TERMINAL END JOINTS IN CONTINUOUSLY REINFORCED CONCRETE PAVEMENT

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INTERIM 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 safety problem for 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 first design is a full-depth open joint. The second design is a reinforced sleeper slab beneath a full-depth open joint. The third design 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. After one year in service all the joints are performing with no signs of failure. The open joint design exhibited the most joint movement followed by the sleeper slab joint design and the dowel joint design, respectively.

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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 safety problem 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, a recent CRCP construction project incorporated three experimental terminal end joint designs. The first design is a full-depth open joint, the second design is a reinforced sleeper slab beneath a full-depth open joint and the third design uses dowel bars across the width of the roadway.

This construction project began in May 1989 and was completed in January 1991. The construction of the terminal joint systems is detailed in the Construction Report prepared by the ODOT Research and Development Division in March 1991.

The ODOT Research and Development Division established a monitoring plan to evaluate the performance of the experimental joints. This report will detail the experimental joint designs, layout the monitoring set up, and report the CRCP joint movement after two and one-half years of service.

BACKGROUND

Project Location

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. The project was completed in January 1991.

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.

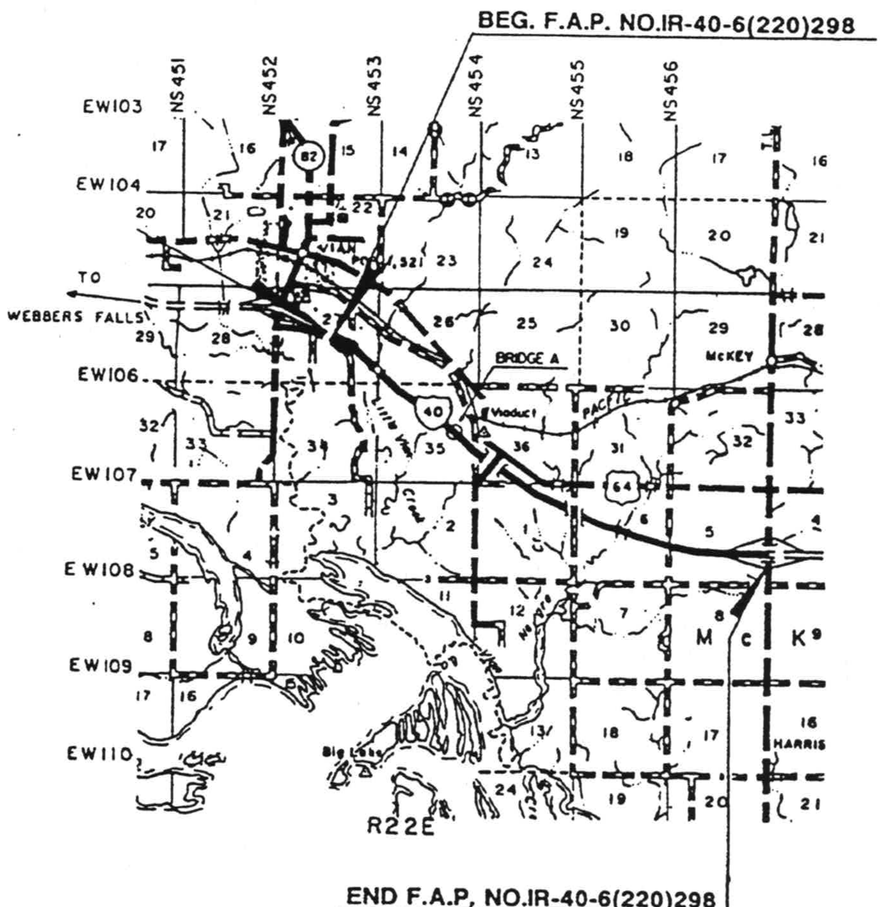

Figure 1. Project Location.

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 2). One 62 foot long reinforced concrete slab and two 32 foot 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 3).

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 (Figure 4). 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. The roadway is 24 feet wide with tied plain concrete shoulders, 4 foot wide on the inside and 10 foot wide on the outside.

CRCP Design

The CRCP design called for 40 No. 6 bars to be placed at mid-depth (5 inches), 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.

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.

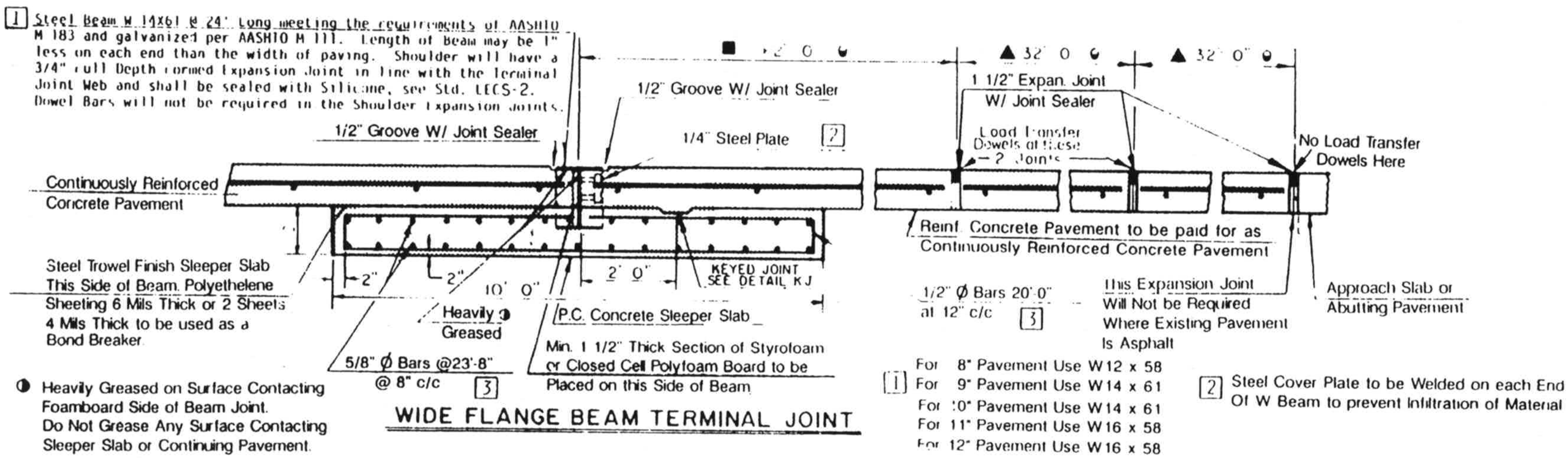

Figure 2. Standard Wide Flange Beam Terminal Joint.

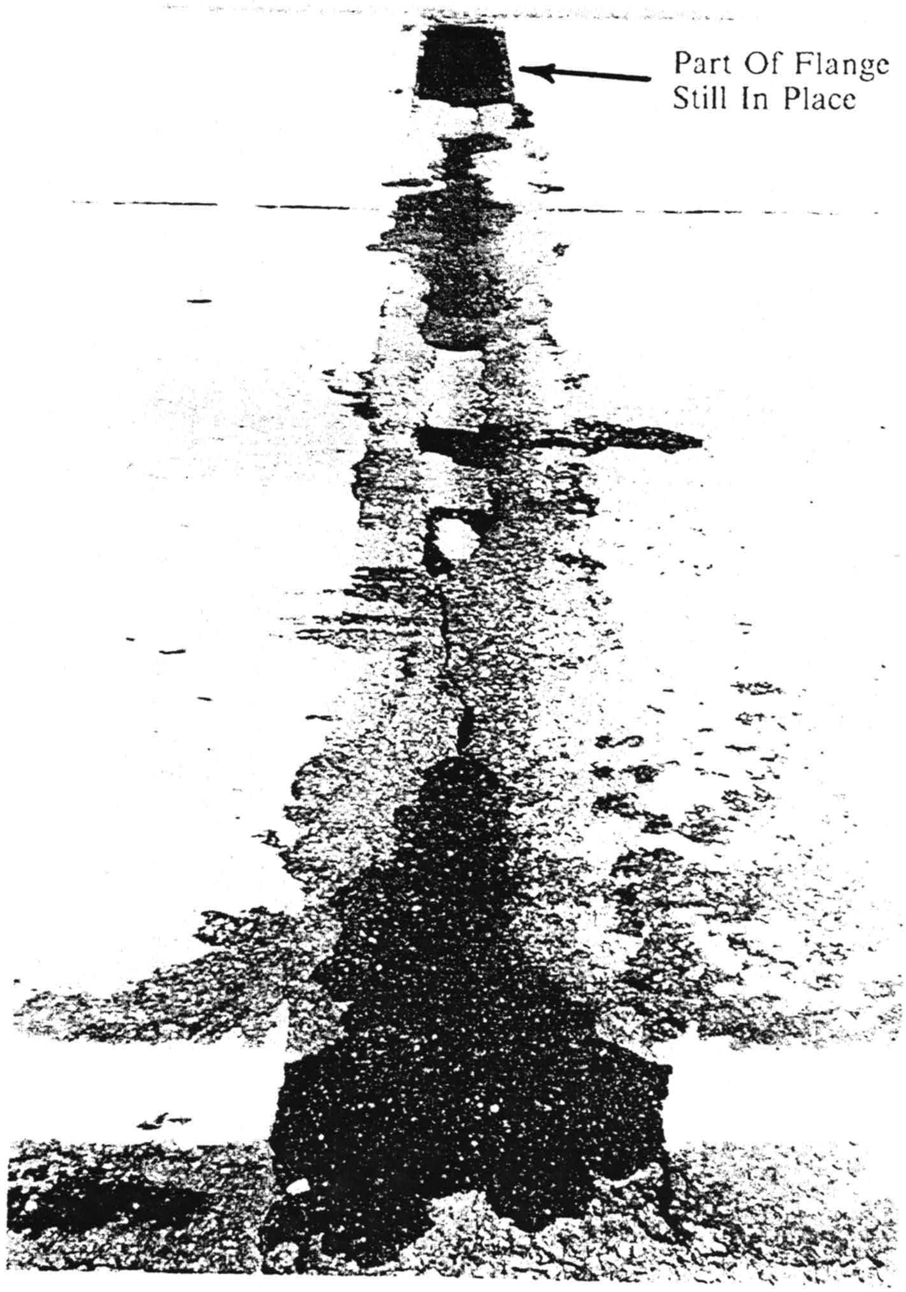

Figure 3. Failed Wide Flange Beam Terminal Joint.

