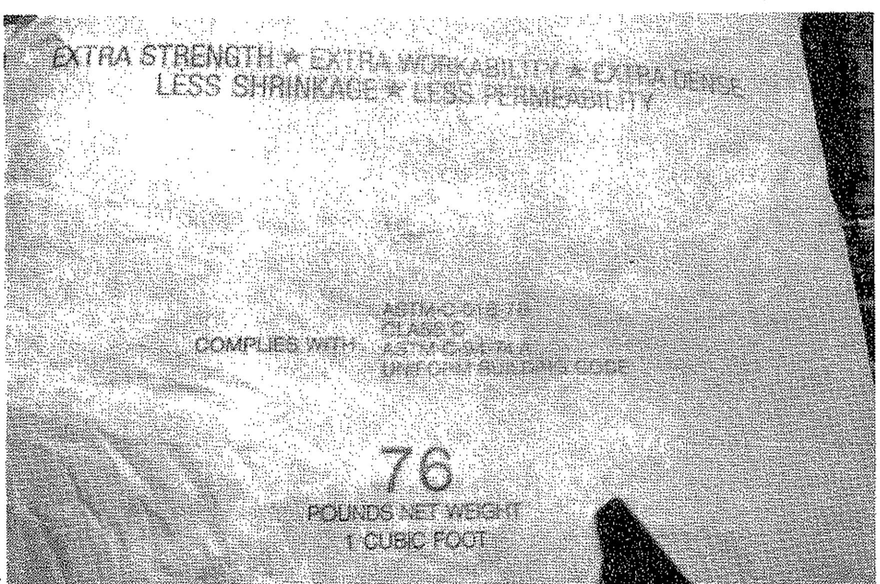
APPENDIX A

PHOTO LOG

Drilling Monitoring Holes in Shoulder (Pressure Relief) over the Subdrain



ChemGrout Unit



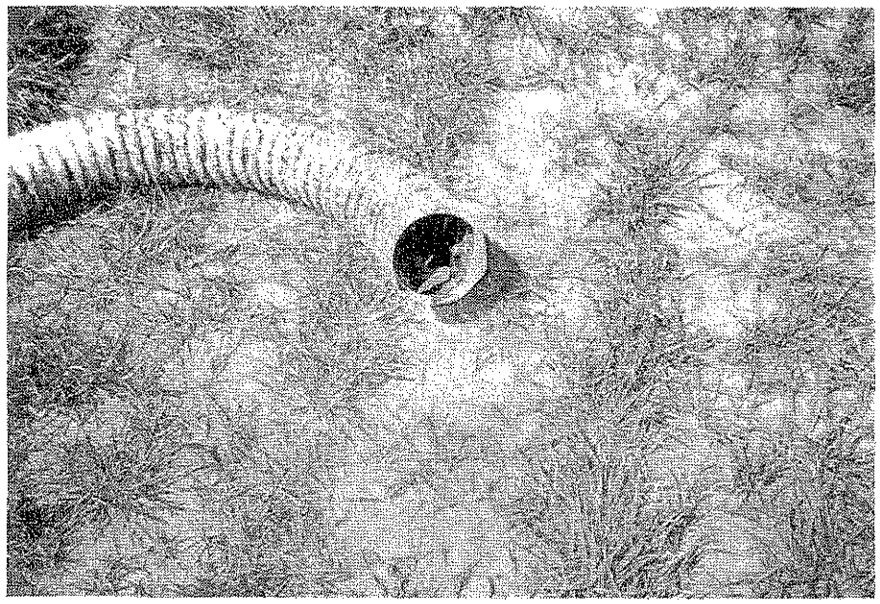
Flyash Used

Cement Used

Mortar Color Used

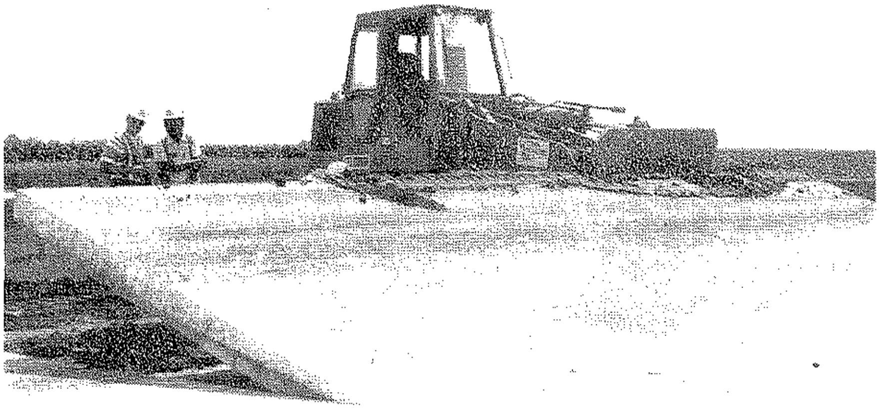
Removing Subdrain

Fragment of Porous Backfill with Intruded Grout, which Encased the Subdrain Pipe.

