

EVALUATION OF LOAD TRANSFER ASSEMBLIES

Progress Report

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MICHIGAN DEPARTMENT OF STATE HIGHWAYS

EVALUATION OF LOAD TRANSFER ASSEMBLIES

Progress Report

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Michigan State Highway and Transportation Commission
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In 1969, the Michigan Department of State Highways and Transportation in cooperation with the Federal Highway Administration constructed a test road for the evaluation of load transfer assemblies. The test pavement is a part of Michigan Project S 262(10), State Project 76011-009 and is located on M 52 between Bennington Rd and Morrice Rd in Shiawassee County (Fig. 1).

The experimental pavement consists of 3.25 miles of 24-ft reinforced concrete of 9-in. uniform thickness placed on a 14-in. granular subbase. The transverse joint spacing is 71 ft 2 in. and load transfer is provided at all joints. All transverse joint grooves are sawed and sealed with neoprene seals. The longitudinal center joint is also sawed but is sealed with a cold-applied liquid sealant.

Construction of the pavement began July 23, 1969, was completed August 12, 1969, and opened to traffic November 10, 1969. Full-width construction was employed, whereby the entire 24-ft width of pavement was placed at one time. The concrete was placed in two layers; the first layer was struck-off 3 in. below the pavement surface and the reinforcement placed at that depth. A second layer was then placed and the surface finished with mechanical equipment. The final surface treatment consisted of hand floating followed by burlap dragging. The pavement was protected during the curing period by applying a white membrane curing compound.

The experimental feature was the use of three different types of contraction joint load transfer assemblies and a new type of assembly for use in end-of-pour construction joints. Each type is described as follows:

1. Michigan's Standard Assembly - Load transfer is accomplished by use of 1-1/4-in. diameter steel dowels 18 in. long. The dowels are held in a wire frame on 12-in. centers and at mid-depth of the slab. Alternate ends of the dowels are welded to the frame. The free dowel ends are sawed to maintain their roundness and thereby reduce restraint of movement. To prevent bonding of the concrete to the free dowel end, a coating of liquid asphalt RC-250 is applied for not less than 2/3 of the length of each dowel.

2. Assembly with Plastic Coated Dowels - This assembly is identical to the standard assembly except the dowels are coated with a plastic material. The coating consists of a 4-mil thick adhesive material overlaid by a 17-mil thick high density polyethylene material. The coating system is applied by an extrusion process before the dowels are sawed and welded into the wire frame. The plastic coating prevents bonding of the concrete to the dowels, thus eliminating application of a bond breaker in the field. In addi-