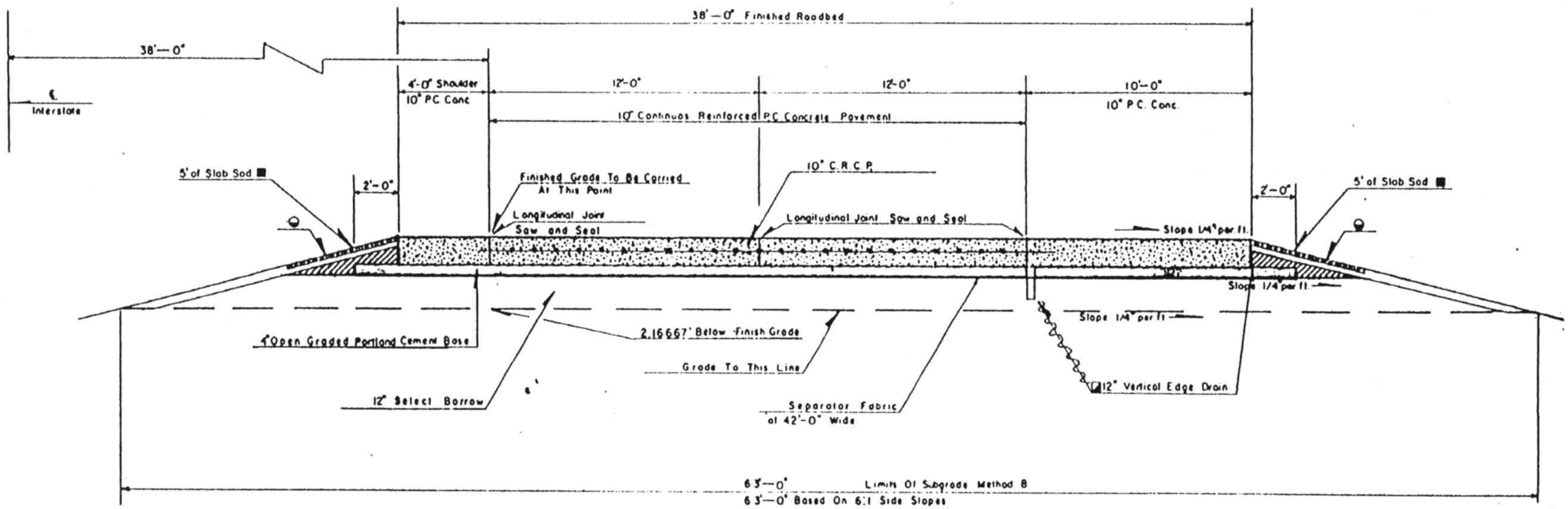

Figure 4. Typical Section.

TERMINAL END JOINT 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, eliminated the intermediate dowelled joints in the open and sleeper slab designs, and modified the spacing for the intermediate joints at the terminal locations.

Experimental Joint Spacing

The joint spacing for the terminal joint locations was modified (as compared to the standard CRCP design) for all designs and was the same for all three experimental designs. 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 5 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.

Each terminal location consists of four (4) joints: one adjacent to existing pavement or bridge approach/leave slab (called the abutting joint), and three (3) joints at 60 foot intervals beyond the abutting joint (Figure 6). The joint which is adjacent to the newly placed CRCP is called the end joint. The two intermediate joints, for purposes of this study, have been labeled as M1 (120 feet from the abutting joint) and M2 (60 feet from the abutting joint).

Open Joint

The open joint design called for a 1.5 inch wide joint to be sawcut or formed the full depth of the pavement (Figure 7). All non-abutting open joints were constructed by paving the mainline to within 58 feet of the abutting pavement. The open joints were then sawcut using a 2-blade saw to a nominal width of 1.5 inches.

Prior to paving, a fabric or plastic sheet was tacked onto the base at joint locations to enable the sawcut section of pavement to slide out easily without bonding to the base, and to keep the cement slurry from penetrating the base when sawing the joint.

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

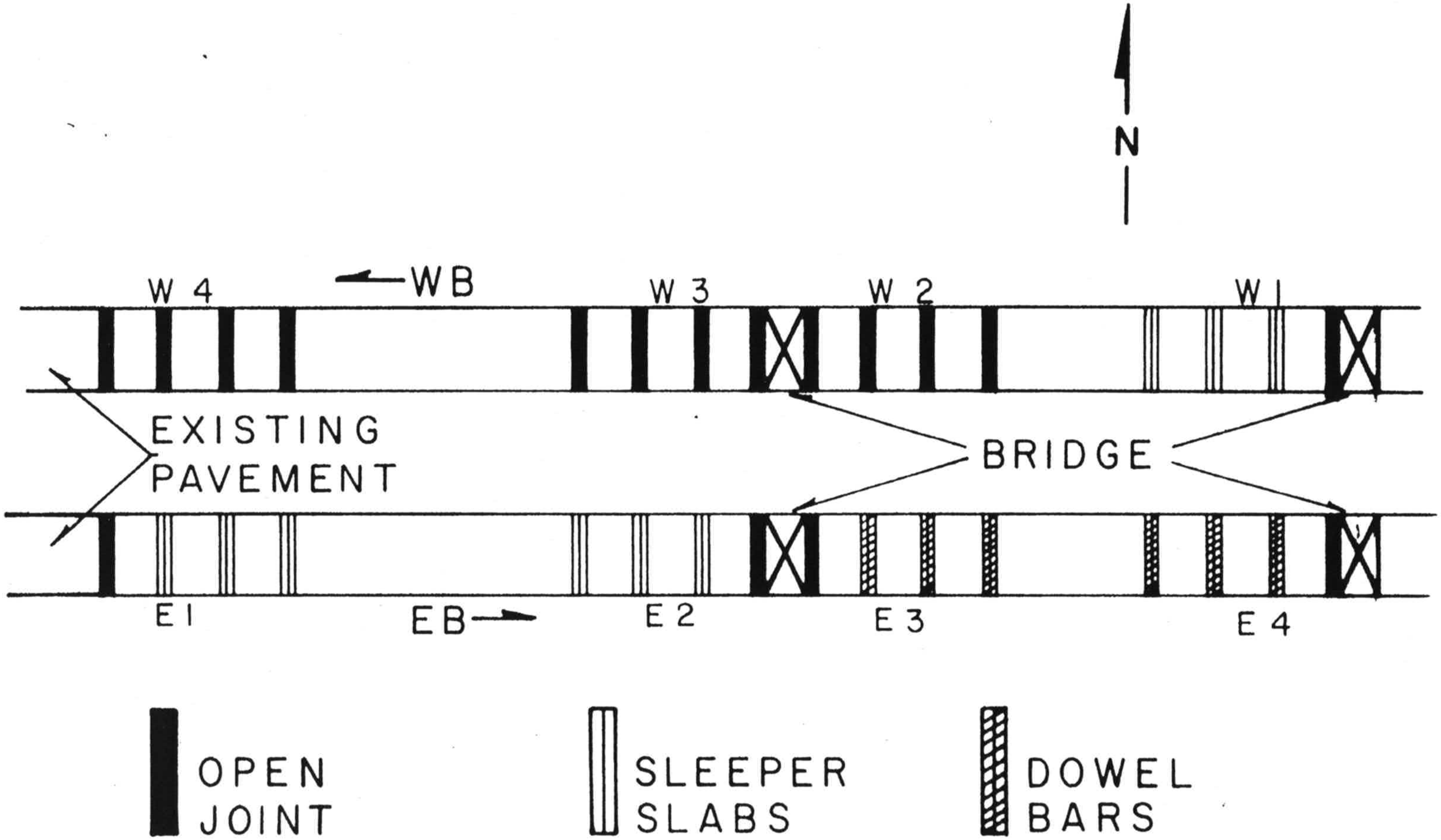

Figure 5. Experimental Design Locations.