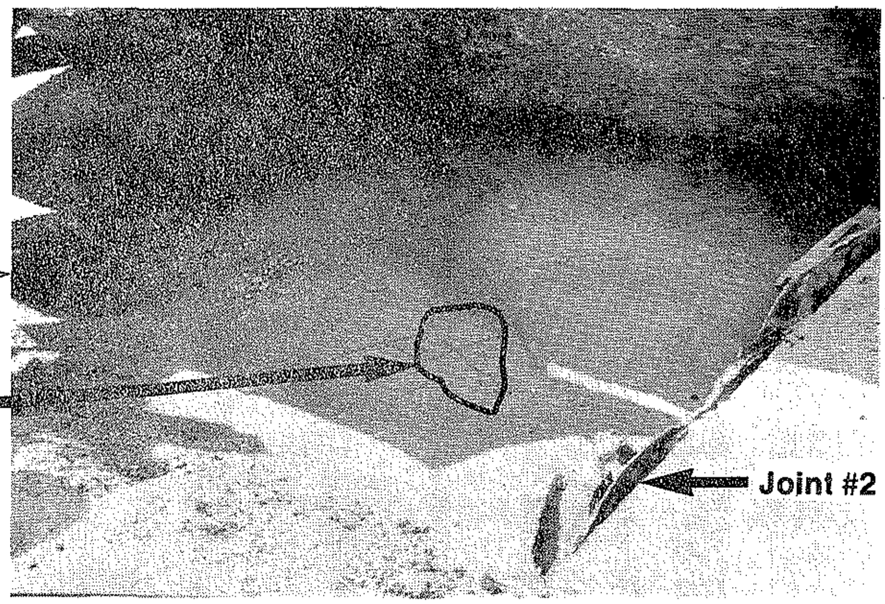


Grout Intrusion Remaining in Subdrain Pipe

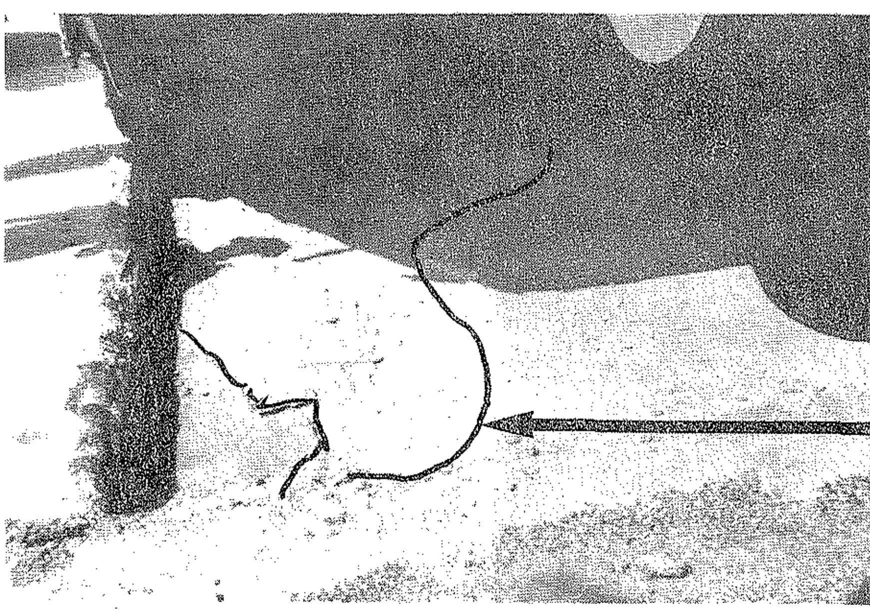
Joint # 13. Pavement edge exposed during subdrain removal. The light area on the edge of the pavement is grout.