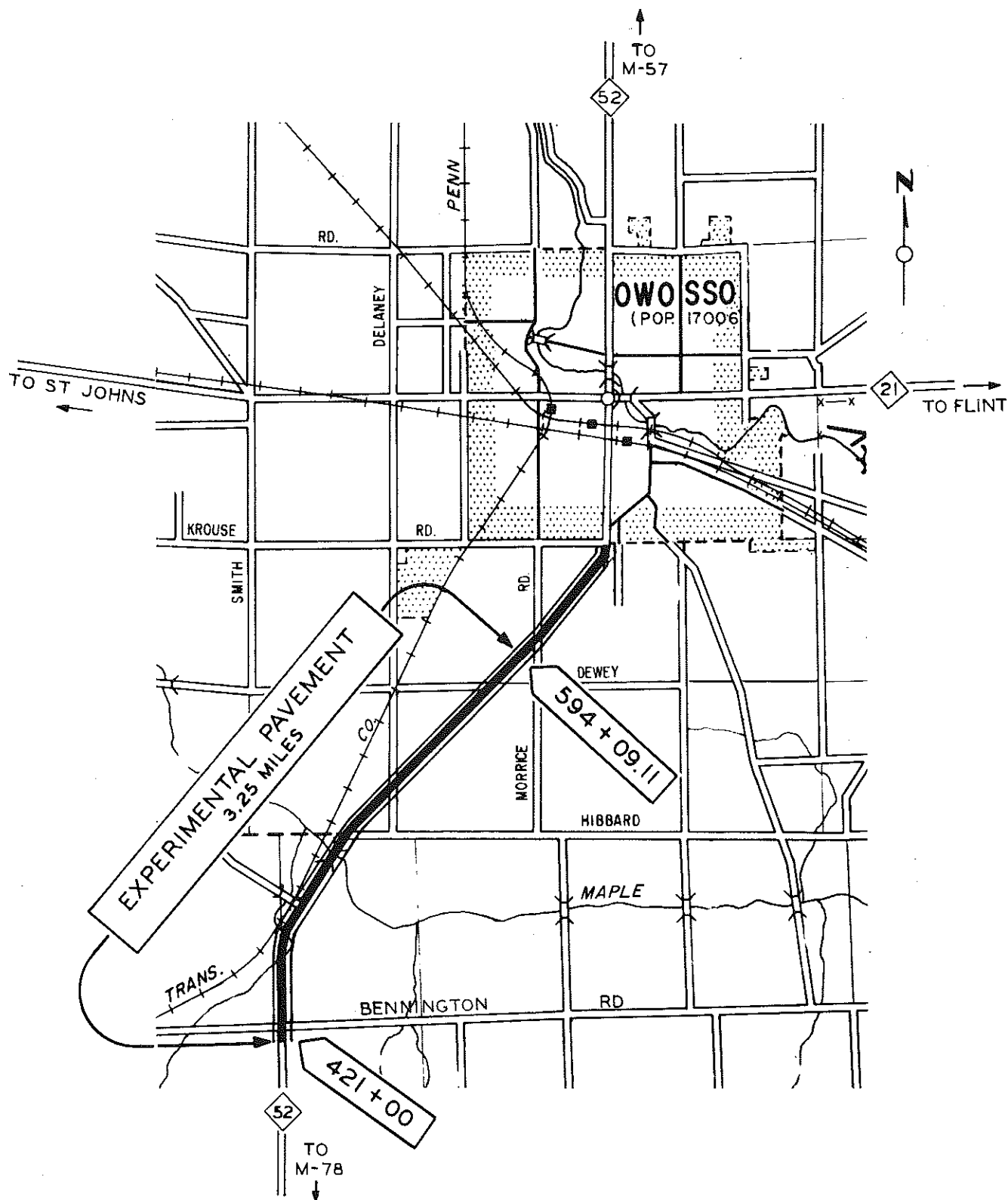


Figure 1. Location of experimental pavement.

tion to acting as a bond breaker, the plastic coating also minimizes corrosion of the steel bar.

3. Acme Assembly - An assembly of this type utilizes malleable iron castings to accomplish load transfer. Each individual transfer unit within a 12-ft assembly consists of a female and male casting which engage for a distance of 1-1/2 in. at the center of the assembly. The castings are straight in the engagement area but then curve down and outward and are fastened to sheet metal angles designed to support the assembly on the subbase. Spacing of the individual units at the center of the assembly is maintained by fastening to a metal plate. Assemblies are designed for load transfer at the mid-depth point of the slab. The assembly is held together during handling and installation by crimping the female casting, which is open on one side, onto the male casting. Because the sliding portion of the units is enclosed on three sides and is only 1-1/2 in. long, no bond breaker needs to be applied in the field before installation.

4. End-of-Pour Assembly - This assembly differs from a standard contraction joint assembly in two ways: first, the dowels consist of a 7-1/2-in. length of bar threaded into one end of a 3-in. long sleeve, and a 10-1/2-in. bar threaded into the other sleeve end, and; secondly, the plain ends of the shorter dowel pieces are welded to one assembly side frame, whereas the other side frame is clipped onto the longer dowel pieces. This design permits the dowels to be supported independently of the bulkhead and allows removal and replacement of the half assembly extending into the second pour area.

Figures 2 through 5 illustrate an assembly of each type. The experimental pavement contains three test sections and eight individual end-of-pour joints. Since the construction was performed in accordance with Standard Specifications the test sections contain expansion joints at intersections of other structures and at the PC's and PT's of curves. Details of the joint layout and location of the test sections are given in Figure 6. Research Report No. R-737 "Construction of Joint Load Transfer Test Road to Evaluate Acme Load Transfer Assemblies, Plastic Coated Dowels, and End-of-Pour Construction Joint Assemblies" issued in 1970 details the construction aspects and gives the initial evaluation results.