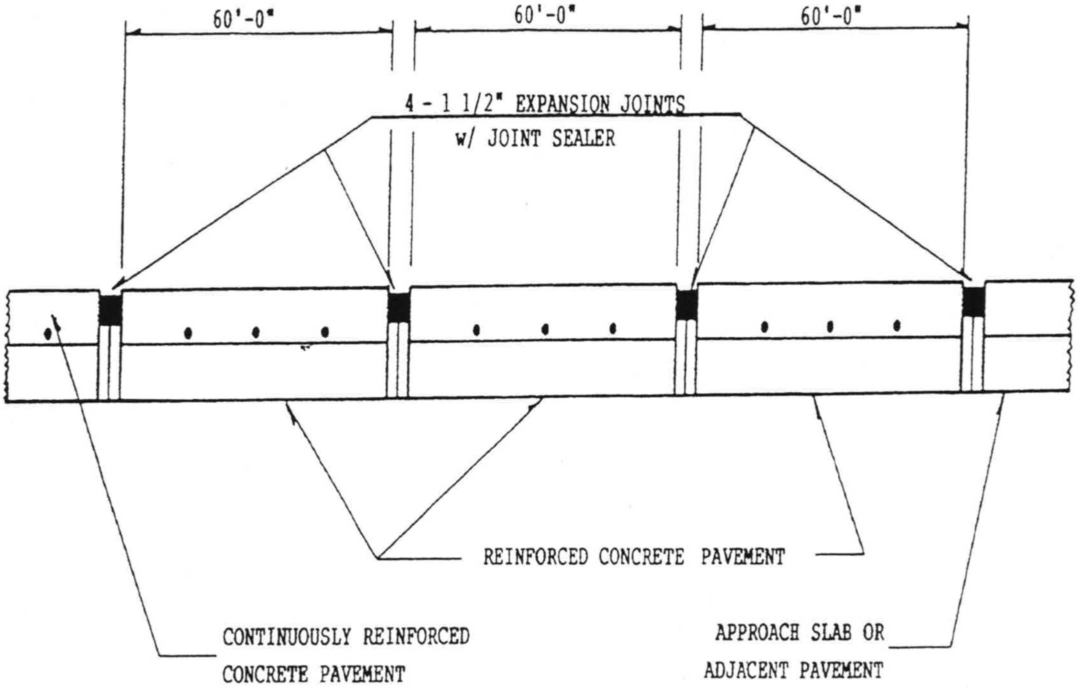

Figure 6. Joint Spacing for Experimental Designs.

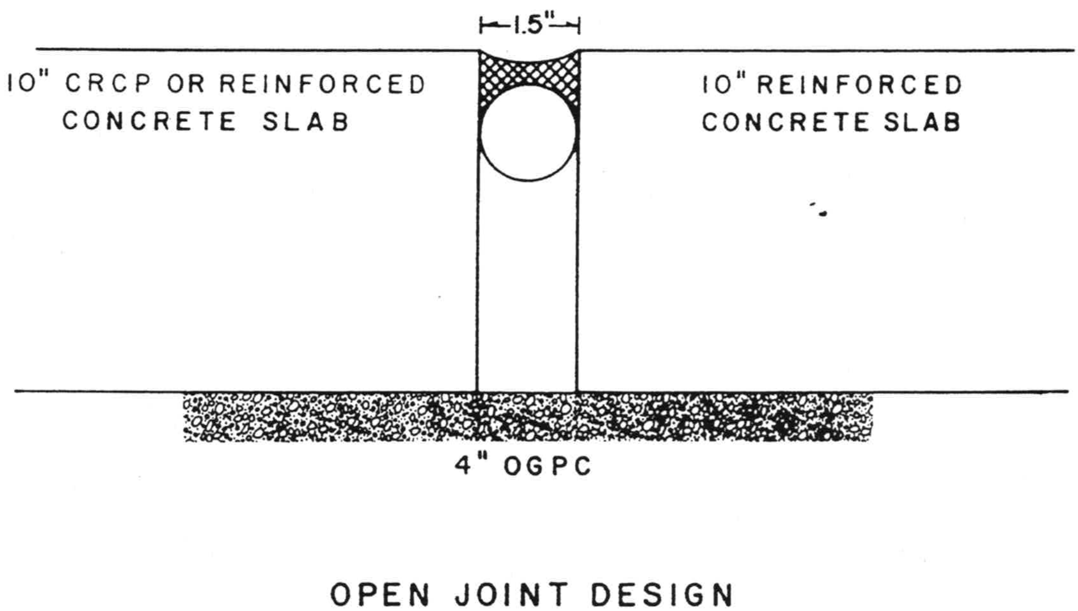

Figure 7. Open Joint Design.

Sleeper Slab

The sleeper slab design called for an open joint, as described previously, with a 5 foot long x 24 foot wide x 10 inch deep concrete sleeper slab placed under the joint. The sleeper slab was reinforced with No. 5 bars at 8 inch centers placed at a depth of 5 inch in both the longitudinal and transverse direction (Figure 8).

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 9).

The sleeper slabs were constructed by sawing out a 5 foot x 24 foot x 10 foot 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.

Dowel Bar

The dowel bar design called for 23-1.25 inch diameter smooth dowel bars, 18 inches in length, spaced at 12 inch centers to be placed at mid-depth in the joint (Figure 10). Two, 1 inch 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 inches 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 inch plastic cap was placed over the greased end with approximately 1.5 inch of free space in the caps (Figure 11).

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.

Joint Sealant

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

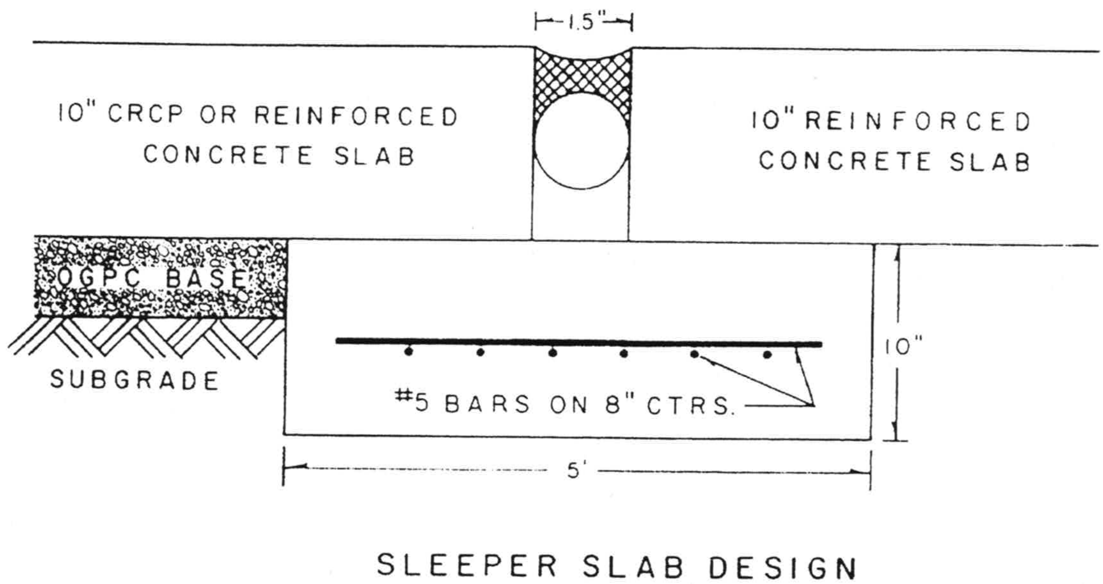

Figure 8. Sleeper Slab Design.

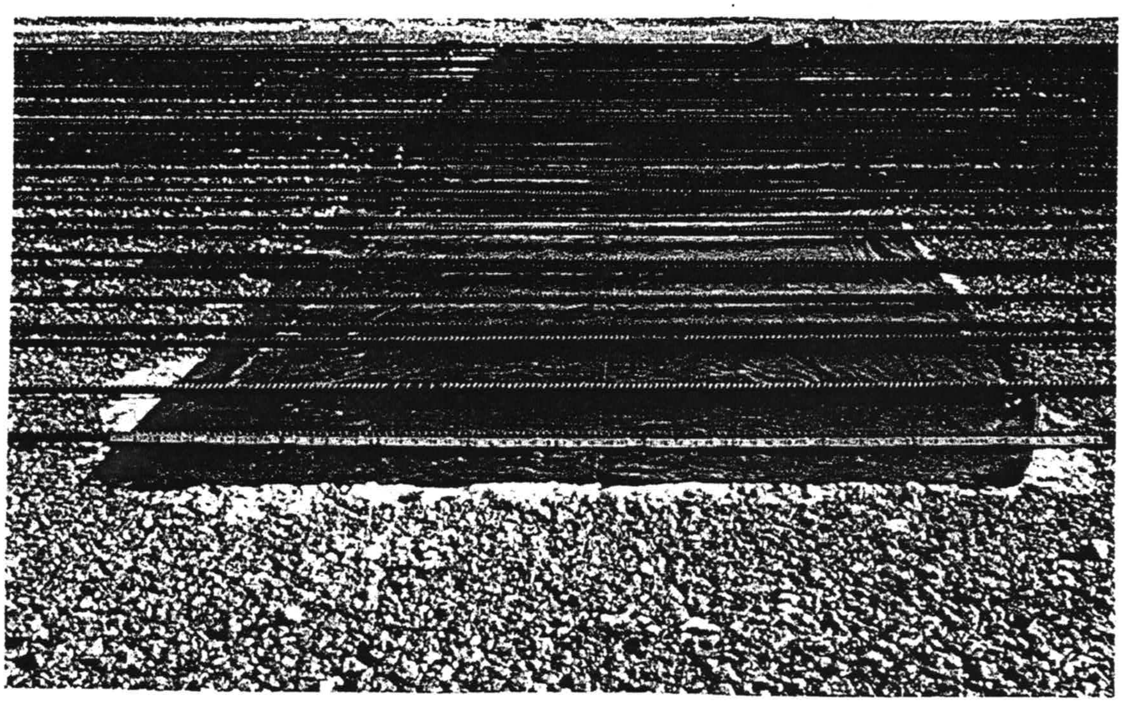

Figure 9. Sleeper Slab with Plastic Covering.

