TERMINAL END JOINTS IN CONTINUOUSLY REINFORCED CONCRETE PAVEMENT

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CONSTRUCTION REPORT

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16. ABSTRACT

During the past 20 years, the Oklahoma Department of Transportation (ODOT) has constructed over 450 lane miles of Continuously Reinforced Concrete Pavement (CRCP) on its interstate and U.S. highway system. Throughout that time, few changes have been made to the original CRCP design.

While the performance of the CRCP has not led to any major design modifications, the terminal end joints have been cause for concern. Designed to restrain the creep of the CRCP, the terminal end joint is located near abutting pavement or bridge approach and leave slabs. The consistent failure of these joints is a nuisance to both the ODOT Maintenance Division and the traveling public.

In an effort to provide a terminal end joint which would accommodate the creep of CRCP and eliminate maintenance and safety concerns from failure, a recent CRCP construction project incorporated three experimental terminal end joint designs. The designs included an open joint design, in which a full-depth open joint was established, a sleeper slab design, adding a reinforced sleeper slab beneath an open joint, and a dowel bar design, which uses dowel bars across the width of the roadway.

The ODOT Research and Development Division established a monitoring plan to evaluate the performance of the experimental joints. This report will provide project information, detail the experimental joint designs, and layout the monitoring set-up.

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INTRODUCTION

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While the performance of the CRCP has not led to any major design modifications, the terminal end joints have been cause for concern. Designed to restrain the creep of the CRCP, the terminal end joint is located near abutting pavement or bridge approach and leave slabs. The consistent failure of these joints is a nuisance to both the ODOT Maintenance Division and the traveling public.

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PROJECT INFORMATION

Project Site

This project, Federal Aid Project Number IR-40-6(220), is located on I-40 in Sequoyah County in eastern Oklahoma. The project, a four lane divided highway, begins at SH-82 and extends east 5.2 miles (Figure 1) and has a design ADT of 10,500 with 31% truck traffic. The contract was awarded to Duit Construction Co., Inc., on May 1, 1989, at a cost of $7.2 million.

A 1.9 mile section in the eastbound direction was excluded by this contract. This section was constructed in December, 1988, as an emergency project and was also a CRCP project.

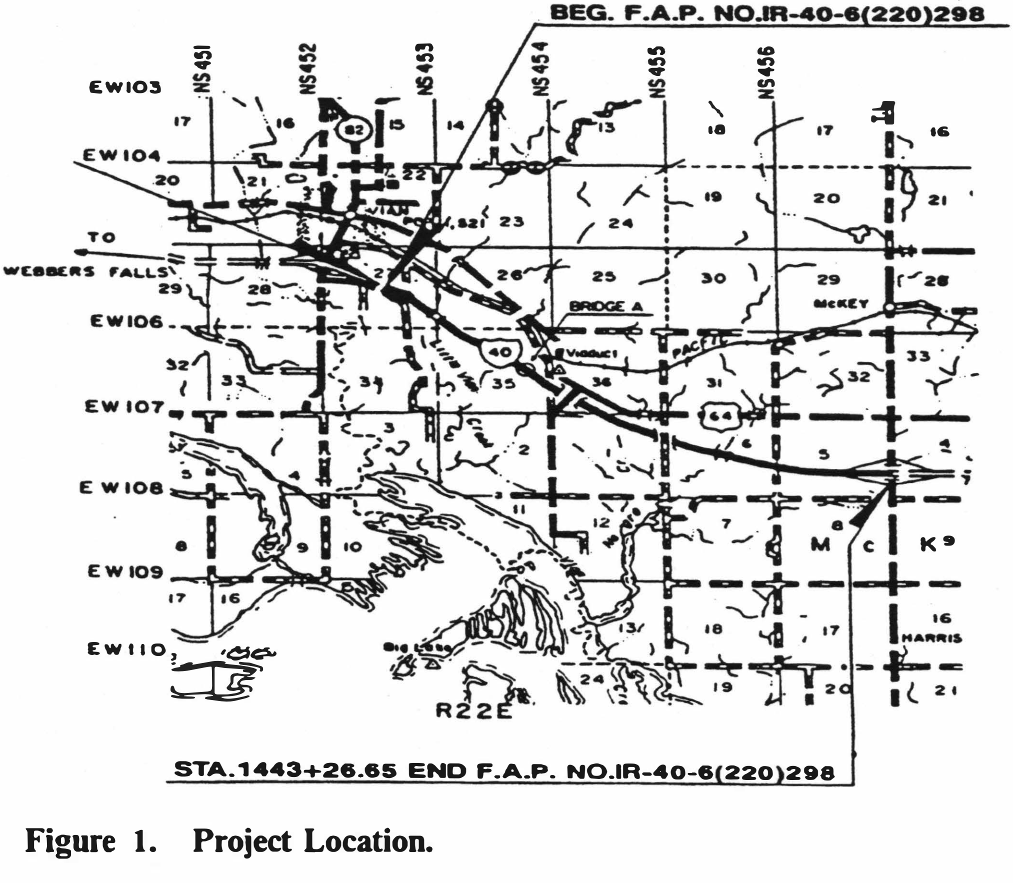


Figure 1. Project Location.

Typical Section

The typical section called for 10 inches of CRCP on 4 inches of Open Graded Portland Cement (OGPC) base with the top 12 inches of subgrade consisting of select borrow. A separator fabric was used between the base and subgrade in conjunction with a 12 inch vertical edge drain, which was installed along the outside edge of the outside shoulder (Figure 2). The roadway was 24 feet wide with tied plain concrete shoulders, 4 foot on the inside and 10 foot on the outside.

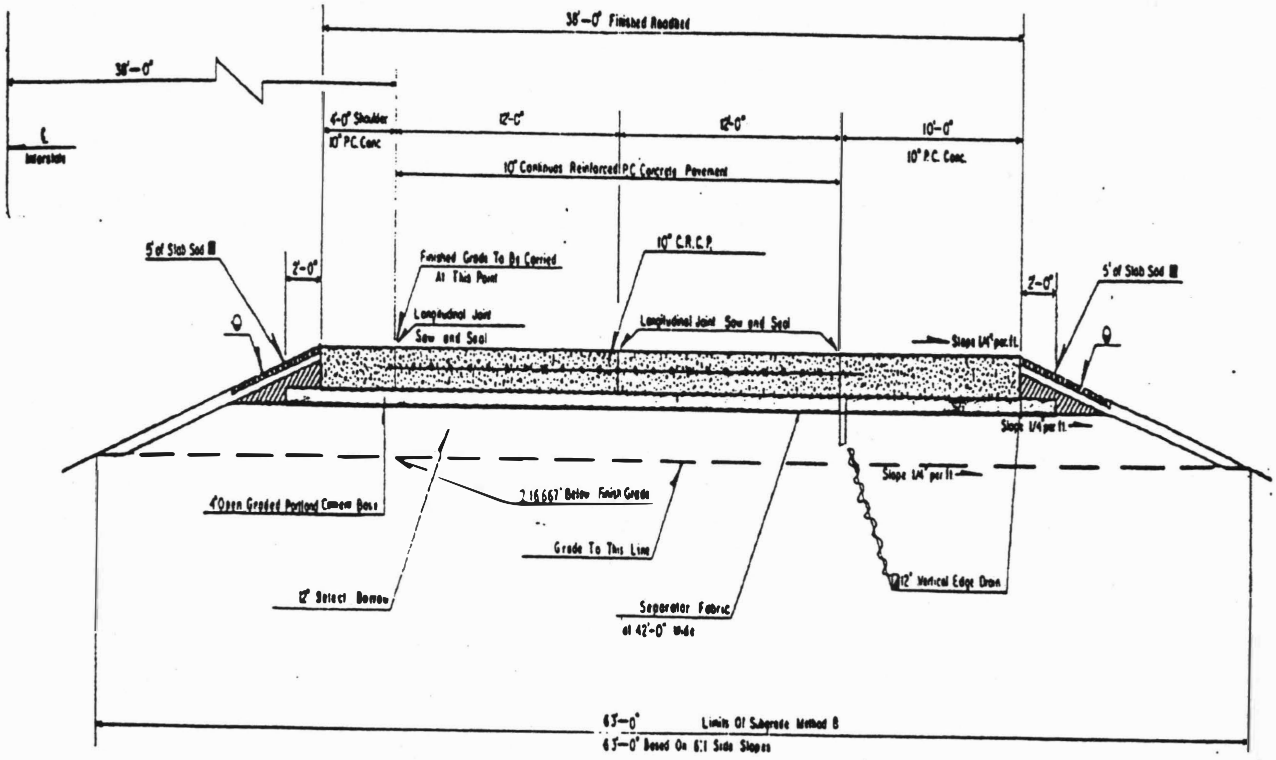


Figure 2. Typical Section.

CRCP Design

The CRCP design called for 40 No. 6 bars to be placed at mid-depth (5″), spaced at 7.25 inches to be used as longitudinal reinforcement, providing a steel ratio of 0.61%. The transverse reinforcement was provided by No. 5 bars at 44 inch centers.

Mix Design

The mix design for the CRCP and the OGPC base are shown in Tables 1 & 2. The gradation specifications for the aggregate in both the pavement and the base were ODOT No. 57 for coarse aggregate (Table 3).

The concrete for the CRCP met the standards for Class "A" concrete: slump of one to three inches and a seven day minimum compressive strength of 3000 pounds per square inch.

The only testing performed on the OGPC was a check of the coarse aggregate gradation.

Construction Sequence

Construction of the CRCP began in November, 1989, on the westbound lanes and was completed in December, 1989. The paving operations progressed from west to east, thus, the westbound lanes were paved in the opposite direction from eventual traffic flow.

The eastbound lanes were constructed in October, 1990, and were paved in the direction of traffic.

Table 1. Mix Design for CRCP.

Portland Cement	479	lbs.
Class "C" Fly Ash	115	lbs.
Entrained Air	4-6	%
Natural Sand	1195	lbs.
Coarse Aggregate	1760	lbs.
Water	30	gals.

Table 2. Mix Design for OGPC Base.

Portland Cement	282	lbs.
Coarse Aggregate	2476	lbs.
Water	98.7	lbs.
Water/Cement Ratio	.35	

Table 3. Coarse Aggregate Gradation for CRCP and OGPC Base.