Objectives

The objectives set forth in the project Work Plan are:

- 1) To evaluate the Acme assembly and assemblies containing plastic

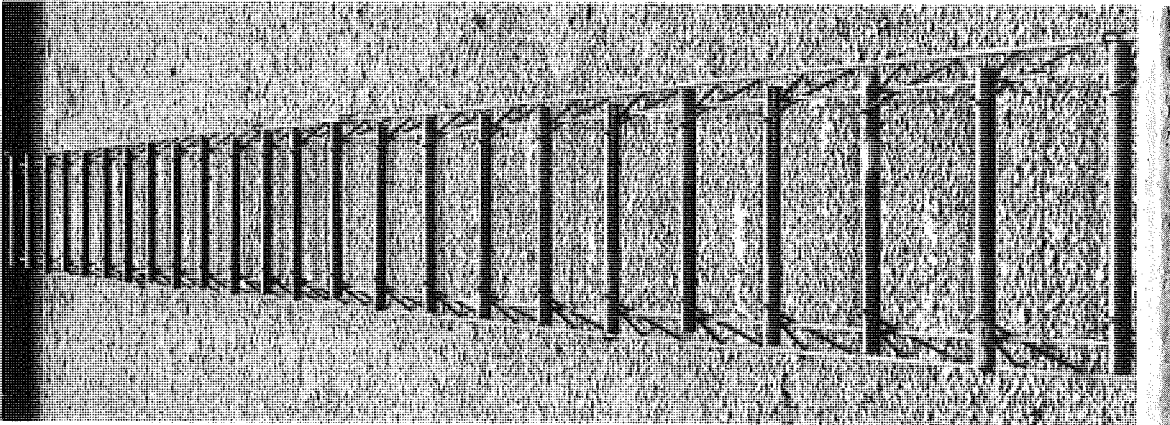


Figure 2. Standard dowel bar assembly.

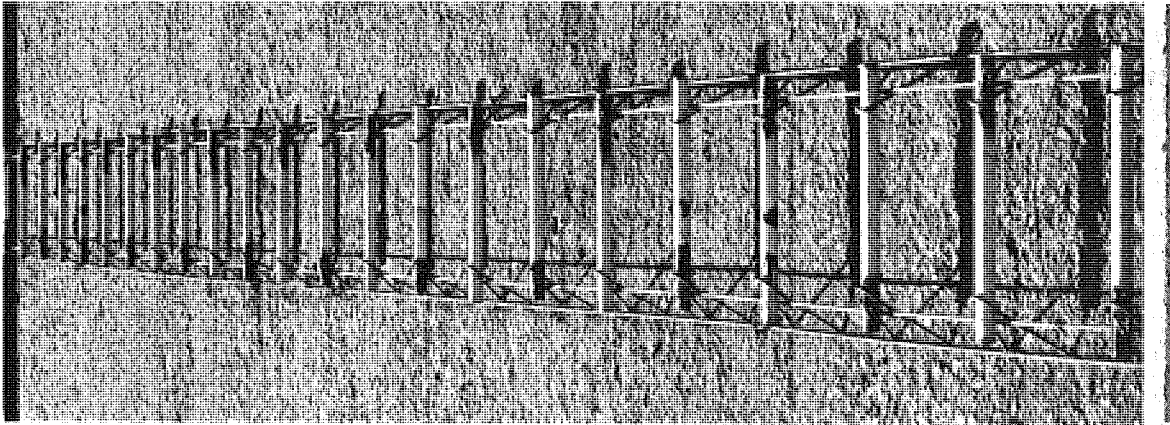


Figure 3. Assembly with plastic coated dowel bars.

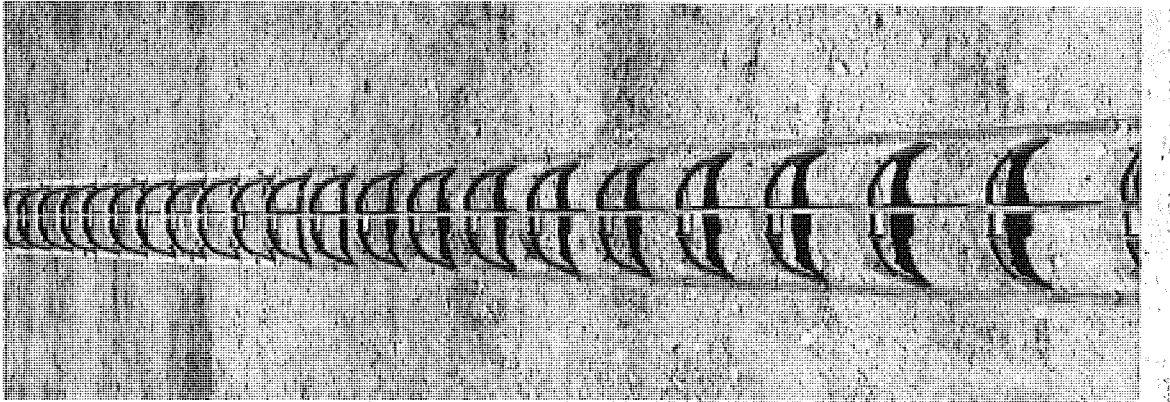


Figure 4. Acme assembly.