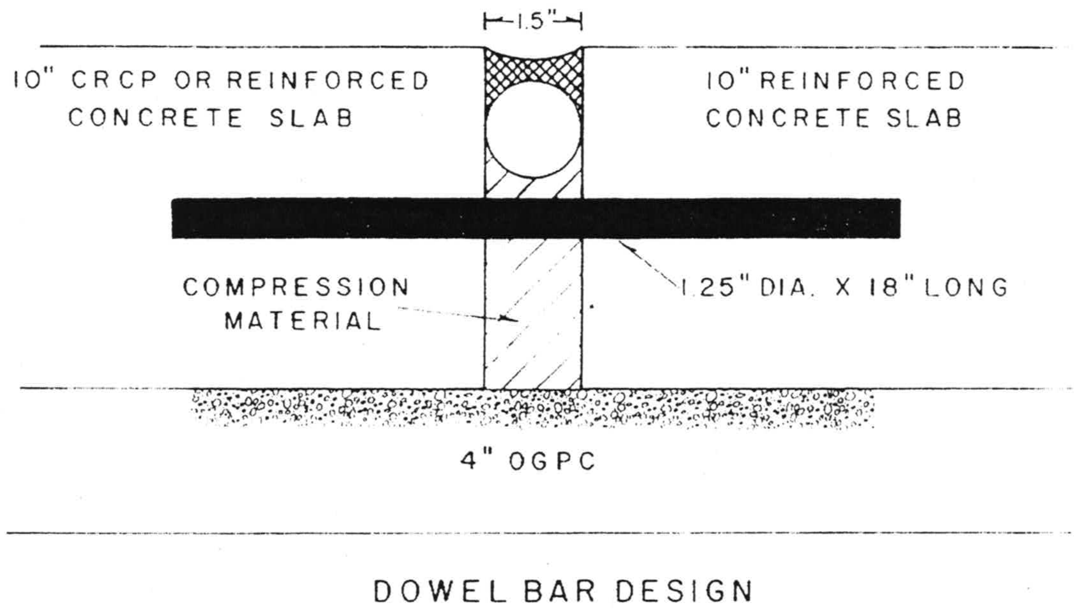

Figure 10. Dowel Bar Design.

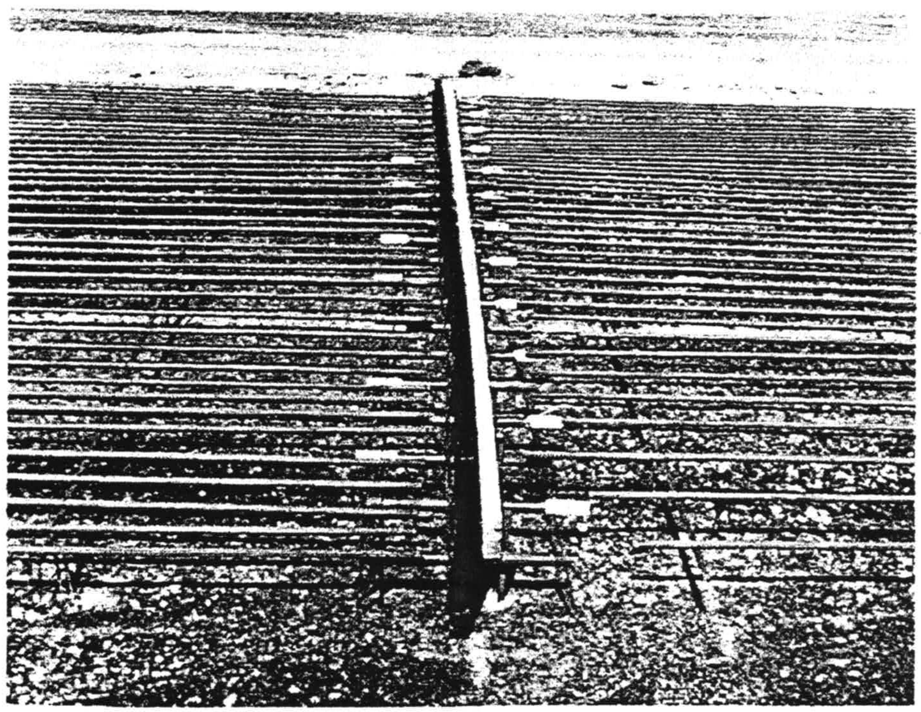

Figure 11. Dowel Bar Joint.

DATA COLLECTION AND MONITORING

The Research and Development Division established a monitoring plan to measure the movement and performance of the joints through stud installations, concrete monument installation, levels, slab length measurements and visual surveys. The measurements and surveys are made bi-annually representing hot and cold conditions to monitor the experimental joints during periods of minimum and maximum openings, respectively.

Pavement Stud Installation

A system was devised to monitor the relative movement of joint width through the use of permanent studs placed into the concrete pavement. This system incorporates a device which measures the distance between the studs across a joint. These measurements are compared to the initial readings and allows for a determination of joint closure and opening over time. The use of permanent studs and not a joint face to monitor joint width movement eliminates any concern over possible deterioration of the joint face (i.e., spalling or shearing) affecting joint width monitoring.

Six pavement studs were installed at each joint, approximately 3 inches x 3 inches from the pavement corner, to be used in conjunction with monitoring joint width movement as shown in Figure 12. Stud installations and initial measurements were performed in April 1990 in the westbound lanes and in December 1991 in the eastbound lanes. In both cases, the installations were made prior to any public traffic use of the new pavement.

The studs consisted of a 3/4 inch coupling nut, a 1/4 inch screw, a 1/2 inch screw, and a washer. A 3/8 inch diameter hole was drilled 1-3/16 inches deep into the pavement to place 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.

A pavement joint monitoring device is used to perform the seasonal measurements of the pavement studs. 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 13). The measurement arm can be leveled, allowing for true horizontal measurements.

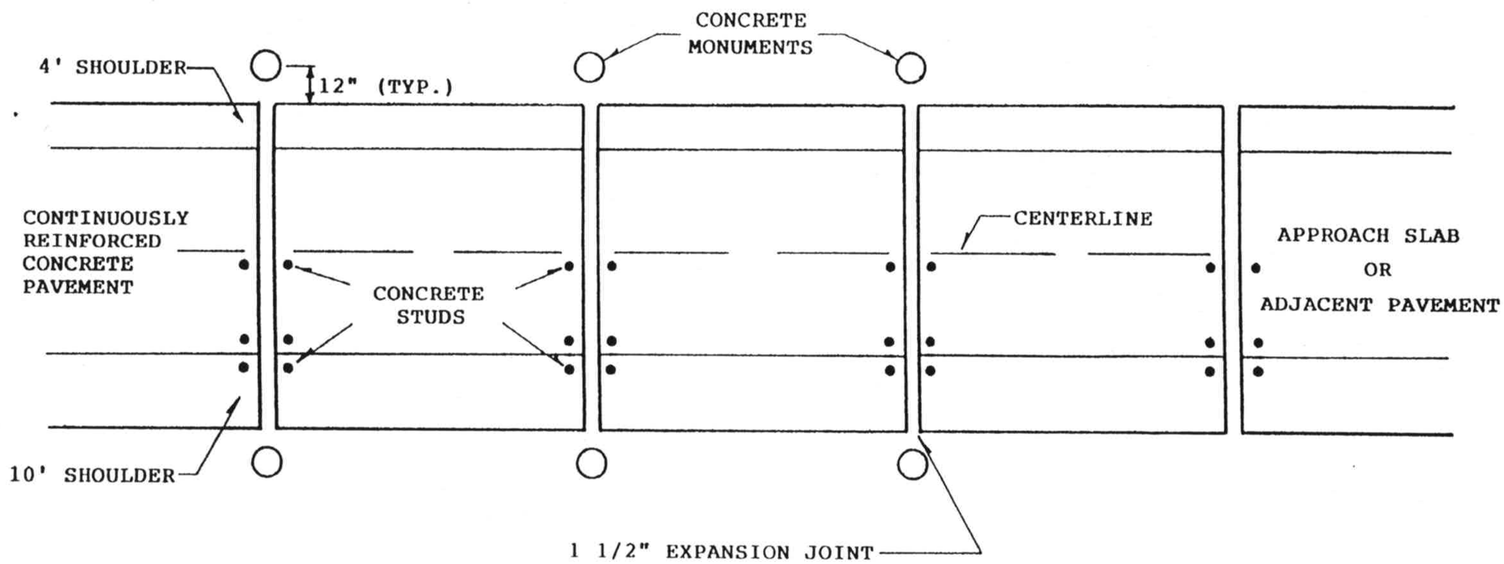

Figure 12. Stud and Concrete Monument Locations.

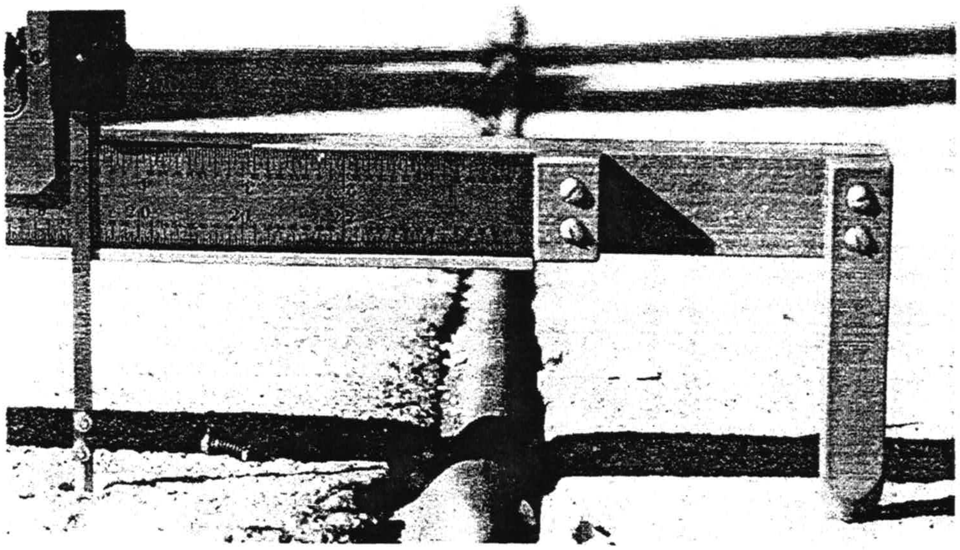

Figure 13. Joint Measuring Device.