Sieve Size	Percent Passing
1.5″	100
1″	95-100
1/2″	25-60
No. 4	0-10
No. 8	0-5
No. 200	0-1.5

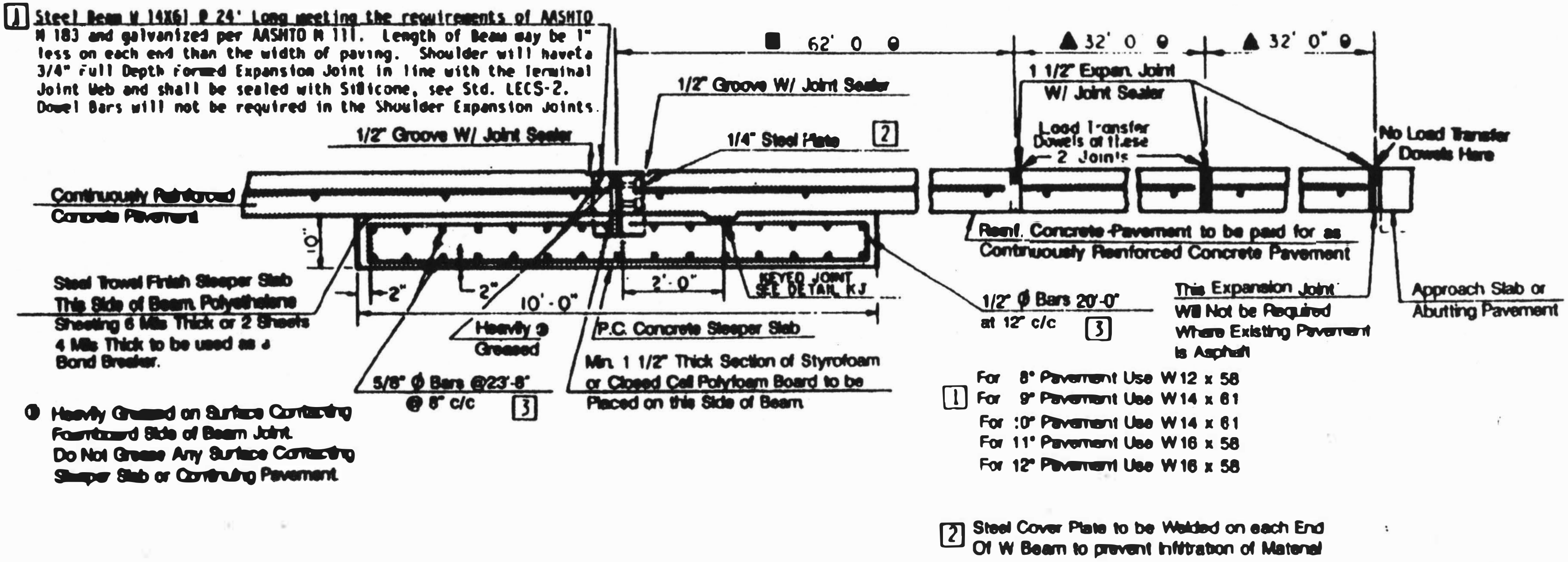
TERMINAL END JOINTS

Standard Design

The standard design of CRCP includes terminal locations to restrain movement of the free end of CRCP. The most commonly used system to restrain this movement, and the one used by ODOT, involves the use of a wide flange beam joint. A wide flange I-beam is set into a sleeper slab at areas where the CRCP is interrupted, such as bridge structures (approach and leave sides) and at abutting pavement.

The standard design calls for a wide flange beam joint to be placed 128 feet from a bridge approach/leave slab, or abutting pavement (Figure 3). One 62′ long reinforced concrete slab and two 32′ long reinforced concrete slabs are placed between the wide flange beam joint and the existing pavement. The two intermediate joints incorporate dowels while the abutting joint does not.

Over the years, the wide flange beam joint has not maintained its integrity, as both the top and bottom flanges of the beam have broken during service. Once the beam fails, it becomes a maintenance problem and a safety concern to the traveling public (Figure 4).



1 Steel Beam W 14X61 @ 24' Long meeting the requirements of AASHTO M 183 and galvanized per AASHTO M 111. Length of Beam may be 1" less on each end than the width of paving. Shoulder will have a 3/4" Full Depth Formed Expansion Joint in line with the Terminal Joint Web and shall be sealed with Silicone, see Std. LECS-2. Dowel Bars will not be required in the Shoulder Expansion Joints.

Steel Trowel Finish Sleeper Slab This Side of Beam. Polyethelene Sheeting 6 Mils Thick or 2 Sheets 4 Mils Thick to be used as a Bond Breaker.

Min. 1 1/2" Thick Section of Styrofoam or Closed Cell Polyfoam Board to be Placed on this Side of Beam.

This Expansion Joint Will Not be Required Where Existing Pavement is Asphalt

ⓐ Heavily Greased on Surface Contacting Formboard Side of Beam Joint.
Do Not Grease Any Surface Contacting Sleeper Slab or Continuing Pavement.

1
For 8" Pavement Use W 12 x 58
For 9" Pavement Use W 14 x 61
For 10" Pavement Use W 14 x 61
For 11" Pavement Use W 16 x 58
For 12" Pavement Use W 16 x 58

2 Steel Cover Plate to be Welded on each End Of W Beam to prevent Infiltration of Material

Figure 3. Standard Wide Flange Beam Terminal Joint.

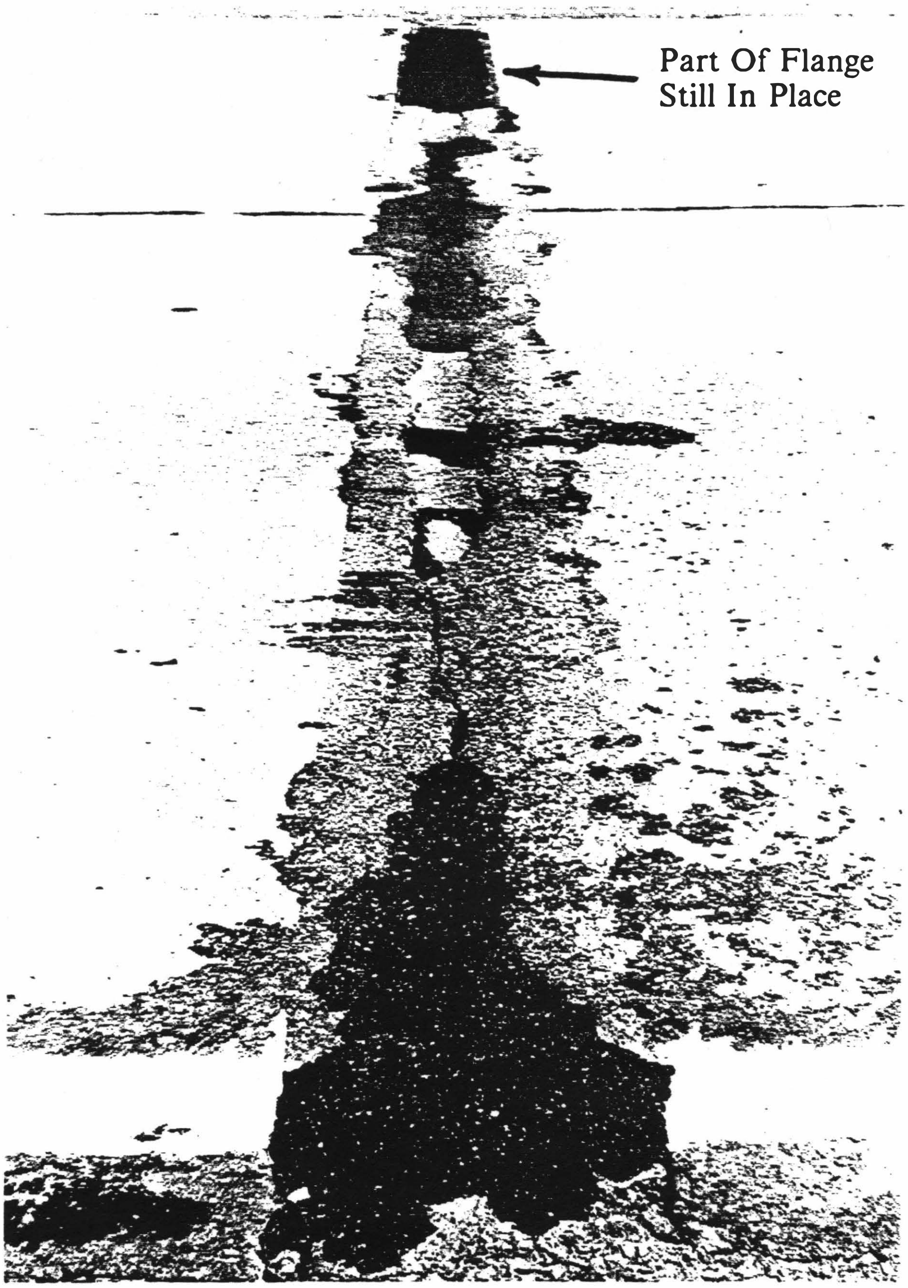


Figure 4. **Failed Wide Flange Beam Terminal Joint.**

Experimental Designs

Three experimental designs were used on this project: an open joint design, a sleeper slab design, and a dowel bar design. These joint designs eliminated the standard wide flange beam and intermediate dowelled joints, and changed the joint spacing at the terminal locations.

The open joint design called for a 1.5″ wide joint to be sawcut or formed the full depth of the pavement (Figure 5).

The sleeper slab design called for an open joint, as described previously, with a 5′ long x 24′ wide x 10″ deep concrete sleeper slab placed under the joint. The sleeper slab was reinforced with No. 5 bars at 18″ centers placed at a depth of 5″ in both the longitudinal and transverse direction (Figure 6).

The dowel bar design called for 24-1.25″ diameter smooth dowel bars spaced at 12″ centers to be placed at mid-depth in the joint (Figure 7).

Each design called for the joints to be sealed with a silicone joint sealant. All joints were sealed with Dow Corning 888.

The spacing for the terminal joint locations was also modified for all designs. Each terminal location consists for 4 joints, one adjacent to existing pavement or bridge approach/leave slab, and 3 joints at 60′ intervals beyond the abutting joint (Figure 8). In all cases the abutting joint was an open joint and the remaining 3 joints were the same type, open joint, sleeper slab, or dowel bar.