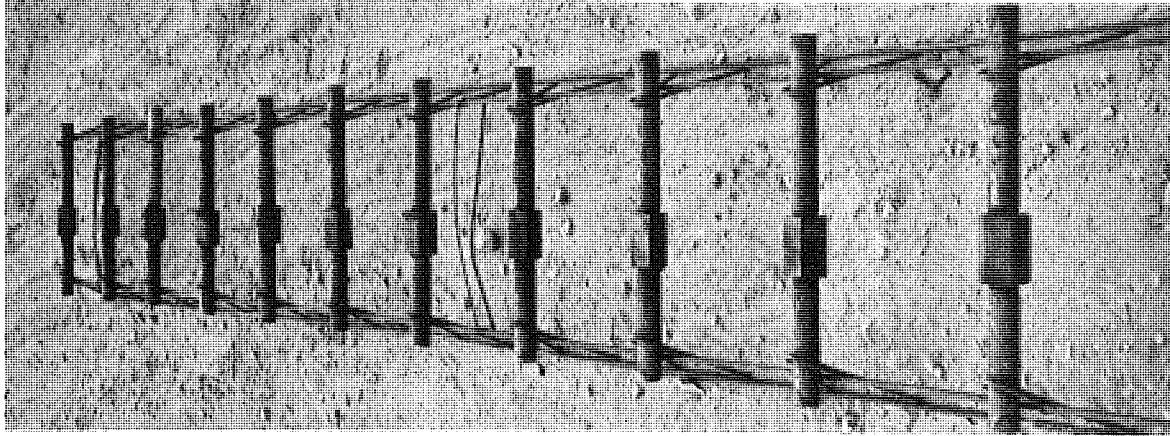


Figure 5. End-of-pour assembly.