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 monuments were installed in April 1990 and December 1991 for the westbound and eastbound lanes, respectively, before any public traffic use.

The concrete monuments were centered on the joint and placed approximately 1 foot beyond the outside and inside shoulders (Figure 14). These locations were augered to a depth of 2 feet and filled with concrete. The monuments were formed using 6 inch diameter concrete cylinder molds with the bottom cut out. This provided a smooth rim to finish the concrete.

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

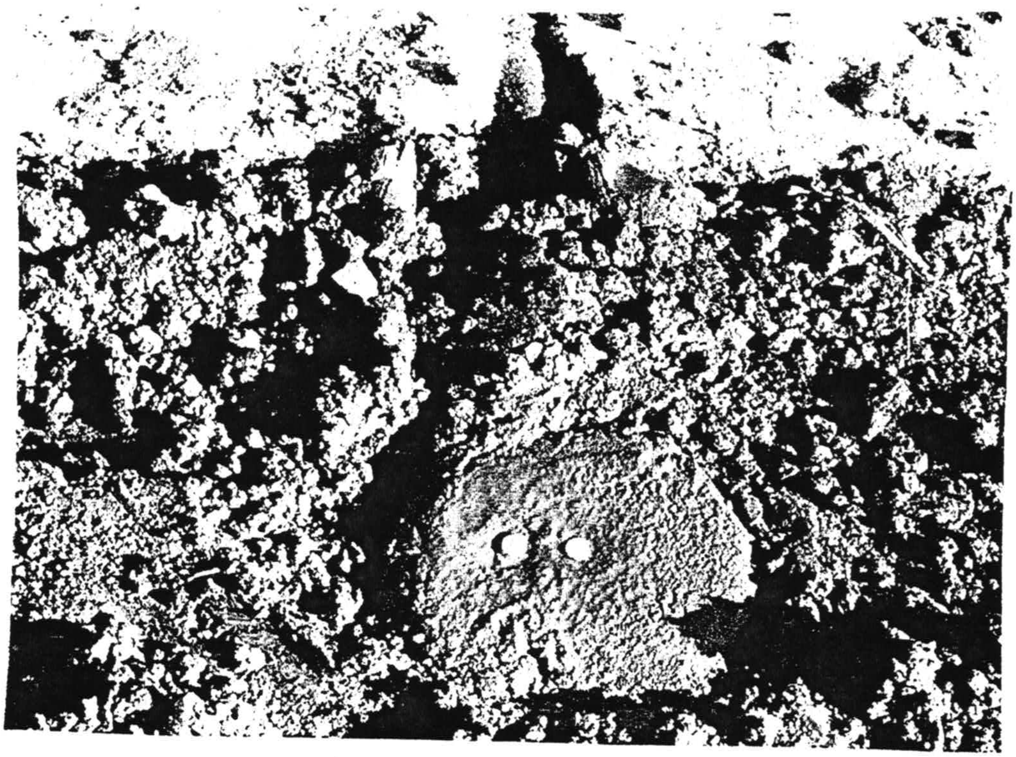

Figure 14. Concrete Monument with PK Nails Set.

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

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

Other Measurements

Slab length measurements were made and elevations of the joint locations were taken. This provides additional information for the horizontal and vertical movement of the joints.

Visual surveys provide distress information for the performance of the joints.

VISUAL SURVEY OBSERVATIONS

A visual survey was performed on each of the terminal joint locations to monitor performance. This visual survey included a crack map survey of each of the sixty foot terminal joint sections. The August 1992 visual survey indicated three areas of interest which will be discussed in this section of the report.

One area of interest is located at the end terminal joint of joint location E1 where two transverse cracks are located 2.5 feet from either side of the joint (Figure 15). This terminal joint system is a sleeper slab design. Both cracks extend across the total 24 foot pavement width and are approximately 1/8 inch in width. Each crack corresponds to the location of the sleeper slab located under the joint and extending 2.5 feet to each side of the joint. Construction records indicate that some of the plastic used as a bond breaker was rolled up, thus resulting in the pavement bonding to the sleeper slab.

These reflective cracks will probably cause maintenance problems in the near future. The midjoint M2 had a transverse crack 2 feet from the joint which may be attributed to bonding to the sleeper slab. Joint M1 and the abutting joint showed no signs of cracking above the sleeper slab. The other two sleeper slab locations (E2 and W1) showed no evidence of cracking above the sleeper slab.

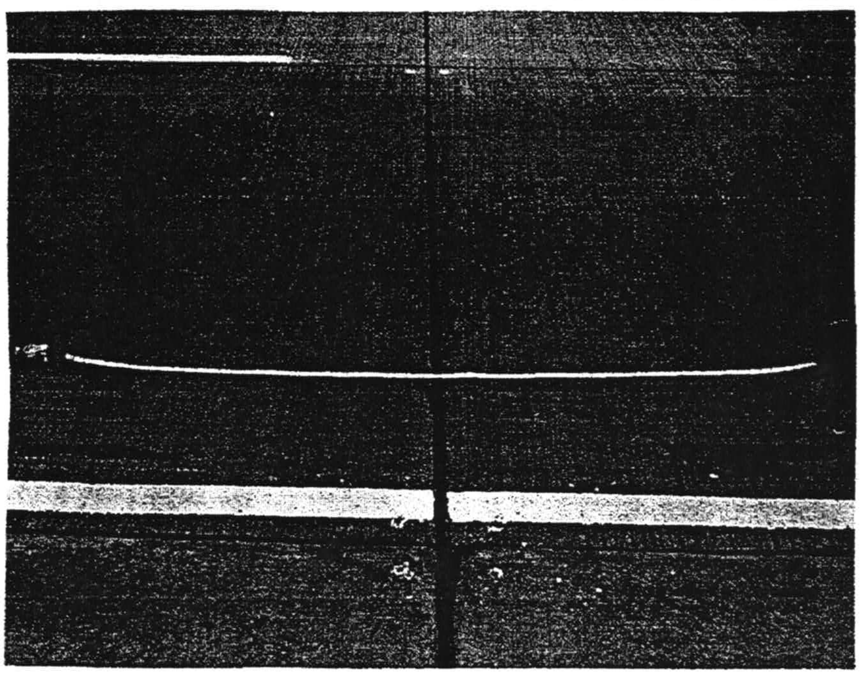

Figure 15. Reflective Cracks Above Sleeper Slab.

The second area of interest was located at terminal joint system E4 where two punchouts in joints M2 and the end joint exist. This terminal joint system is a dowel joint design. At joint M2 of this system there is a punchout section approximately 8 inches square (Figure 16). This punchout is located at the outside lane/shoulder interface and appears to have been patched during construction. This punchout will have to be replaced by maintenance personnel and the pavement stud will have to be replaced. This punchout appears to coincide with the location of the first dowel location next to the pavement shoulder. This joint system was difficult to construct due to the placement of steel and maneuvering the slipform paver around the dowels which were located at each joint.

A small corner spall developed at the end joint which is 10 inches long by 3 inches wide and is on the leave side of this joint and at the outside lane/shoulder interface. A pavement stud is in this spall area but appears to be firmly in place. It is difficult to determine if this spall is reflective of the dowel placement.

Figure 16. Corner Punchout Above Dowel Bar.

The third area of interest in the visual survey was transverse cracking located every 15 feet in each of the 60 foot terminal slabs. Thus, each 60 foot terminal slab had a transverse crack at approximately 15, 30, and 45 foot locations. These cracks ranged in severity from a high of 1/8 inch across the entire pavement width to a low of hairline extending only two feet out from the shoulder. This type of cracking was expected in accordance with CRCP design and does not present any concern at this time.

ANALYSIS

The Research and Development Division has obtained the measurements biannually to monitor the movement of the CRCP terminal joints. The recent measurements were taken in August 1992. Summer 1992 was mild in terms of maximum temperature recorded. The highest recorded temperature in Sallisaw in 1992 was 95 degrees. Normally two weeks of greater than 100 degree temperatures can be expected in the summer. Thus, the joint closures were not as large as expected.

Pavement Studs

A pavement joint measuring device was used to perform the measurements between the pavement studs. Seven readings were recorded for each terminal joint location. These readings included the reading between the studs at the roadway centerline and all measurement combinations between the four studs on the right edge of the pavement and the shoulder. A sample field data sheet is shown in Figure 17 with all readings recorded in inches.

The initial readings for the westbound lanes were taken in April 1990 (Time = 0 years) and the initial readings for the eastbound lanes were taken in December 1990 (Time = 0 years). The first time the eastbound and westbound joints were measured together was summer 1991. Thus the westbound joints are 2 1/2 years old and the eastbound joints are 1 1/2 years old. There were no readings taken for the westbound joints in summer 1990 due to construction procedures. Readings have been taken five times in the westbound lanes and four times in the eastbound lanes.