Figure 9 shows a schematic layout of the project and locates the various joint designs. Each terminal will be classified according to the type of joint design used in the three non-abutting joints, as each location has the abutting joint as an open joint.

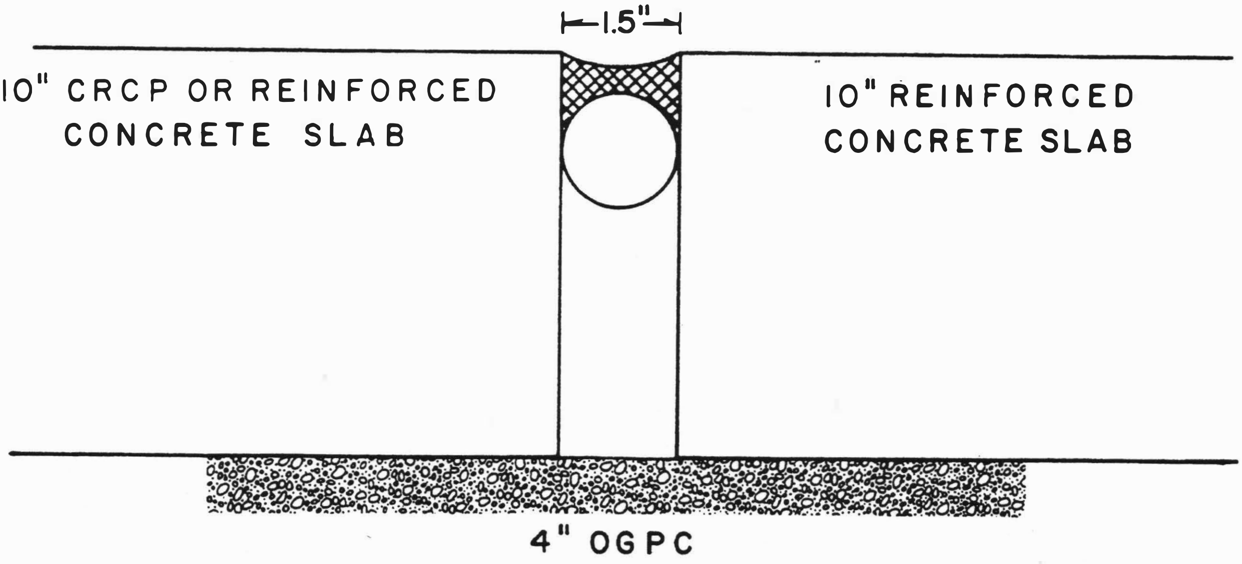


Figure 5. Open Joint Design.

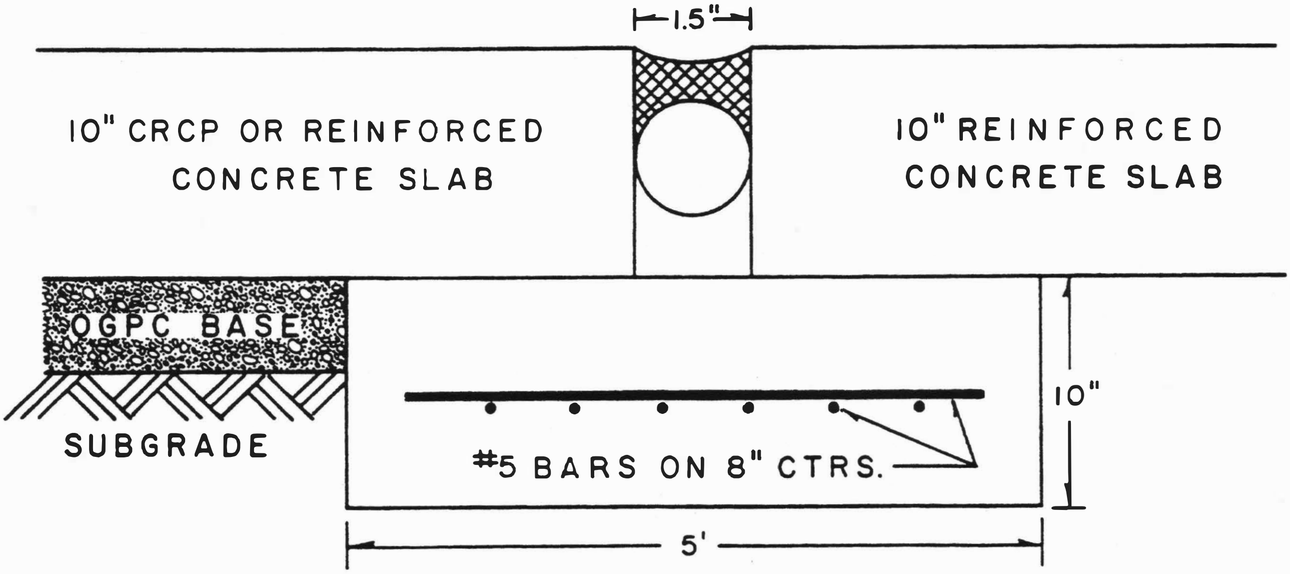


Figure 6. Sleeper Slab Design.

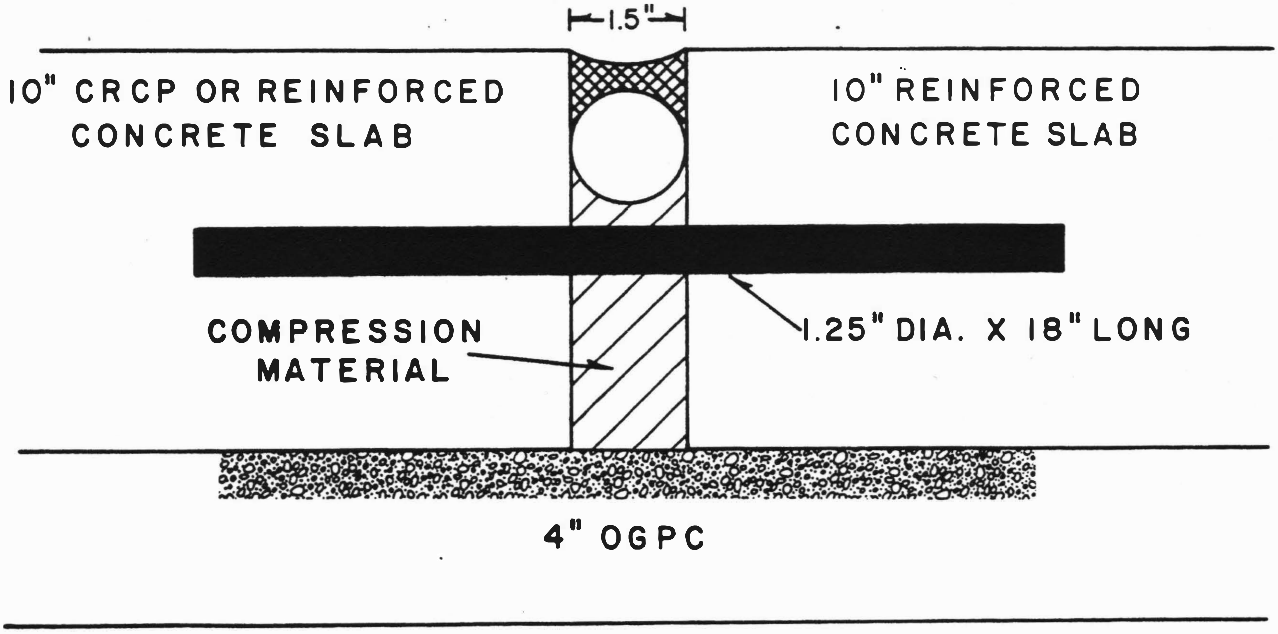


Figure 7. Dowel Bar Design.

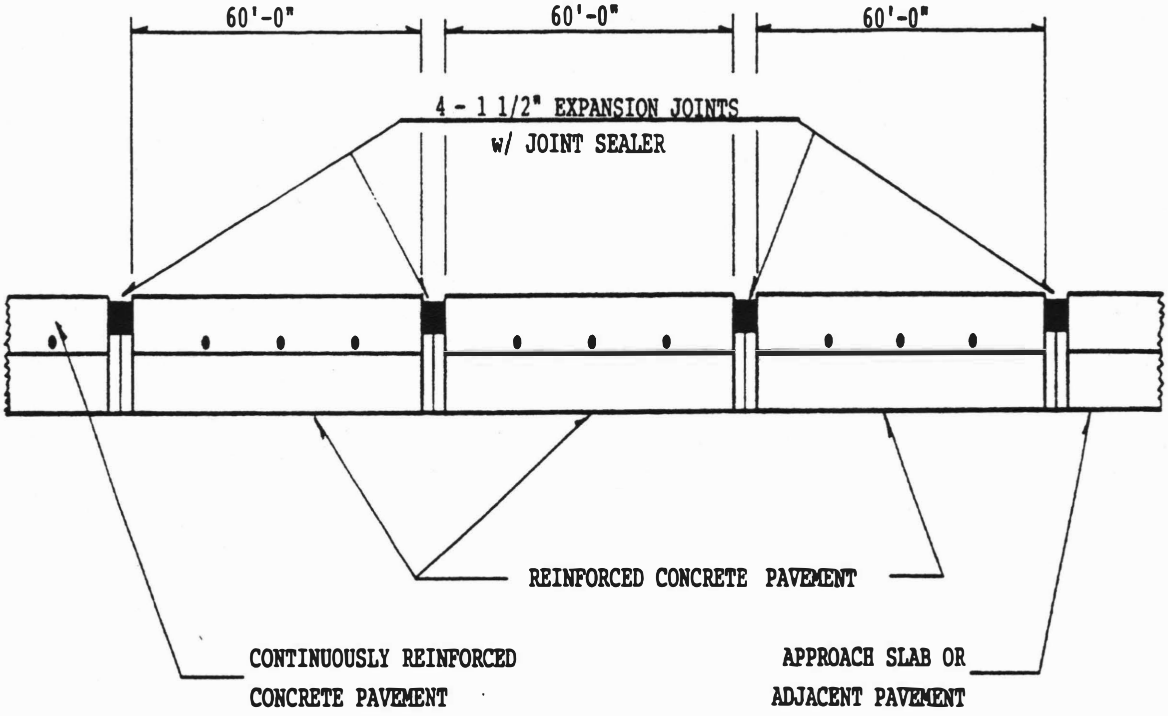


Figure 8. Joint Spacing for Experimental Designs.