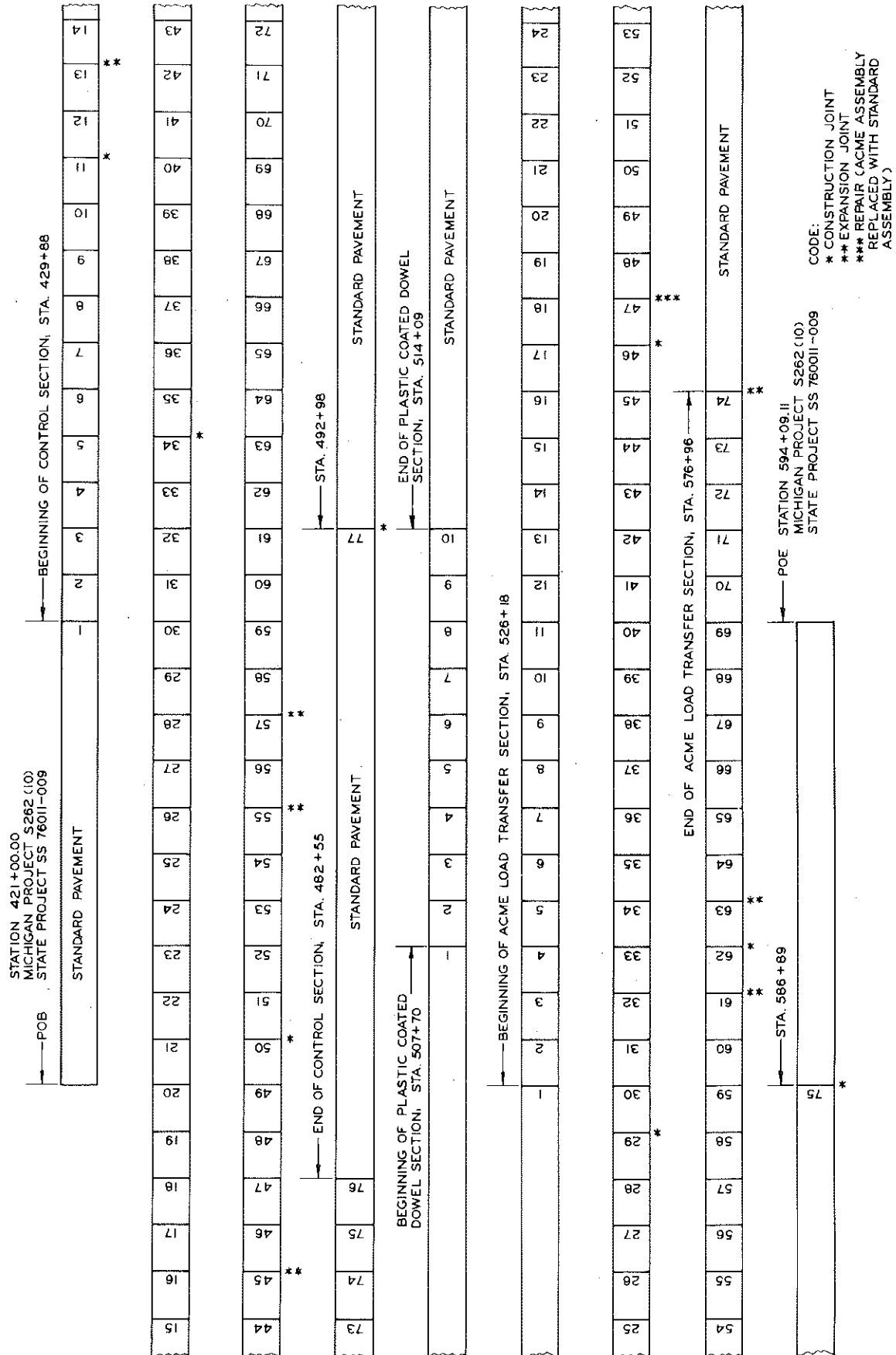


Figure 6. Test section locations and joint layout.