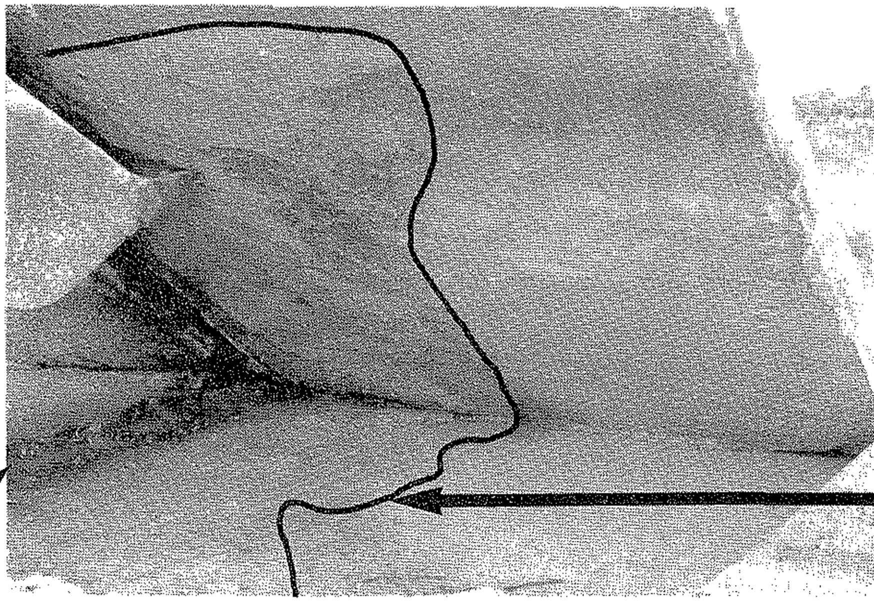
Lifting Procedure



Joint #1 and Joint #2



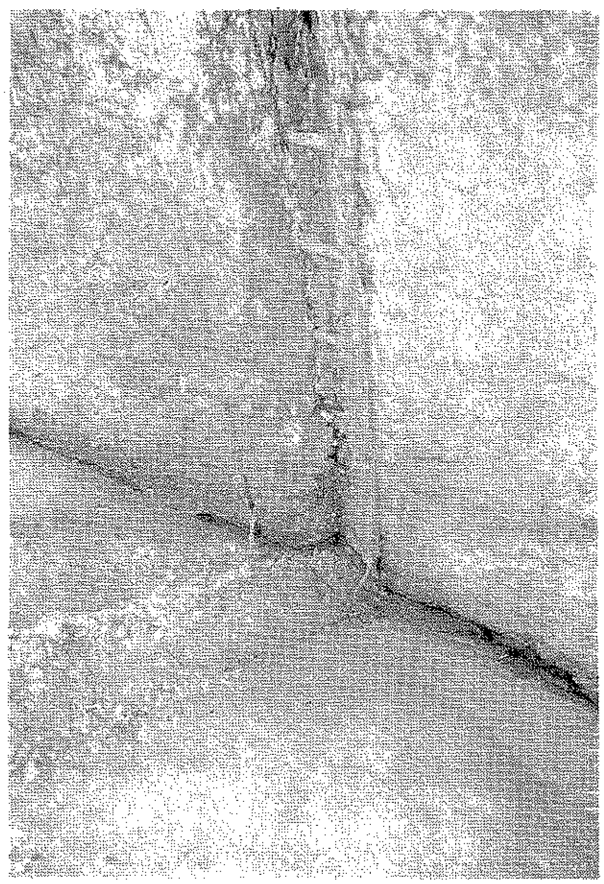
Joint #2



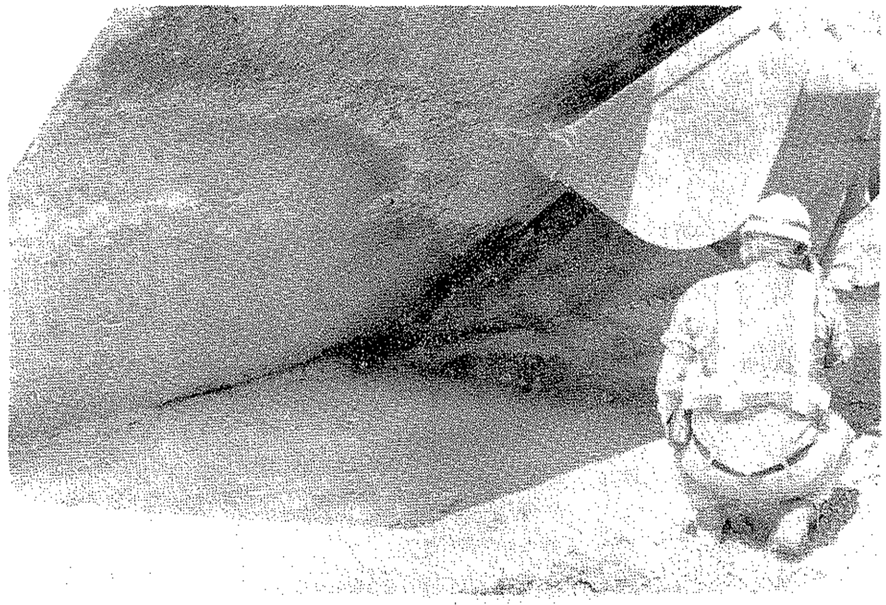
Grout boundary

Joint #5 Leave Panel: Grout and subbase material is adhereing to underside of panel.