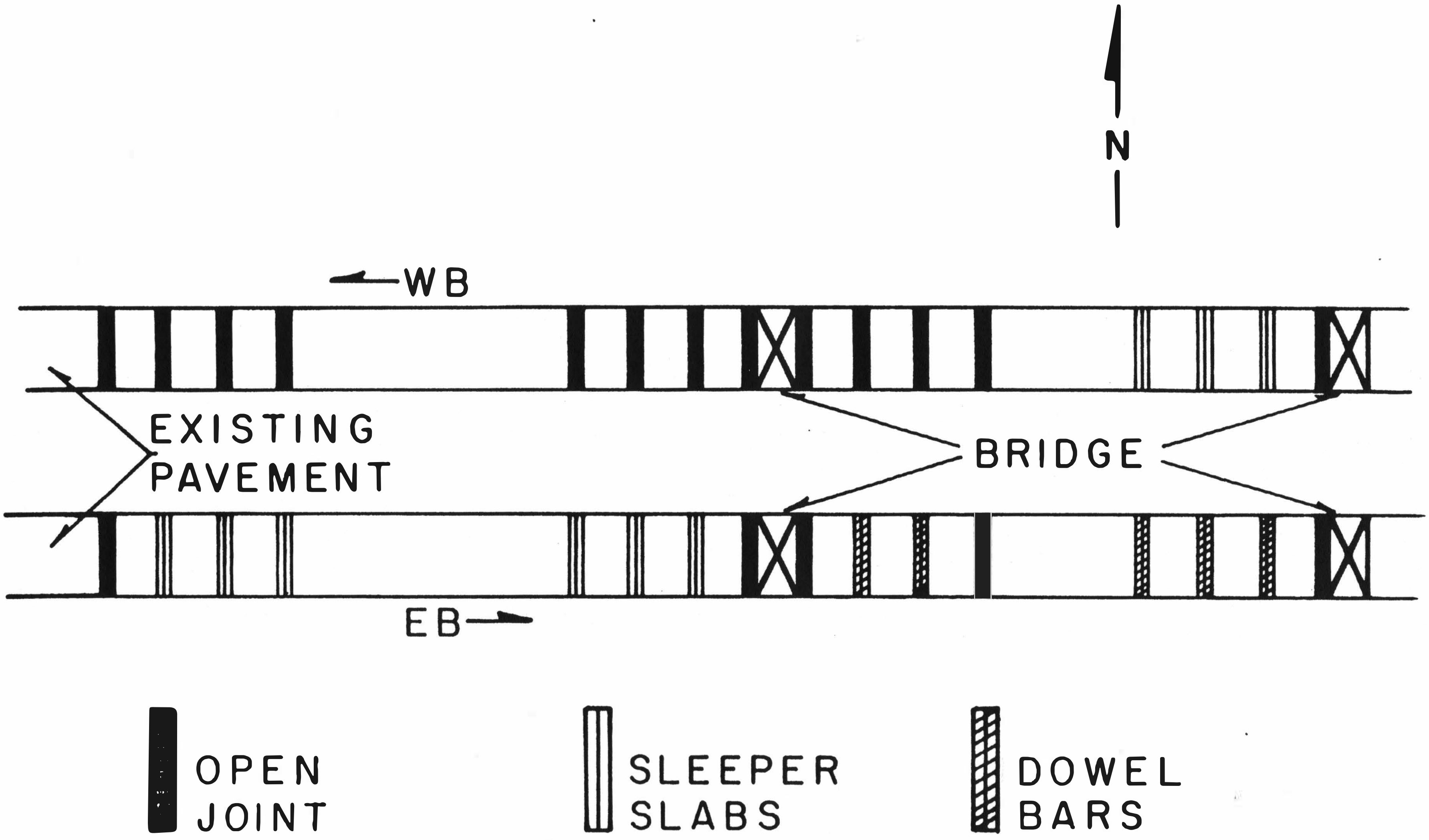


Figure 9. Experimental Design Locations.

CONSTRUCTION OF EXPERIMENTAL JOINTS

Open Joint

All non-abutting open joints were constructed by paving the mainline to within 58′ of the abutting pavement. The open joints were then sawcut using a 2-blade saw to a nominal width of 1.5″ (Figure 10).

Prior to paving, a fabric or plastic sheet was tacked onto the base to enable the sawcut section of pavement to slide out easily, without bonding to the base (Figure 11).

Following the sawcuts, reinforcing steel was placed and tied on chairs for the remaining 60′ section (Figure 12). Once concrete was placed on the last section, the joint at the abutting pavement was sawcut.

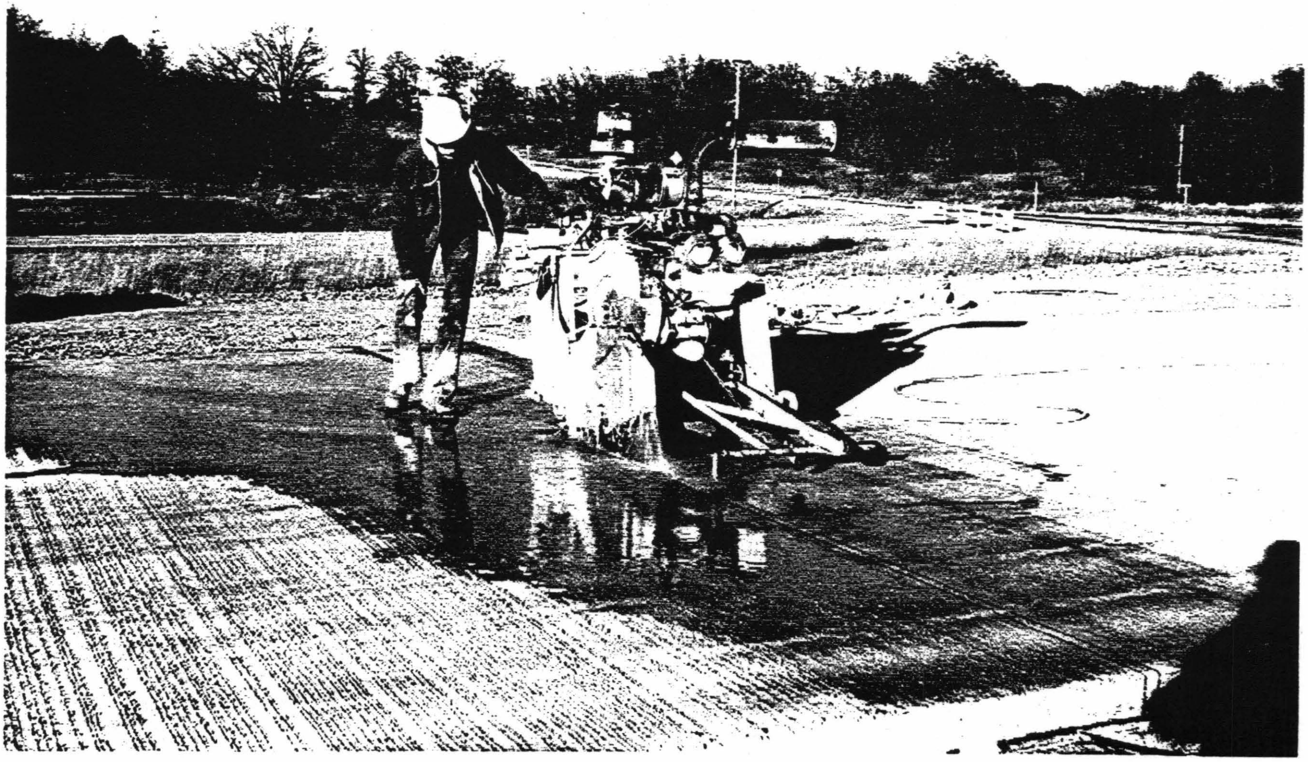


Figure 10. Sawing Open Joint.

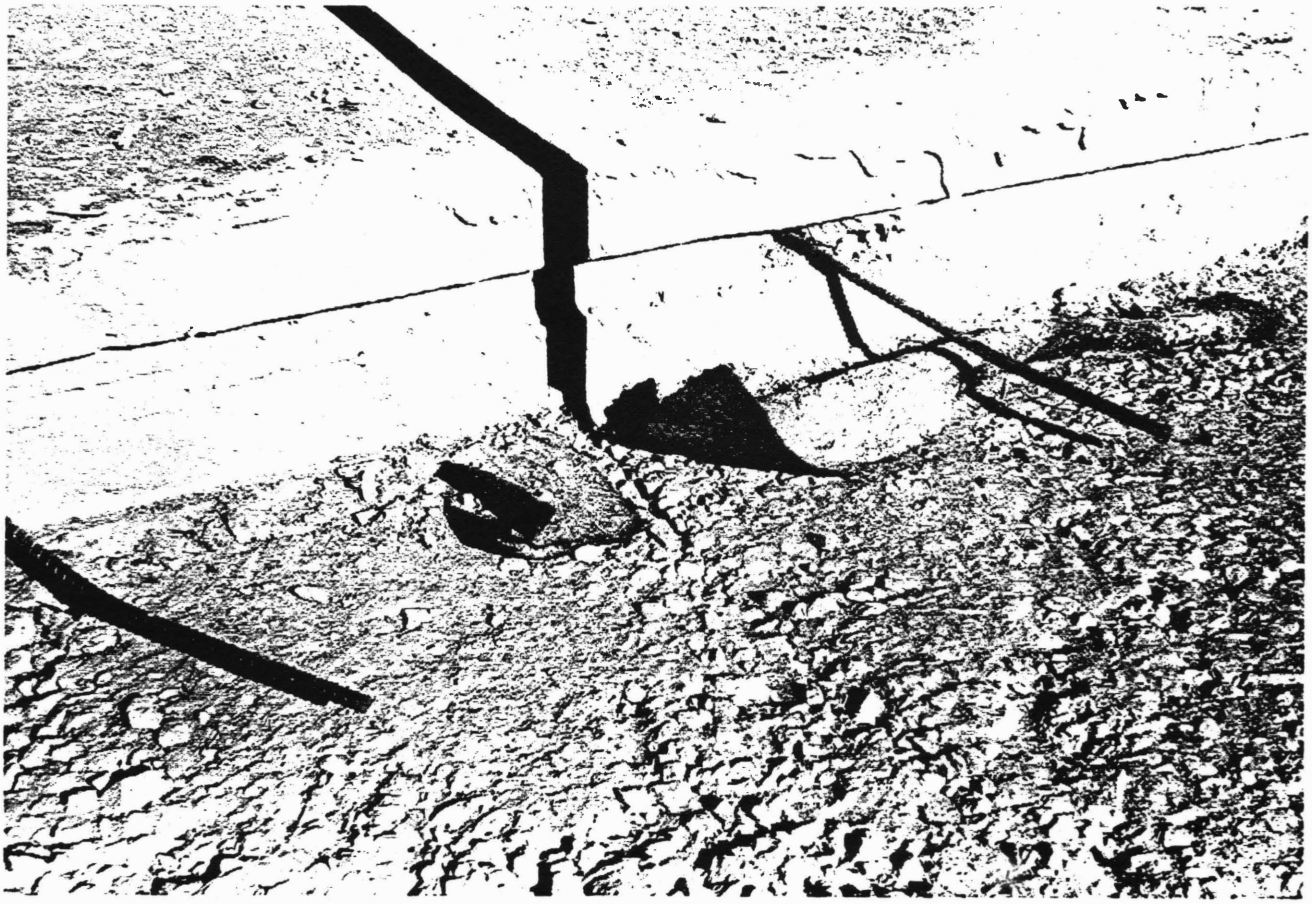


Figure 11. Open Joint Following Saw Cut and Removal.