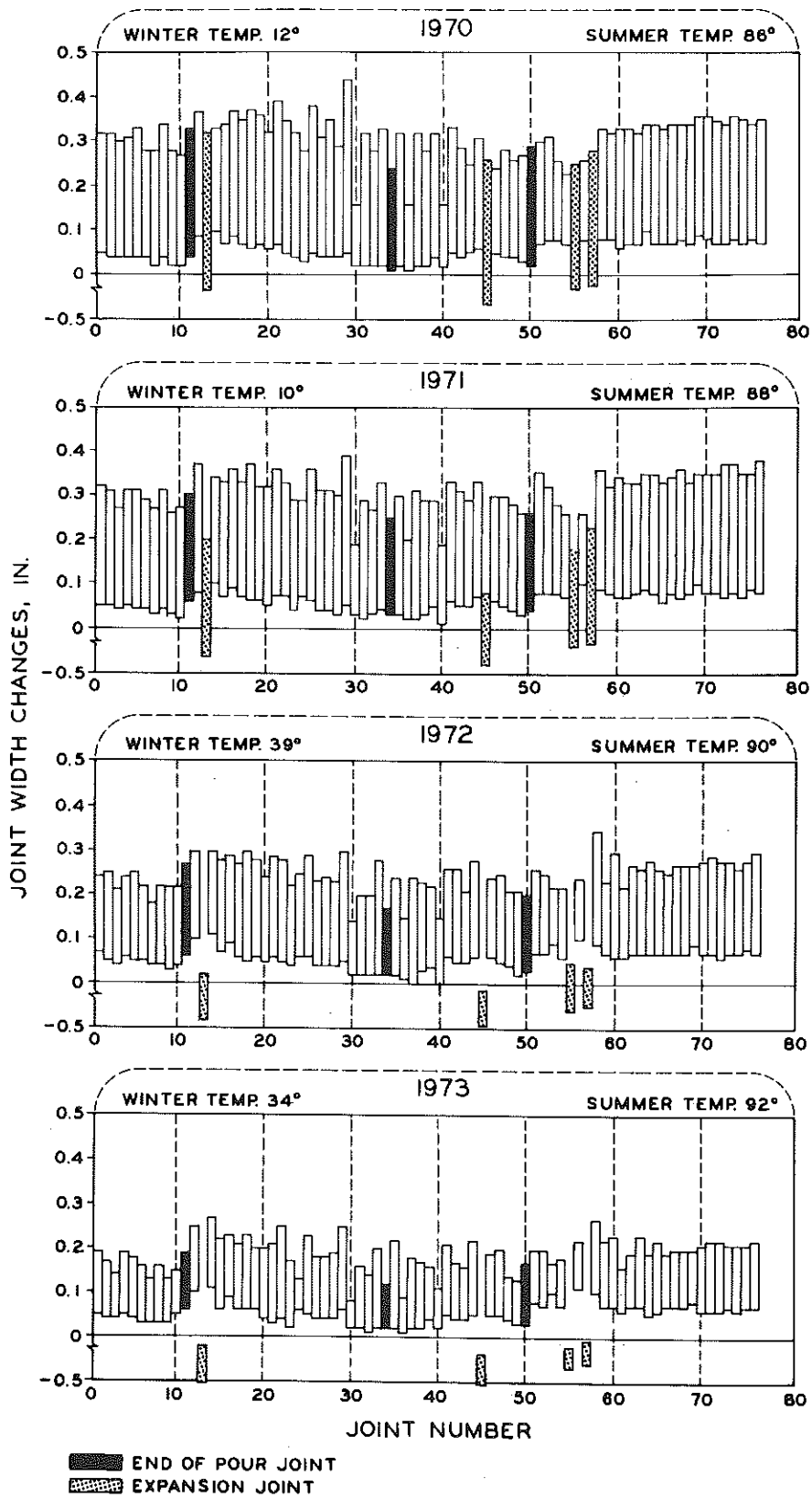


Figure 7. Seasonal joint width changes (standard dowels).

coated dowel bars by comparing them with the performance of standard assemblies in light of the following criteria:

- a. load transfer capability
- b. joint movement restraint
- c. joint and slab deterioration
- d. corrosion of load transfer unit.

2) To determine the feasibility of using the proposed type of assembly in end-of-pour joints by observing installation procedures.

The feasibility of using an assembly in end-of-pour joints was covered in Research Report No. R-718, dated October 1969. On the basis of observations made during construction of this type of joint it was recommended that the assembly be approved as a standard end-of-pour joint load transfer assembly. The assembly is now approved and included on the Department's Standard Plan for Concrete Pavement Joints.

Evaluation

The performance of the Acme assembly and the plastic coated dowels will be determined on the basis of a comparison of the following factors with the same performance factors for standard dowels:

1. uniformity of joint movement
2. pull-out resistance of load transfer unit
3. formation of transverse slab cracks
4. amount of joint groove spalling
5. load-deflection at joints
6. corrosion resistance of the load transfer unit.

Joint Movement

The summer-winter changes in joint opening for each joint in each test section are shown graphically in Figures 7, 8, and 9, for standard, Acme, and plastic coated dowels, respectively. The temperatures at the time the measurements were made are shown on each figure. Seasonal movements of expansion joints and end-of-pour construction joints located within the test sections are also included on the graphs.

There are many factors that affect the uniformity of joint movements, some of which are; dowel alignment and lubrication, uniformity of concrete mix, curing conditions, pour temperature, and subbase friction. With so