Joint.
Note Joint
Deterioration



Joint #5 Note Joint Deterioration

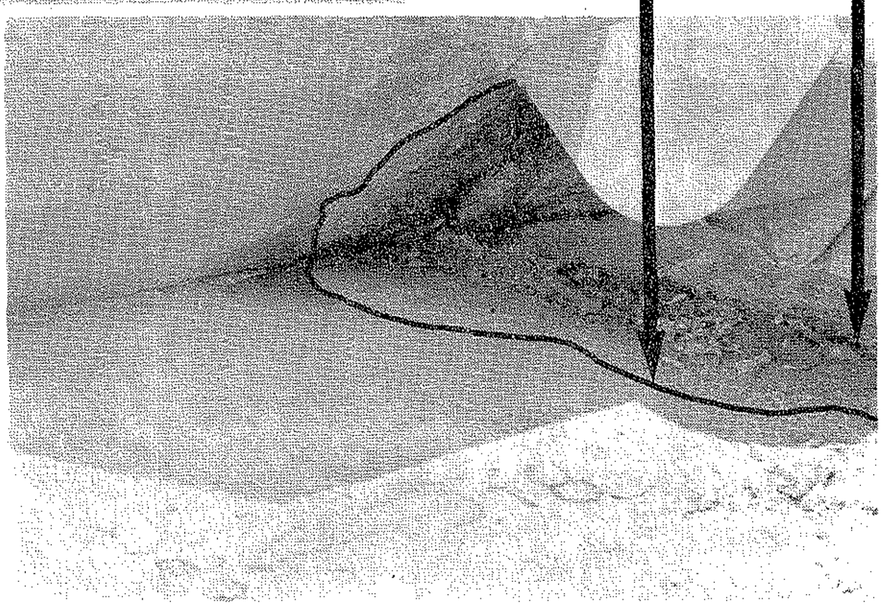


**Joint #5 Approach Panel
No grout distribution
under approach panel.**

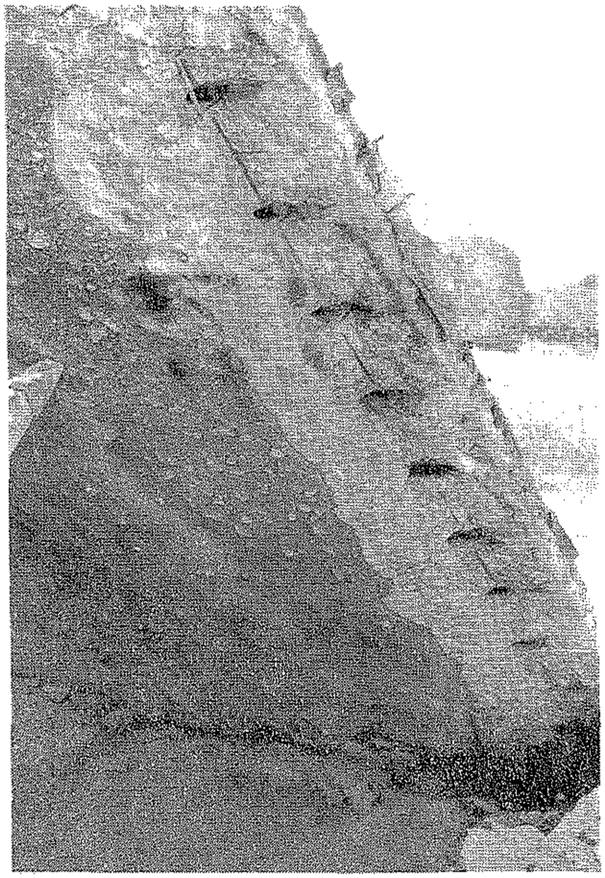
**Joint #8 Leave Panel: Note
Joint Deterioration. Grout and
subbase material adhereing
to underside of panel.**