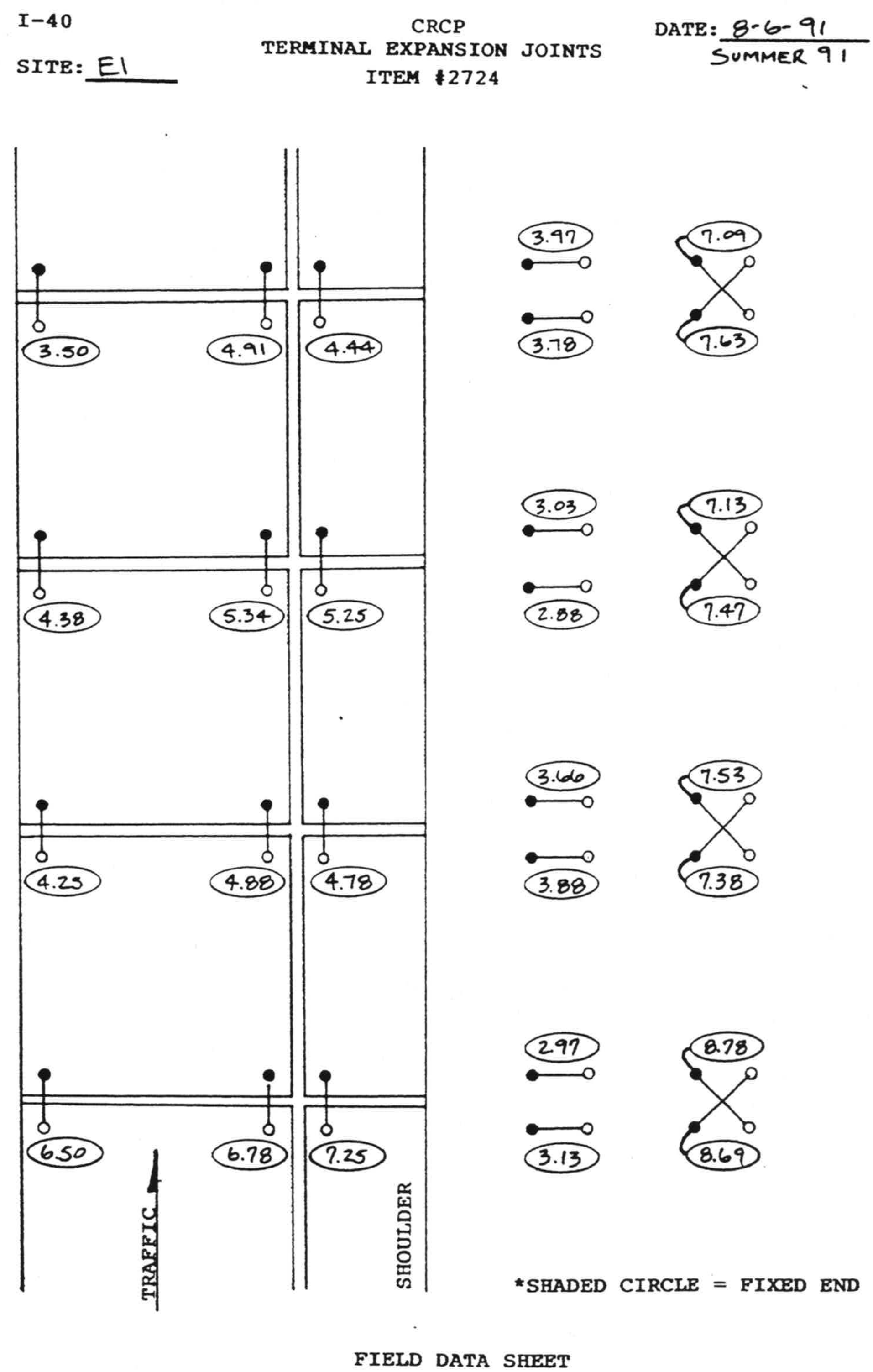

Figure 17. Field Data Sheet for Joint Measuring Device.

The largest closures occur at the end terminal joint of each terminal joint system. The end terminal joint is defined as the joint closest to the CRCP pavement. The closures of the end terminal joints can be largely attributed to the creep movement of the CRCP during warm weather cycles.

The end joints have had closures ranging from 0.55 inches to 1.14 inches. The midjoints (M1 and M2) and the abutting joints have had small closures compared to the end joints. Figure 18 illustrates the movement of the the sleeper joint system where the end joints move much more than the mid and abutting joints during the hot weather. Similar movements were seen for the open joint system and the dowel joint system.

It should be noted that the end joints did not return to their initial position during the cold weather cycle. This may be attributed to possible permanent creep. The mid and abutting joints nearly returned to their initial position during the cold weather cycles. The movements of the mid and abutting joints can be attributed to thermal expansion and contraction of the sixty foot terminal slabs.

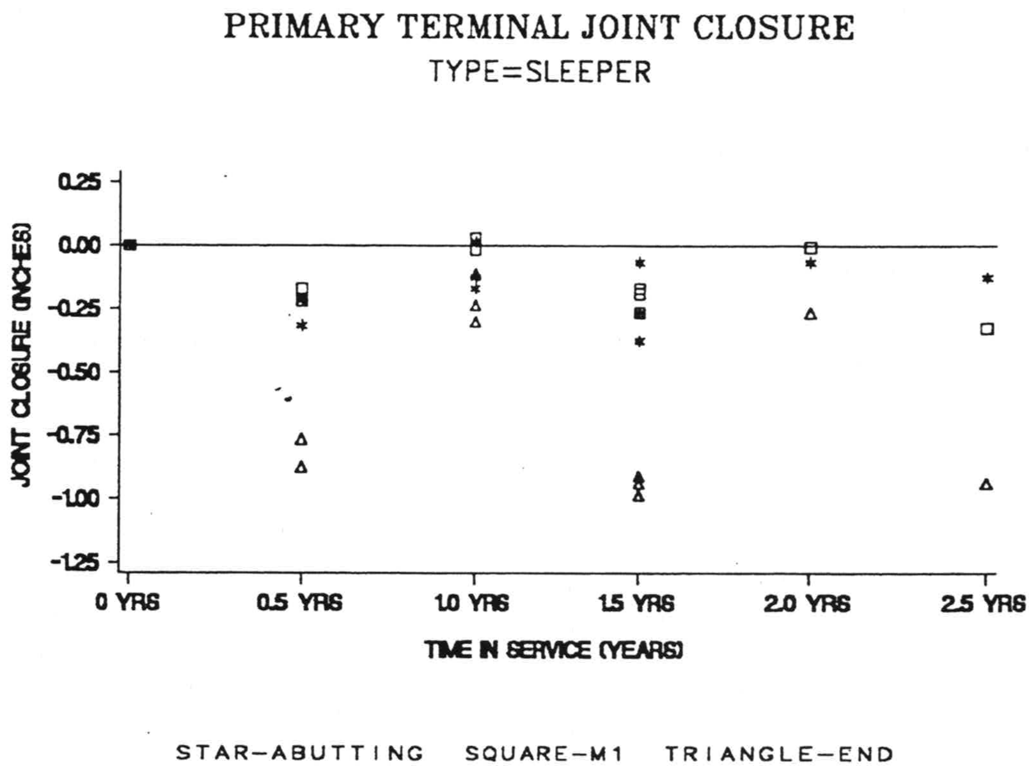

Figure 18. End Joint vs. Mid and Abutting Joint Closures.

The end terminal joint closures for the three different joint system designs were evaluated. The open joint system exhibited the most closure ranging from 0.77 inches to 1.14 inches. The sleeper system exhibited the the second most closure ranging from 0.76 inches to 0.98 inches. The dowel system had the least closure ranging from 0.52 inches to 0.82 inches.

Figure 19 illustrates the difference in closures of the end joints of the three joint system designs. Figures 20, 21, and 22 illustrate the closures of the open, sleeper, and dowel system respectively.

All joints exhibited a minimum closure of 0.50 inches from winter to summer. One joint of note was the end joint at W4 (open joint). In Summer 1991 it was observed to be closed shut with a joint closure of 1.14 inches while in Summer 1992 this joint had a closure of 1.01 inches.

The three joint systems are performing similarly in their expansion and contraction during the warm and cold weather cycles. Also, it should be noted that the Winter 1992 indicated that none of the end joints had returned to their initial open position.