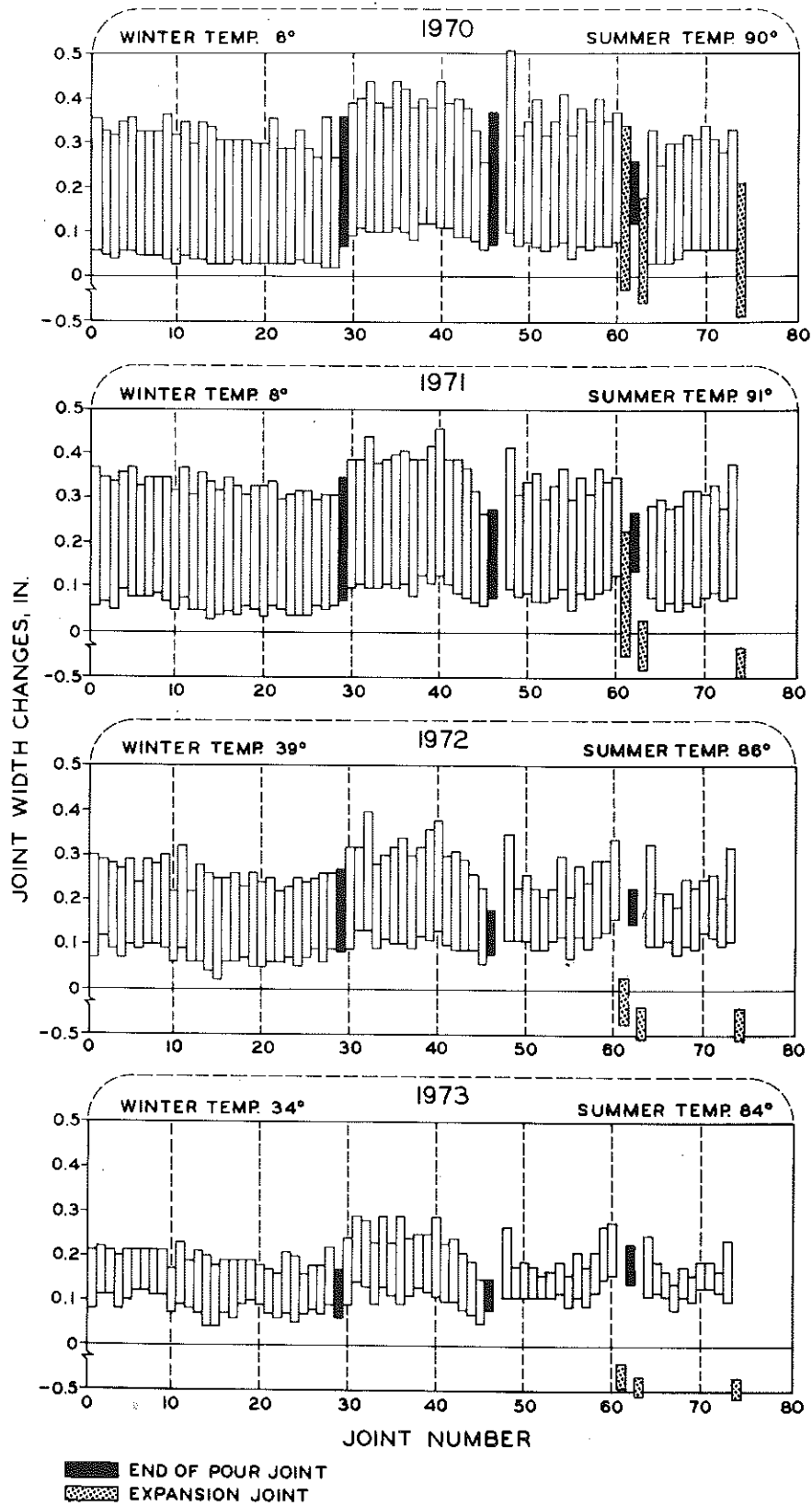


Figure 8. Seasonal joint width changes (Acme assemblies).

many elements affecting the movement of concrete pavement joints, variations in the amount that each joint moves is to be expected. The variations notable in Figures 7, 8, and 9 are believed to be caused by a combination of factors affecting joint movement rather than caused by any single one.

There are, however, two additional items that are known to cause non-uniformity in joint width changes and they are "frozen" joints and expansion joints. The effect of a frozen joint can be seen in Figure 8 where it is shown that joint No. 47 has never opened (the Acme assembly in this joint was tilted during construction and was replaced with a standard dowel assembly). As a result, joint No. 48 has a seasonal movement about twice as much as the adjacent working joint. The effect of the frozen joint cannot be detected in the movements of joint No. 46. As shown, this is an end-of-pour joint containing dowels and it is suspected that the joint restraint of the dowels in this case is greater than the restraint of the Acme assembly in joint No. 48 and could have caused all the additional movement to occur at No. 48.

Expansion joints, when installed among contraction joints generally continue to close until all the space is used up. The changes and progressive closure of the expansion joints included in the standard and Acme sections can be seen in Figures 7 and 8. This closure tends to result in larger openings of the adjacent contraction joints as evidenced by the larger summer openings recorded at these joints. At this time the non-uniformity caused by closure of the expansion joints is of little consequence.

The joint width changes recorded for the plastic coated dowels have been very uniform during the past four years and it appears that uniformity of joint movement of these joints is somewhat better than that of the Acme and standard joints (Fig. 9). However, the data in all three cases indicate only relatively small changes in the amount of seasonal movements and there appears to be no serious problem developing at this time.

Pull-Out Resistance

From each of the three test sections, three individual dowels were removed to check the amount of load required to open the joints. All dowels removed were adjacent to the northbound shoulder edge. At each location a 12-in. wide, by 24-in. long, full-depth piece of concrete was removed by sawing the slab full depth. The blocks were removed carefully, placed on pallets and transported to the Laboratory for testing.

To apply the load to the block 4-1/2-in. diameter expansion anchors were installed in each block, two on each side of the joint. Two steel yokes,