**Joint - Note
Joint Deterioration**

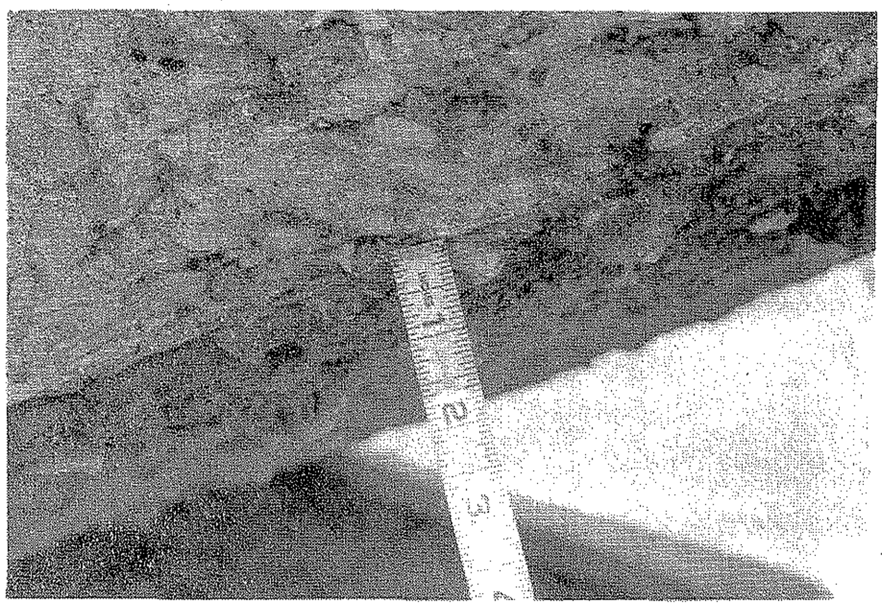
Grout Boundary



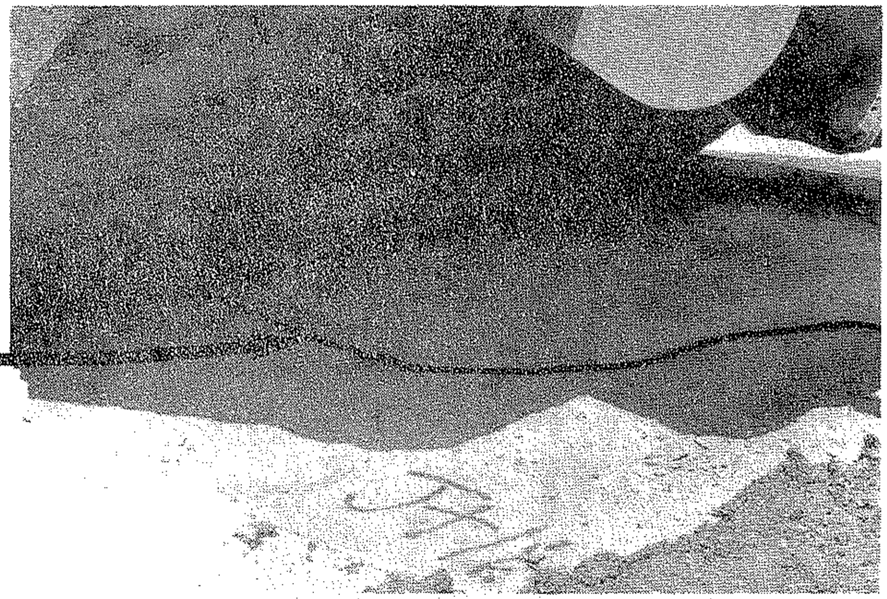
**Joint #8 Approach Panel:
Grout and subbase material
adhereing to underside of
panel.**



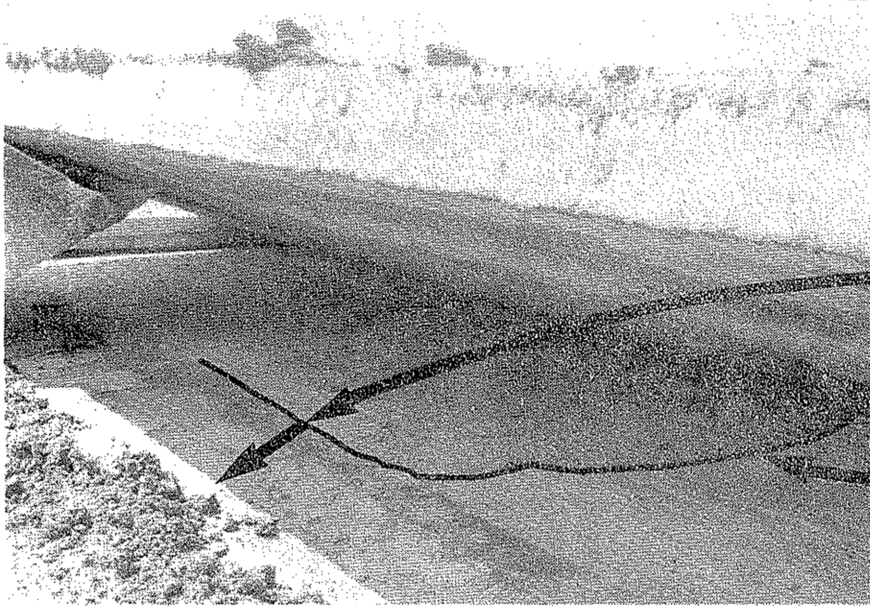
Joint #11
Indicates deterioration of concrete below dowel bars.



Joint #11: ½" of grout and subbase material adhereing to underside of panel.