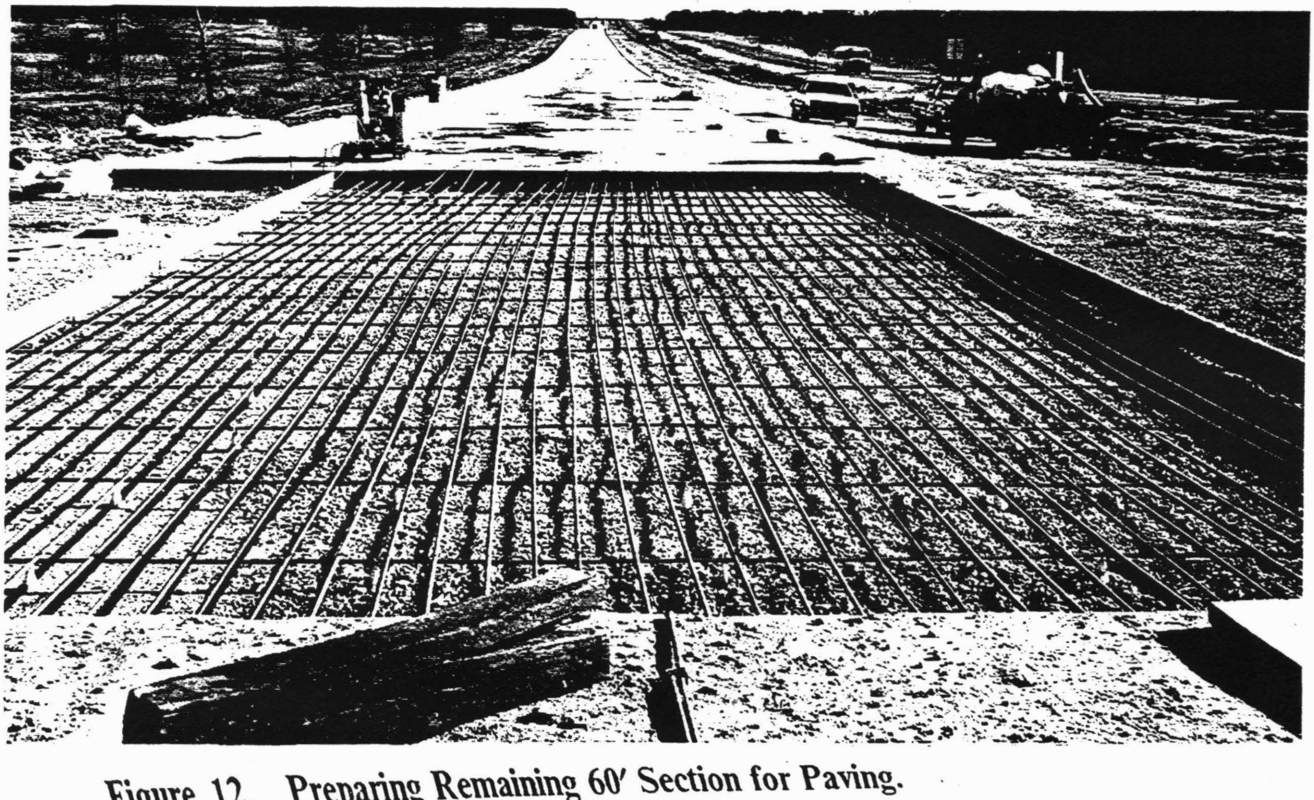


Figure 12. Preparing Remaining 60′ Section for Paving.

Sleeper Slab

The sleeper slab joints were constructed in the same manner as the open joint with the sleeper slabs being constructed prior to paving. A fabric or plastic sheet was placed over the entire sleeper slab to prevent bonding (Figure 13).

The sleeper slabs were constructed by sawing out a 5′ x 24′ x 10″ section of the base prior to paving, centered under the joint locations. The steel was placed on chairs and tied in the cut out sections. Concrete which met the same requirements as was used for the CRCP was placed in the cut out sections, completing the sleeper slabs.

The fabric at one location was found to have pulled back during paving operations. The pavement had bonded to one corner of the sleeper slab and cracked following the sawcut, presumedly from shrinkage of the pavement. A 6′ x 6′ area of pavement at this location was removed and patched. The concrete was jackhammered out and the existing steel from paving was left in place. Fabric was then placed over the sleeper slab prior to patching.

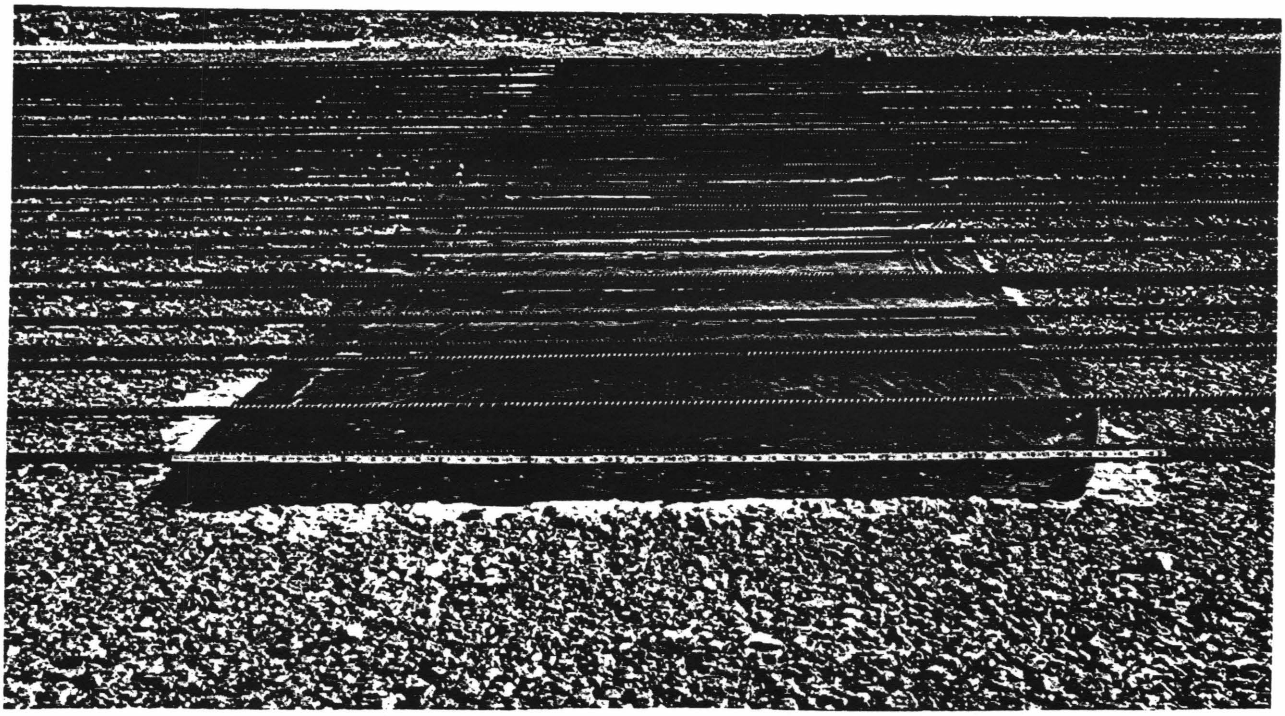


Figure 13. Sleeper Slab with Plastic Covering.

Dowel Bar

The dowelled joints consisted of 24 dowel bars at 12″ centers placed at mid-depth, 5″. The dowel bars were 18″ long with a 1.25″ diameter (Figure 14). Two, 1″ thick compression sheets were used in the joint and the dowel bars were centered longitudinally through the expansion material.

The dowel bars were coated with the exception of 3″ on one end. The bars were alternately placed in the dowel basket, based on the end coating. Once in the basket, the coated ends were greased and a 3″ plastic cap was placed over the greased end with approximately 1.5″ of free space in the caps.

The joints were hand finished following machine finishing to ensure a smooth joint. Channel iron and wood was used to help initially form the joint.

Figure 14. Dowel Bar Joint.

Tie-In to Existing CRCP

The emergency contract constructed in 1988 used the standard wide flange beam terminal joint design. At that time, the project abutted asphalt pavement.

The current project did not use an experimental joint abutting the emergency project. The tie-in called for No. 10 bars, 2′-6″ long, to be dowelled into the existing CRCP at 12″ centers, with 1′-3″ of the No. 10 bars to be deformed and the remaining length to be smooth (Figure 15). The smooth end of the bars were greased prior to paving and the bars were placed at an average depth of 5″.