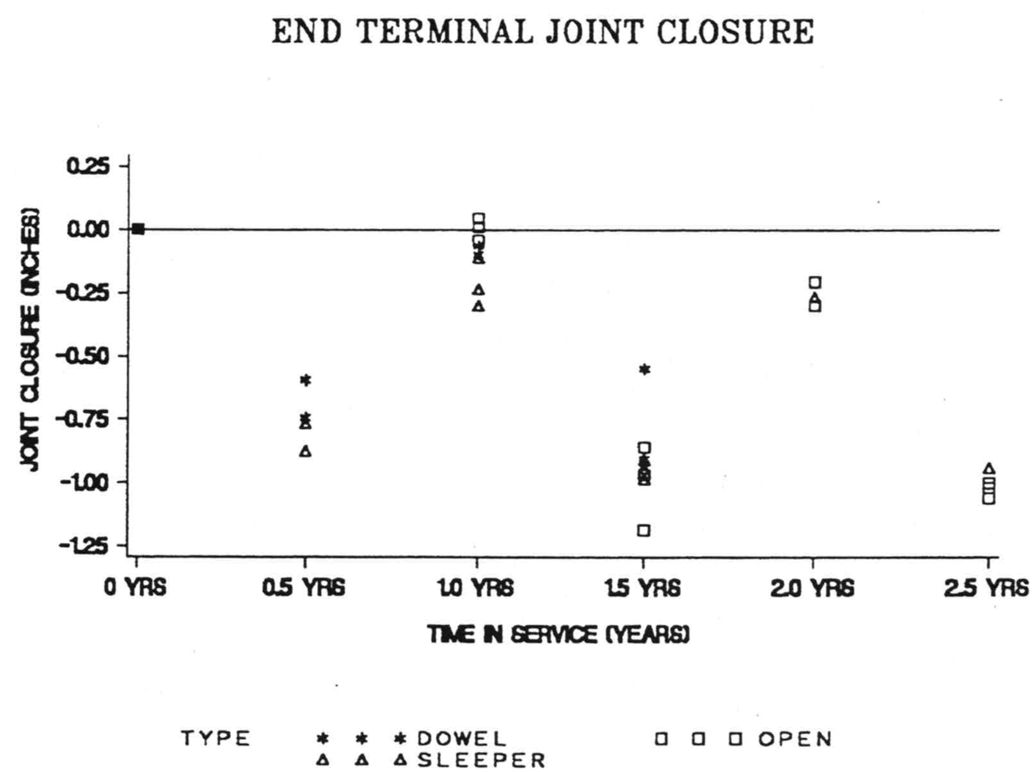

Figure 19. End Joint Closures for Three Joint Systems.

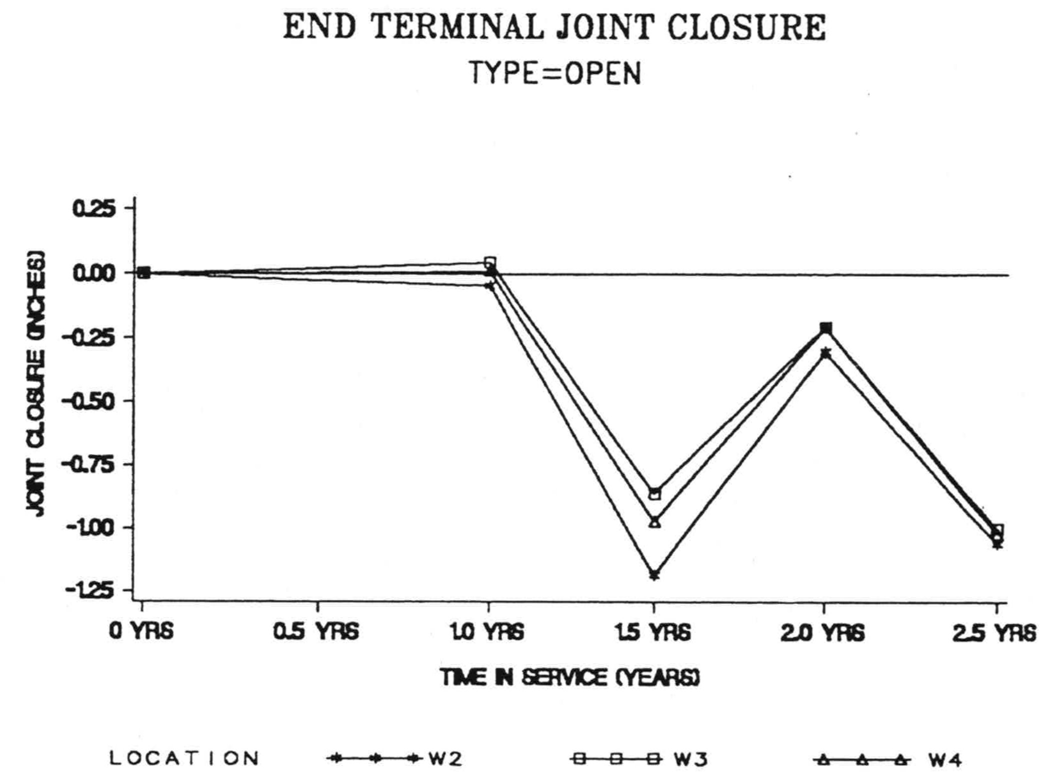

Figure 20. End Joint Closures for Open Joint Systems.

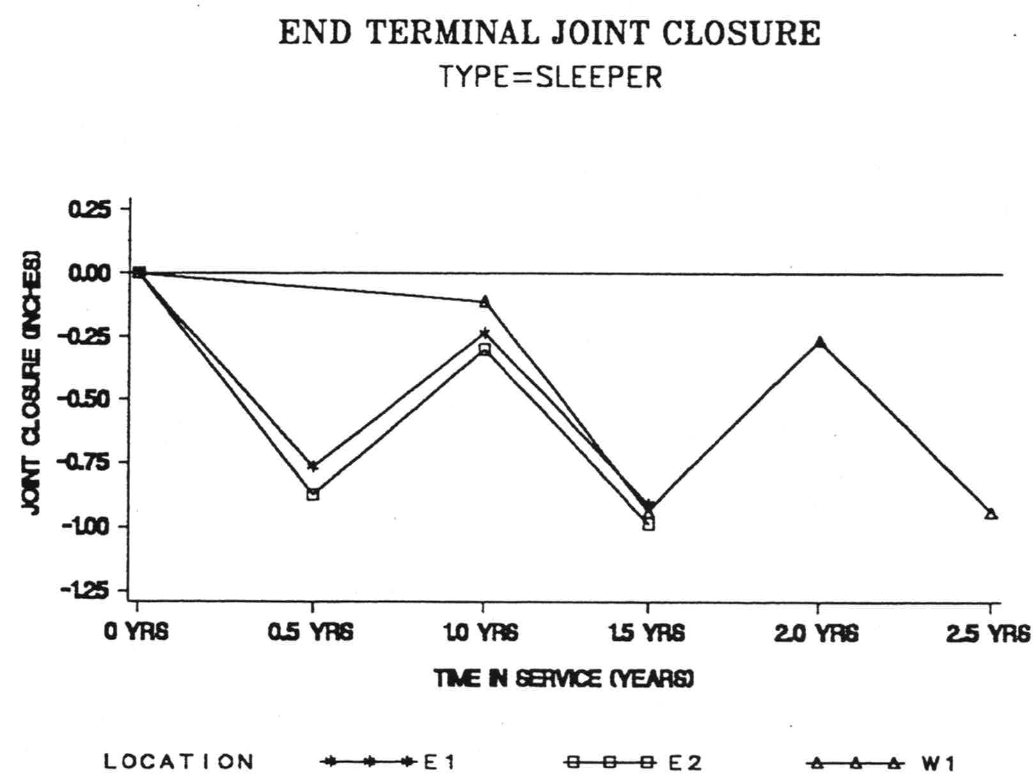

Figure 21. End Joint Closures for Sleeper Joint Systems.

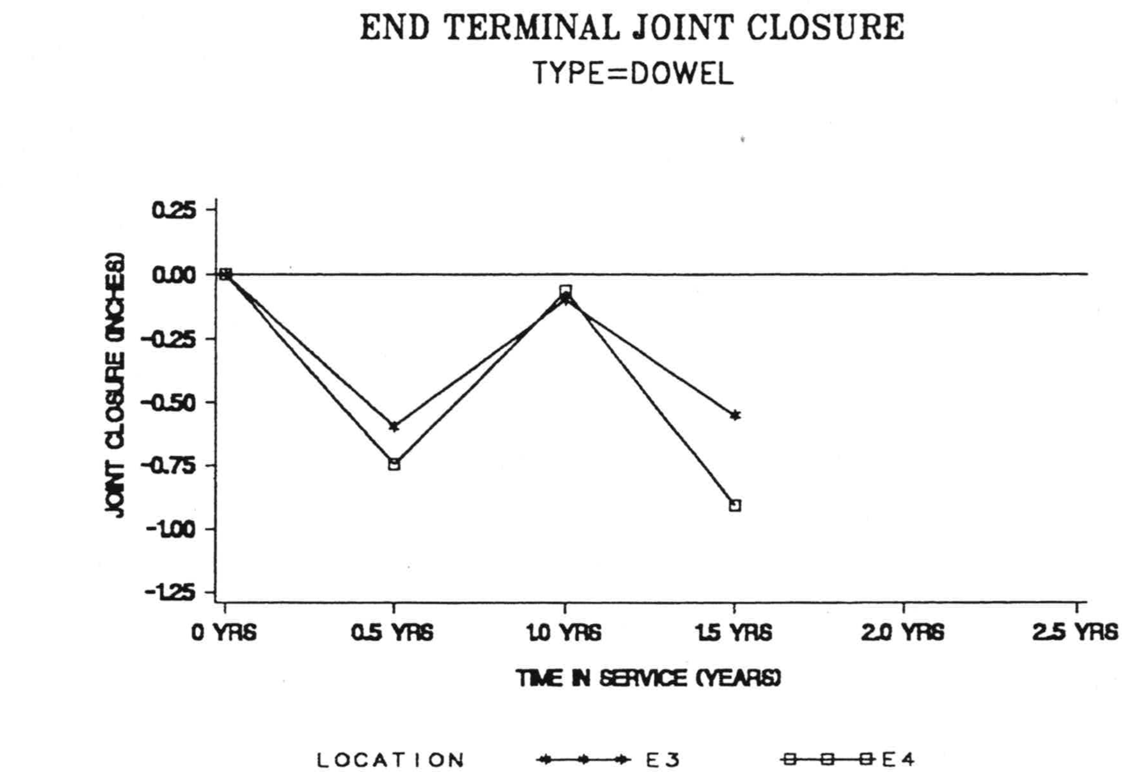

Figure 22. **End Joint Closures for Dowel Joint Systems.**

The stud measurements indicated minimal transverse movement between the CRCP pavement and the shoulder. These movements were mainly 0.05 inches to 0.10 inches which can be attributed to slab expansion or to test reading error. Figure 23 indicates the transverse movements for all of the joint systems.