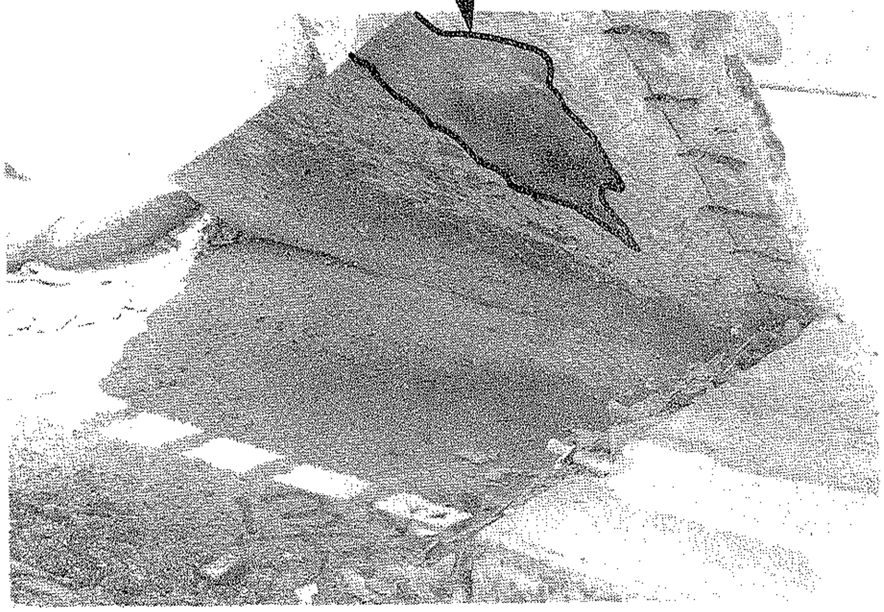


Joint #11 Leave Panel

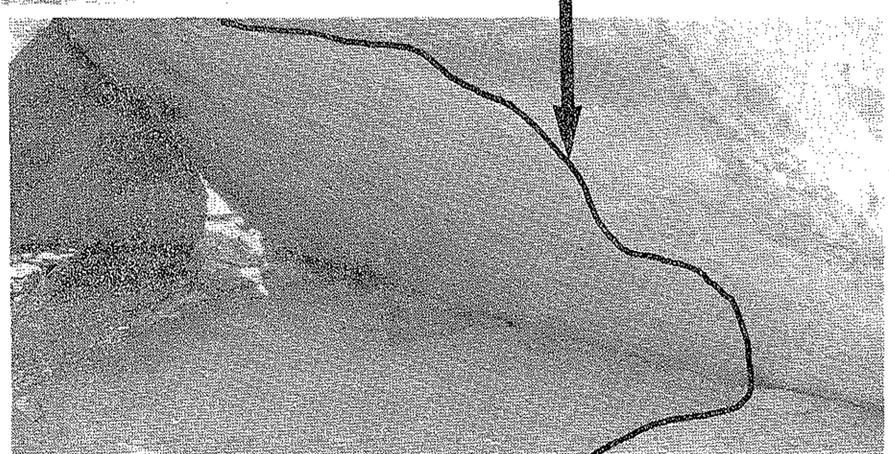


Crack #12 Leave Panel

Crack #12 Leave Panel



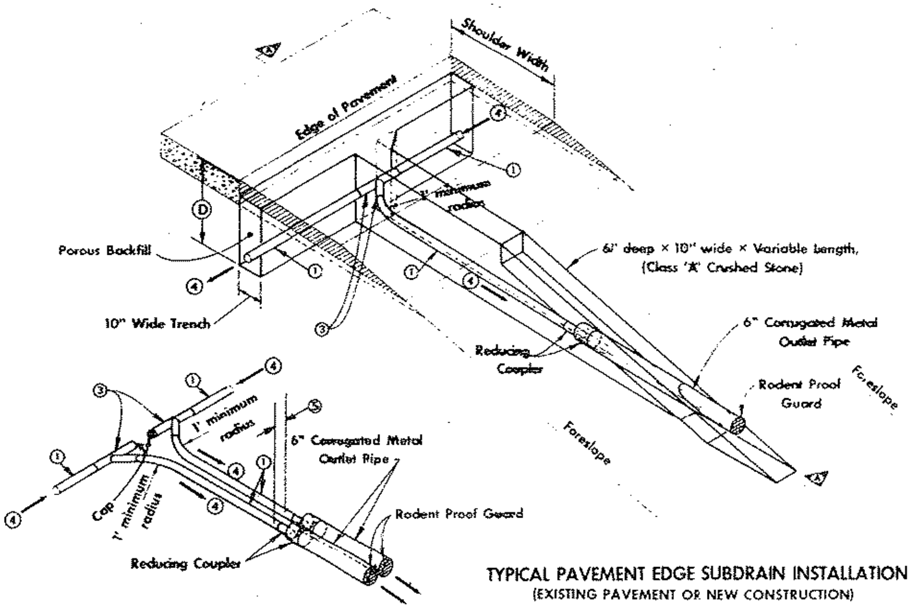
Joint #13 Approach Panel
Grout and subbase
material adhereing to
underside of panel.



Crack #14 Leave Panel
Grout and subbase material
adhereing to underside of panel.