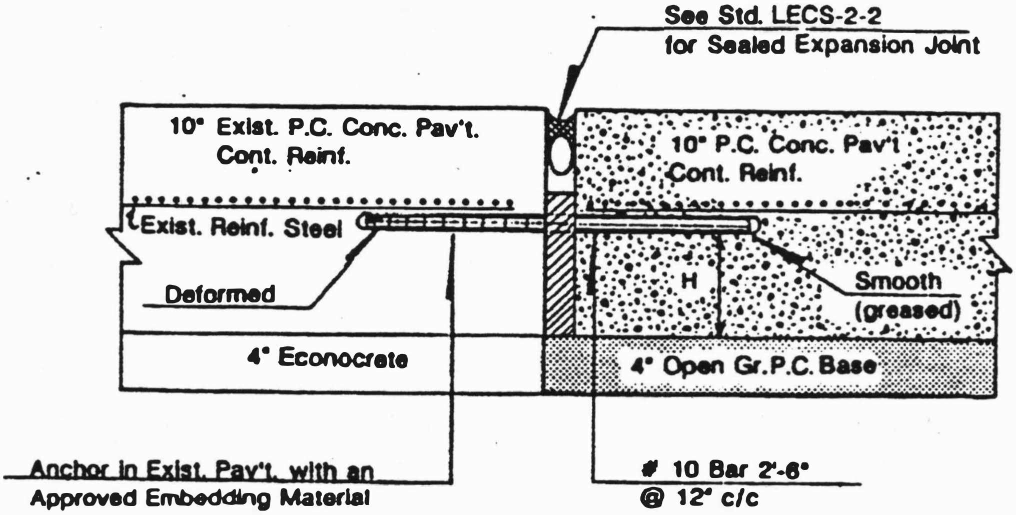


Figure 15. Tie-In Detail at Existing CRCP.

MONITORING SET-UP and PROCEDURE

The Research and Development Division established a monitoring plan to measure the movement of the joints through stud installations, concrete monument installation, levels, and slab length measurements.

Stud Installation

Pavement studs were installed at each joint to be used in conjunction with monitoring joint width movement. The studs consisted of a 3/4″ coupling nut, a 1/4″ screw , a 1/2″ screw, and a washer (Figure 16). A 3/8″ diameter hole was drilled 1-3/16″ deep into the pavement to accommodate the studs. Epoxy was used to set the stud into the pavement and the washer was used to keep water and debris out of the coupling nut. Plumbers putty was placed on top of the studs following installation to help retard water and debris infiltration.

Figure 16. Pavement Stud.

Six studs were installed at each joint, as shown in Figure 17. The studs were placed approximately 3″ x 3″ from the pavement corner. The studs will used to measure the change in width of the joint over time.

A pavement joint monitoring device will be used to perform measurements. This device has a measurement arm with a fixed end which can be placed into a stud location. A moveable pointer is placed over the longitudinally opposing stud and a measurement is made to the nearest 1/32nd of an inch (Figure 18 & 19). The measurement arm can be leveled, allowing for horizontal measurements.

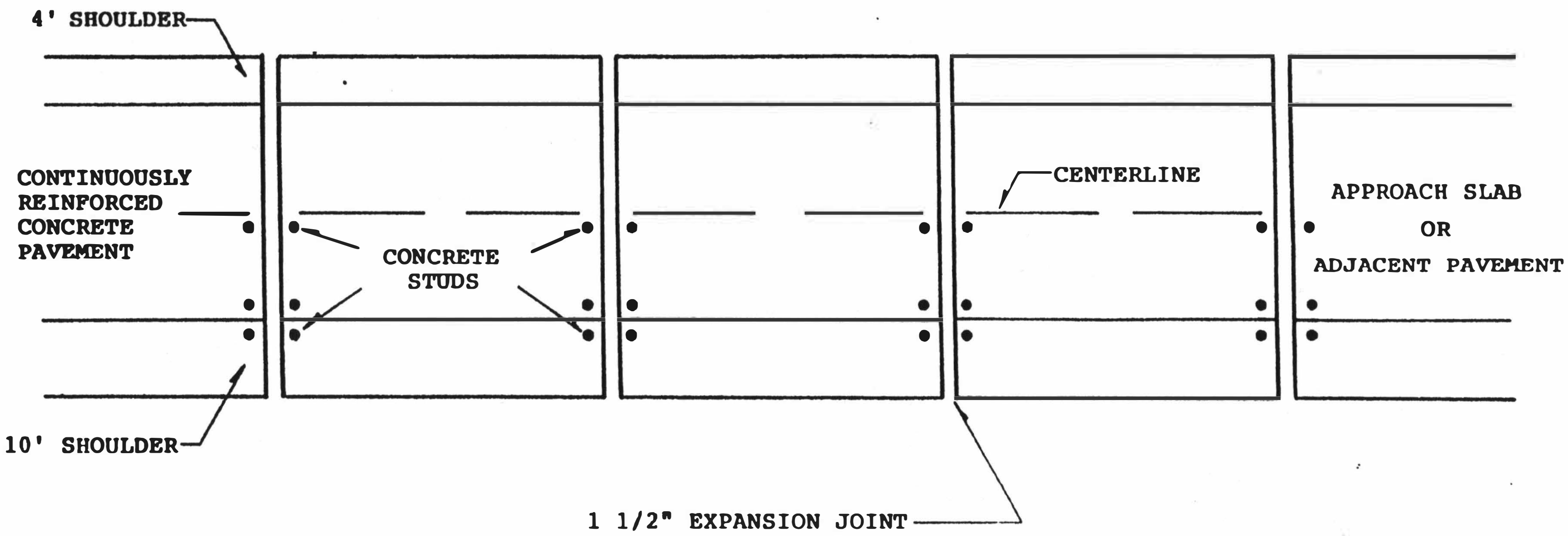


Figure 17. Stud Locations at Terminal Joints.

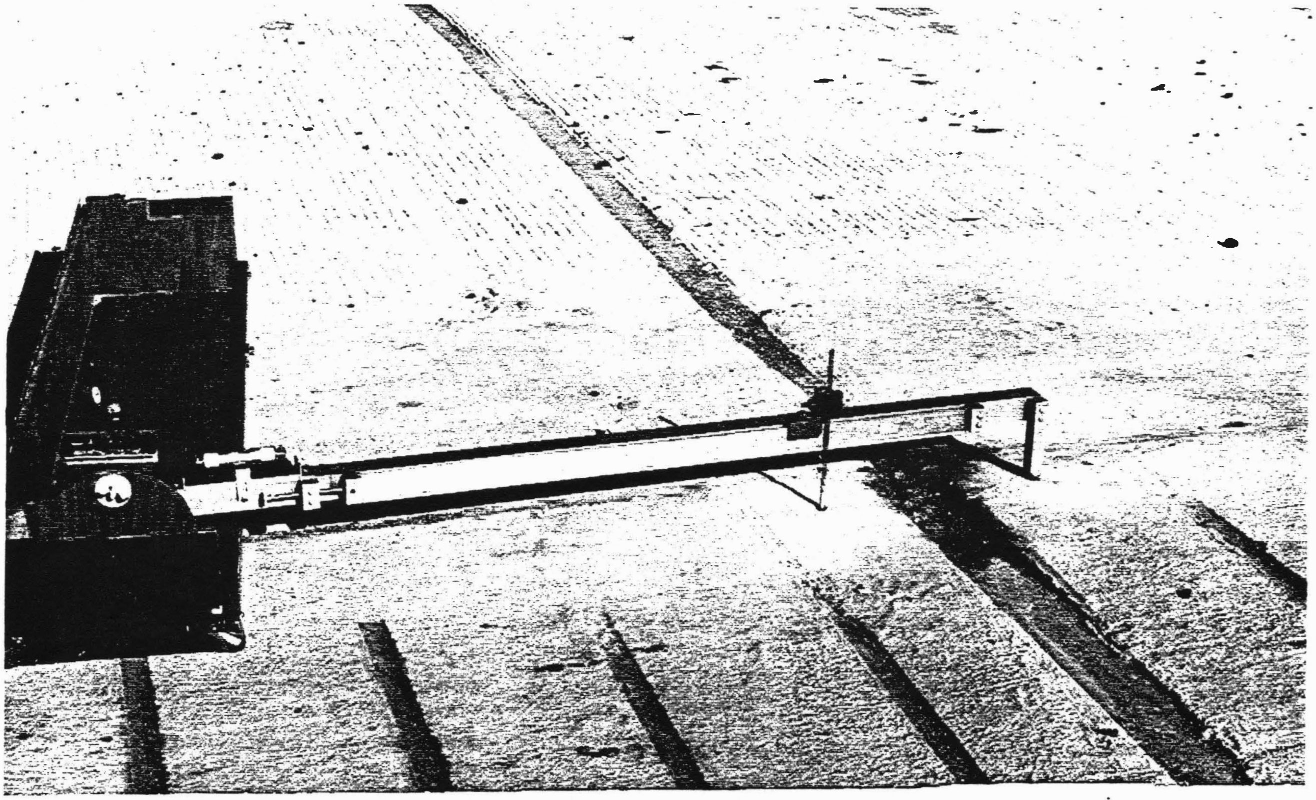


Figure 18. Joint Measuring Device.