The stud measurements also indicated the shoulders are moving longitudinally with the CRCP pavement. This movement is indicated in Figure 24 for all of the joint systems. This movement was expected since the shoulders are tied to the pavement.

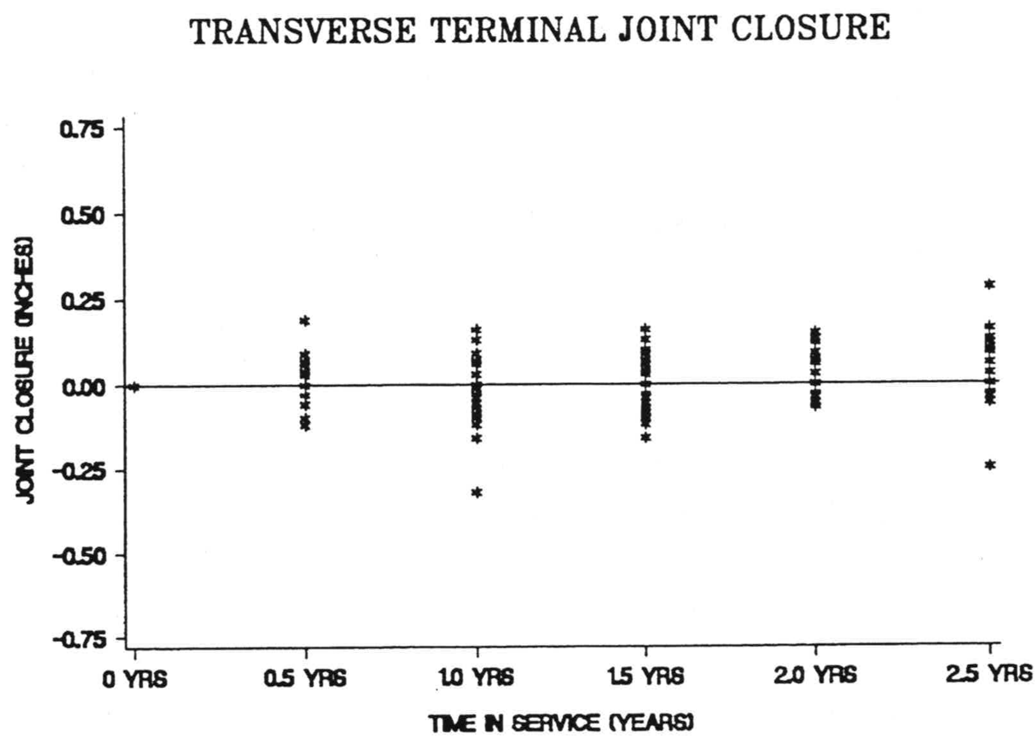

Figure 23. Transverse Terminal Joint Closure.

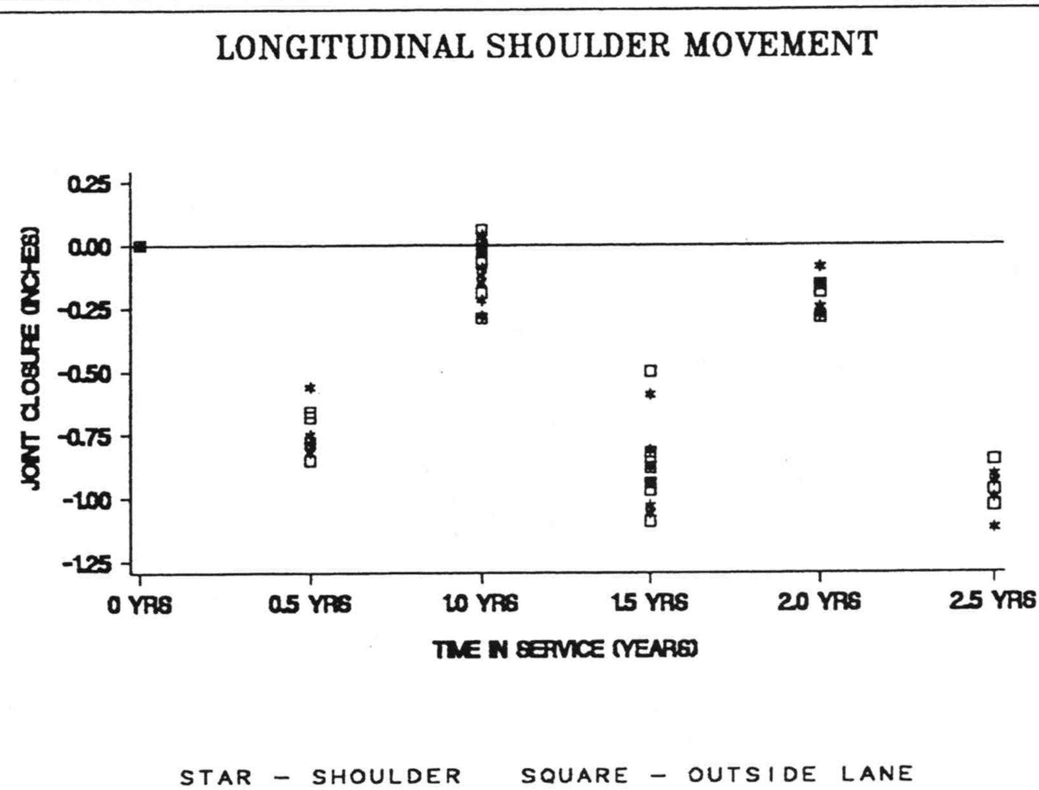

Figure 24. Longitudinal Shoulder Movement.

Concrete Monuments

Four of the monuments located in dirt were found destroyed in August 1991 and three more of the monuments were found to be destroyed in August 1992. Unlike 1991, there are two terminal joint locations where no monument is present on either the inside or outside shoulder. The four monuments were destroyed by box blades in 1991 when the sod along the roadway had to be replaced by the contractor. The reason for the three monuments being destroyed in 1992 is unknown. The measurements at the concrete monuments have resulted in no significant trends in joint movement.

Slab Lengths and Elevations

Slab length measurements were made for each 60 foot terminal section and every bridge approach slab. These measurements have been compared to the initial readings taken in January 1991 and to each subsequent set of readings. Some small slab expansions can be detected when comparing the summer and winter readings.

Elevations were recorded for every corner of each terminal slab. These elevations were also compared to the initial elevations and each subsequent elevation. No significant differences were noted except at W2 (Open joint) where the bridge approach slab and first terminal slab were raised with grout after construction was complete.

Joint Sealant Performance

Dow Corning 888 was the silicone joint sealant chosen to seal the terminal joints on this project. As mentioned earlier in the report, the open joint systems have had as much as a 1.14 inch closure. At the open joint system located at the west end of the project the end terminal joint appears to be almost closed tight. Thus, the joint sealant has been pushed up above the pavement level. Traffic is beating on this exposed joint sealant and pushing it out of the joint and onto the pavement on the far side of the joint.

In addition to the open joints, the sleeper joint systems are experiencing joint sealant failure. Five of the nine sleeper joints have failed joint sealant and in three of the remaining four joints the sealant has slightly debonded. To help the performance of the terminal joint systems, these failed joint sealant locations need to be resealed.

DISCUSSION

The testing performed on the three different terminal joint designs over 2 1/2 years revealed definite movement differences between the three designs. The open joint design had joint closures of up to 1.14 inches, the sleeper design had joint closures of up to 0.88 inches, the dowel design had the least amount of closure, with closure as high as 0.77 inches. Most of the joint movement occurred at the end terminal joint of the joint system. The end joint was expected to exhibit the most movement since it has the greatest lengths of pavement on one side of the joint.

The measurements indicated no significant lateral slab movement over time. Also, the shoulder slabs were tied to the roadway pavement during construction and the measurements indicated the shoulders are exhibiting the same longitudinal movement as the roadway pavement. The elevations indicated no upward or downward movement of any slabs. Thus, no rotational movement of the slabs was detected.

The 1992 visual survey revealed certain distresses which will be monitored closely in the future. The reflective cracking above the sleeper slab at joint system E1 can be attributed to construction technique. If increased severity results in the joint being repaired, subsurface investigation will be performed to verify that the pavement had bonded to the sleeper slab at this location.

The punchouts found at dowel joint system E4 appear to be tied to the dowel placement nearest the pavement shoulder. Possibly the first dowel bar needs to be placed farther from the pavement edge to avoid the punchout. If these sections are repaired, an investigation will be performed to determine the relation between the repaired areas and the dowel spacing.

The cracking which occurred every 15 feet in each terminal slab appears to common to this pavement type. These cracks will be monitored closely for increased severity.

The weather pattern in 1992 was mild compared to normal seasonal changes for this location. The winter was very warm and the summer was very cool, thus, the maximum temperature differential for 1992 was small. If 1993 proves to be normal with respect to temperature differential then end joints may shut in the summer and either force some upward movement at the end joint or push the 60 foot section adjacent to it.

REFERENCE

1. Ooten David A., "Terminal End Joints in Continuously Reinforced Concrete Pavement (Construction Report)", Oklahoma Department of Transportation in Cooperation with FHWA, FHWA/OK 91(01), 1991.