APPENDIX B

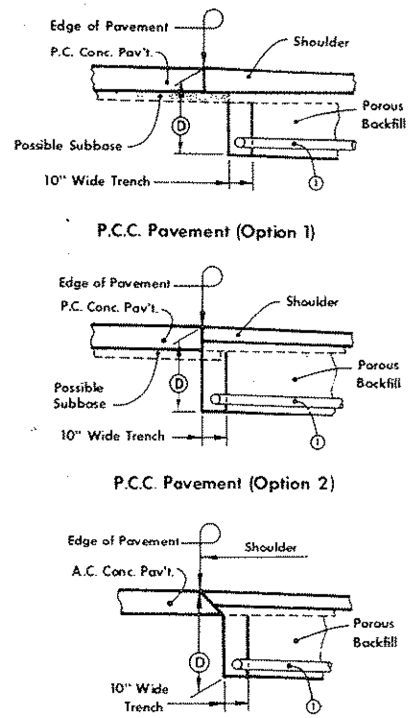
CURRENT DESIGN DETAILS OF LONGITUDINAL SUBDRAINS



TYPICAL PAVEMENT EDGE SUBDRAIN INSTALLATION
(EXISTING PAVEMENT OR NEW CONSTRUCTION)

SAG OUTLET
(DOUBLE OUTLET)

① 4" Perforated Subdrain (Polyethylene Corrugated Tubing).
② Refer to specifications for finishing shoulder on existing pavement construction.
③ Use only 45° 'Y' as shown ('T' connection shall not be allowed).
④ Direction of Flow.
⑤ 5' Maximum distance between outlet tubing



SECTION A-A
TYPICAL SUBDRAIN OUTLET
(NEW CONSTRUCTION)

GENERAL NOTES:

Details indicated hereon are for the construction of longitudinal subdrains and outlets. 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.

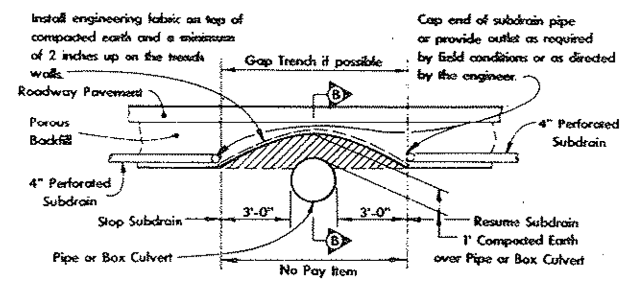
Areas of shoulders in project limits not shown in tabulation of longitudinal subdrain and other areas conflicting with subdrain installation will not be trenched.

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.

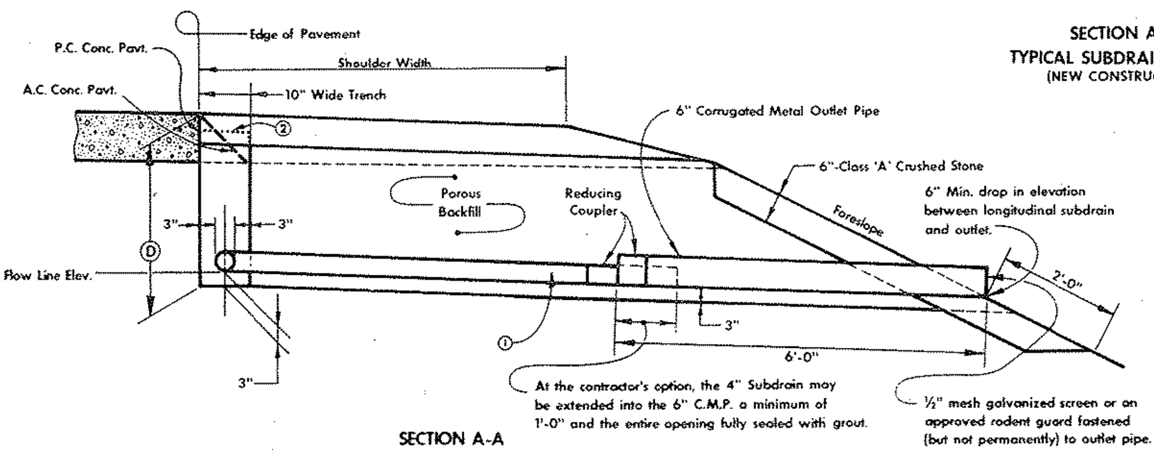
Each outlet shall be covered with ½" mesh galvanized screen or an approved commercial rodent guard. The guard shall be securely fastened (but not permanently) to the outlet pipe end by means approved by the engineer.

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 engineer. On existing roadways, the trench shall be capped with material per current Standard and Supplemental Specifications.