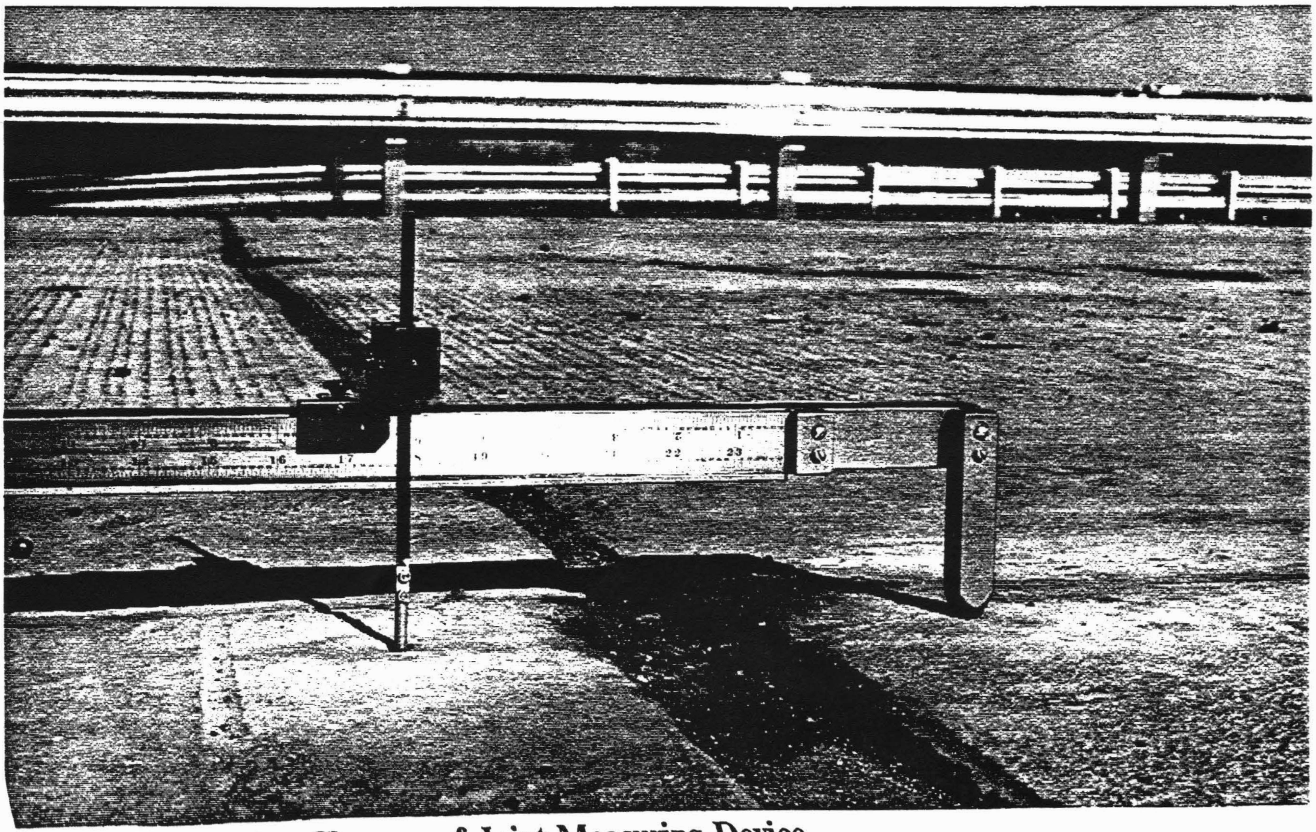


Figure 19. Close-up of Joint Measuring Device.

Concrete Monuments

Concrete monuments were installed to monitor the longitudinal movement of the joints over time. These monuments were installed on all joints except the abutting joints of each terminal location.

The concrete monuments were placed approximately 1′ beyond the outside and inside shoulder, centered on the joint (Figure 20). These locations were augured to a depth of 2 feet and filled with concrete. The monuments were formed using 6″ diameter concrete cylinder mold with the bottom cut out. This provided a smooth rim to finish the concrete (Figure 21).

Some monuments located near the bridges were placed in asphalt used to secure the guardrail (Figure 22). These locations were cored through the asphalt and augered to a depth of 2 feet.

While the concrete was plastic, PK nails were placed in the monuments corresponding to each face of the joint (Figure 23). The PK nails were placed by using a stringline placed along each face of the joint, running from corner adjacent to the centerline joint to the corner adjacent to the shoulder joint, for both the inside and outside shoulders (Figure 24).

The original PK nail locations will be used to monitor the longitudinal movement of the joint. A stringline will be used to perform these measurements, as described previously.

Other Measurements

Slab length measurements will be made and levels of the joint locations will be taken. This will provide additional information as to the horizontal and vertical movement of the joints.

Visual surveys will provide distress information as to the performance of the joints.

In an attempt to measure the joints at the maximum and minimum widths, measurements will be made in February and August.

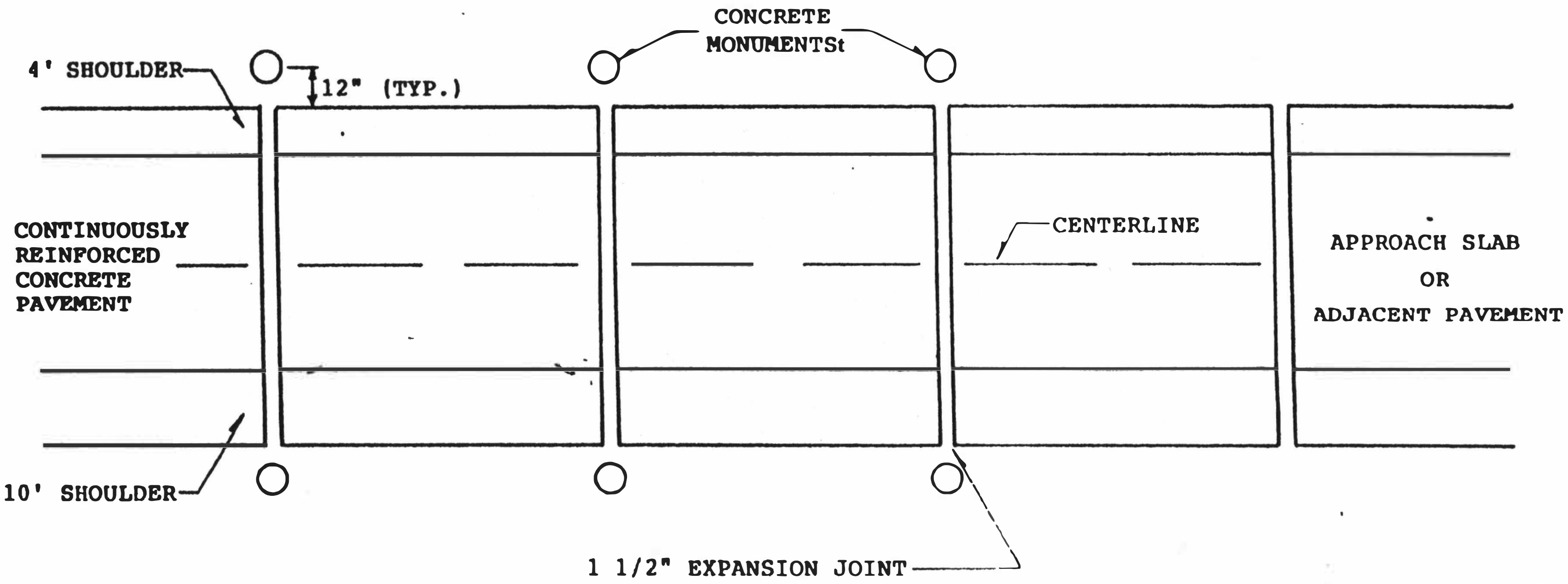


Figure 20. Concrete Monument Locations at Terminal Joints.

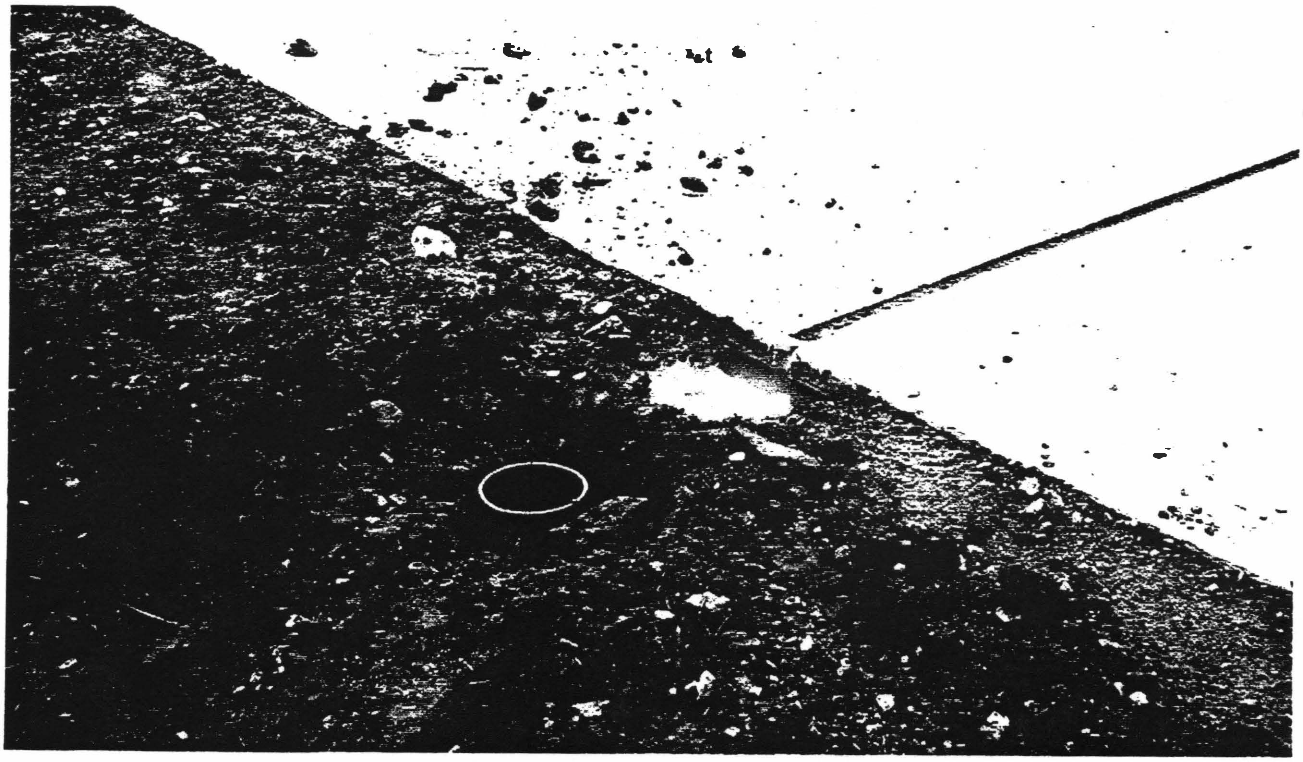


Figure 21. Concrete Monument Location Ready for Concrete.