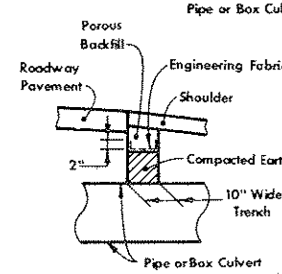
Price bid for "Longitudinal Subdrain, (Shoulder)" (in lin. ft.) and "C.M.P. Subdrain Outlet" (No.) shall be considered full compensation for all installation work and materials necessary as detailed hereon, and as required by project plans. Double outlet is considered two outlets for payment count.



TYPICAL DETAILS TRENCH REPAIR
AT R.C.B. CULVERTS OR RF-1 CONCRETE PIPE CULVERTS



SECTION A-A
TYPICAL SUBDRAIN OUTLET
(EXISTING PAVEMENT)



SECTION B-B

DETAIL SHEET 500-7

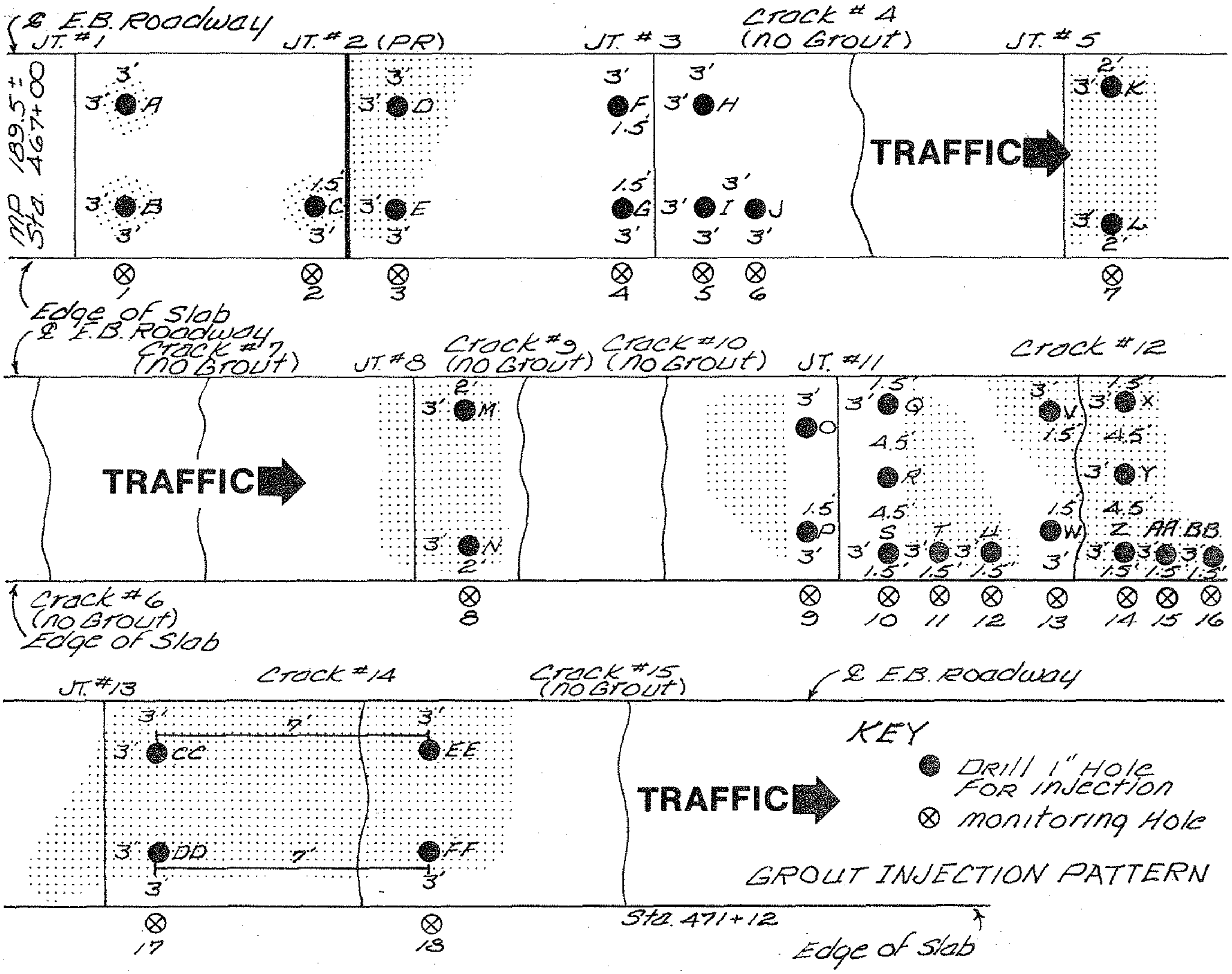
Revision Date 9-9-83

DETAILS OF LONGITUDINAL SUBDRAINS
(Shoulder)

APPENDIX C

FIGURE 1

HOLE PATTERNS AND GROUT SPREAD



LIMITS OF GROUT AT UNDERSEALING LOCATIONS

Figure 1