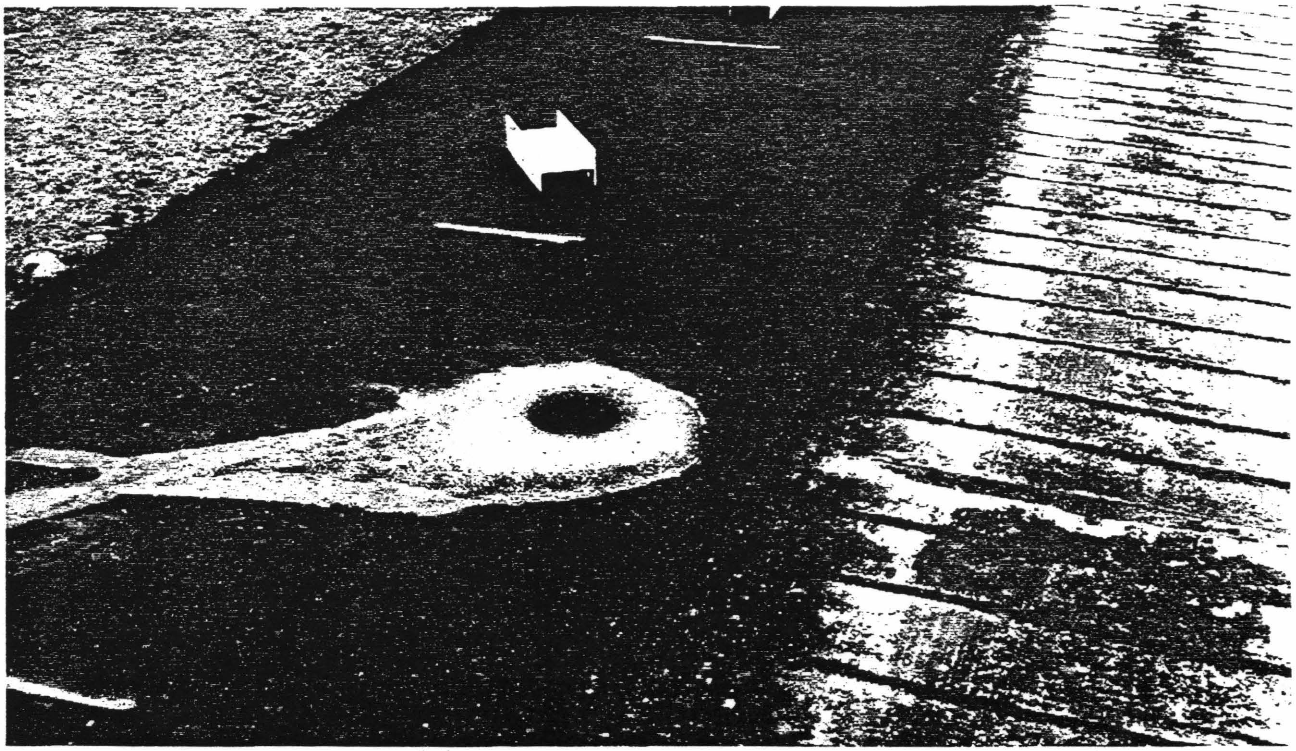


Figure 22. Concrete Monument Location in Asphalt.

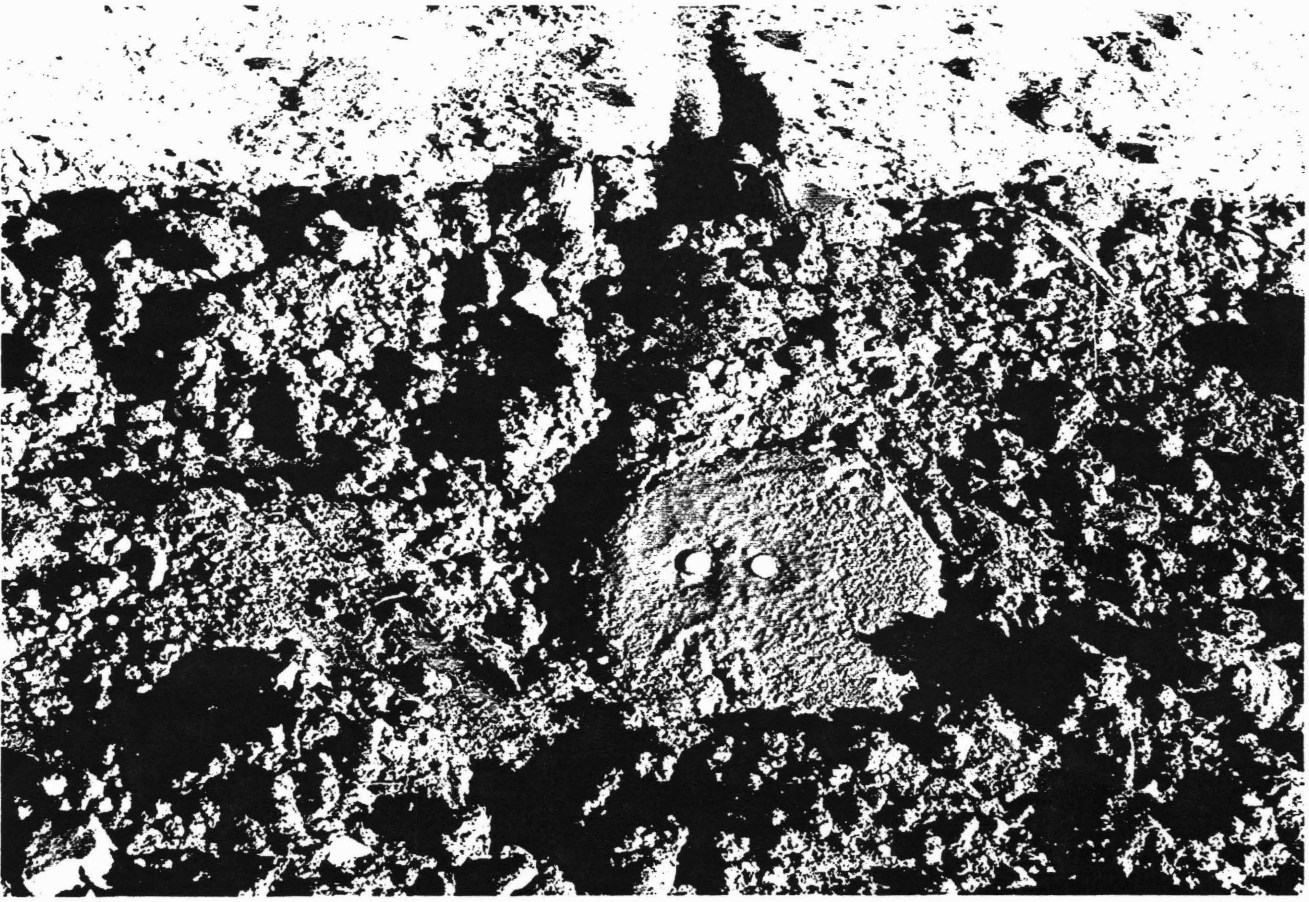


Figure 23. Concrete Monument with PK Nails Set.

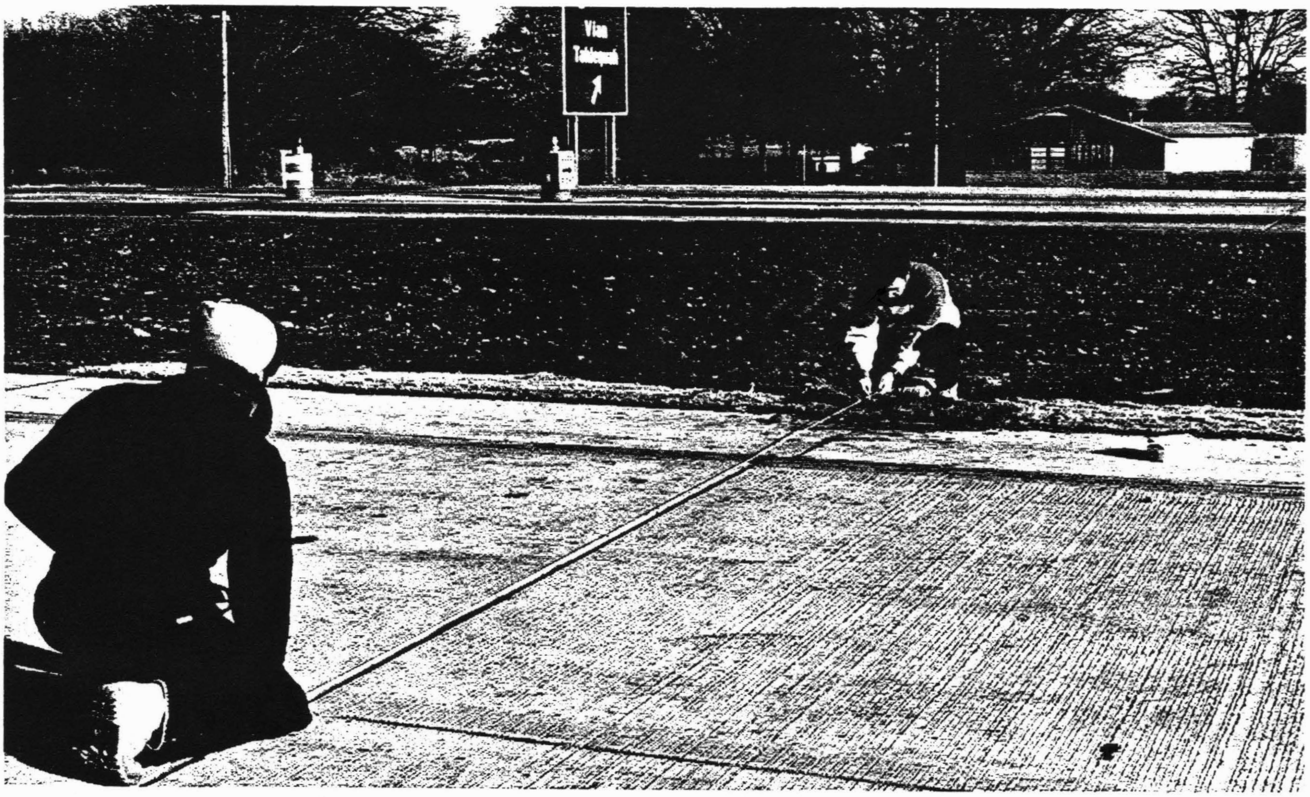


Figure 24. Setting PK Nails with Stringline.

LONG-TERM MONITORING AND REPORTNG

The experimental joints on this project will be monitored twice a year for three consecutive years.

A Final Report addressing the overall performance, including joint width movement, horizontal and vertical movement of the joints, slab length measurements, and visual survey observations, will be prepared following the three year monitoring effort.

Conclusions as to the three-year effectiveness of the experimental joints will be made and recommendations on future monitoring will be addressed.