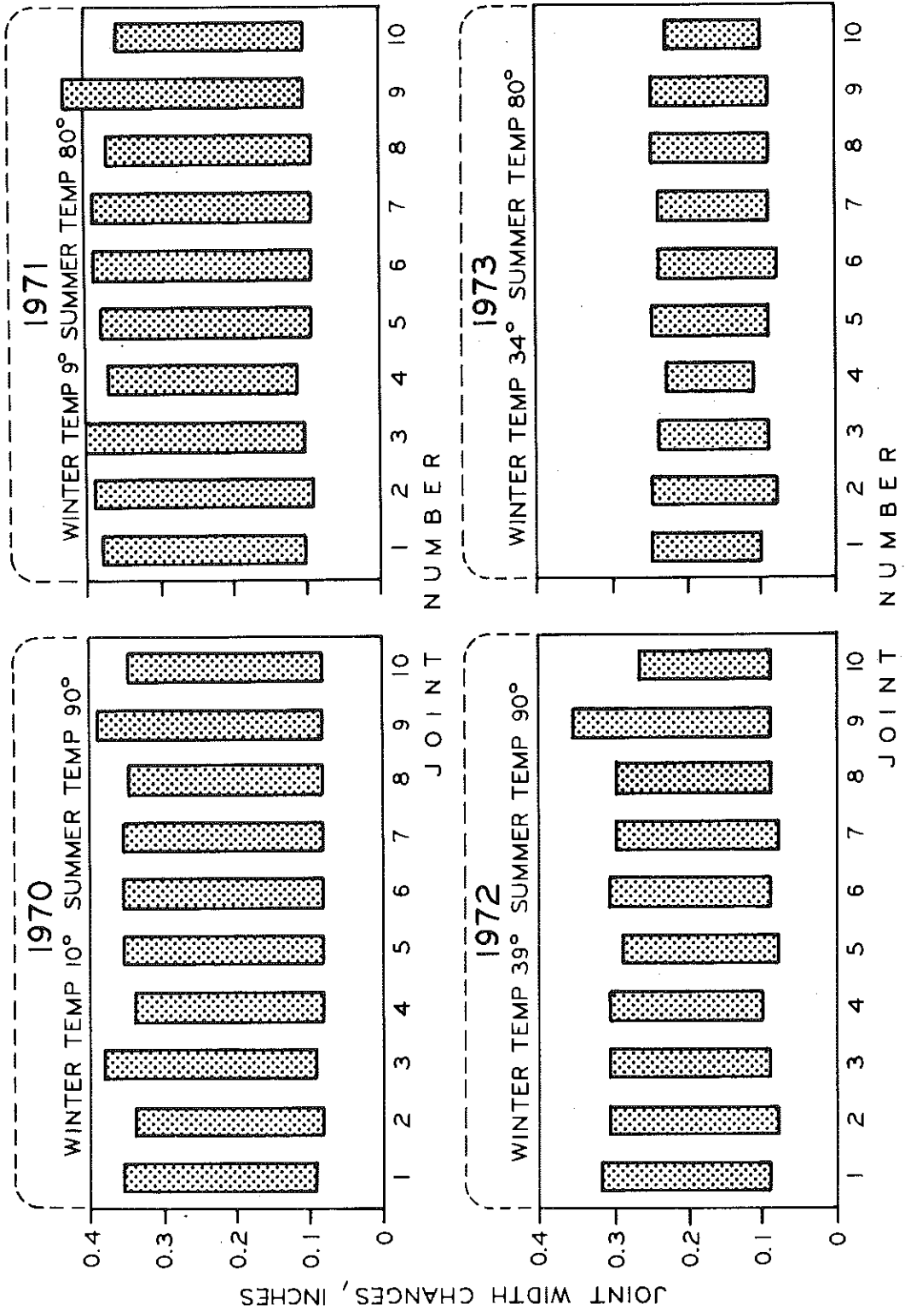


Figure 9. Seasonal joint width changes (plastic coated dowels).

one at each end, were bolted to the anchors. One end of the block was held stationary by fastening to an angle plate bolted to the floor. At the other end the load was applied with a hydraulic jack positioned in a frame made for this type of testing. The load was measured with a dynamotor load ring. The movement of the joint was determined by using a 0.001 in. dial gage. The test set-up is shown in Figure 10.

The results of the pull-out tests are given in Table 1. The load, as noted, was recorded at 0.01 in. movement, and at 0.50 in. movement, the maximum distance the joint was opened. In addition, the maximum load and the movement at which it occurred are given in the table.

TABLE 1
PULL-OUT TESTS

Joint No.	Dowel Type	Lubricant	Load (lb) at Movement (in.)					
			Load	Move- ment	Load ¹	Move- ¹ ment	Load	Move- ment
22	Standard	Asphalt ²	6,200	0.010	7,400	0.018	2,200	0.50
26	Standard	Asphalt	7,400	0.010	8,200	0.021	1,800	0.50
30	Standard	Asphalt	6,000	0.010	8,500	0.023	3,400	0.50
2	Plastic coated	None	800	0.010	2,000	0.250	2,000	0.50
6 ³	Plastic coated	None	6,200	0.010	9,000	0.100	1,800	0.50
9	Plastic coated	None	600	0.010	1,400	0.200	1,400	0.50
18	Acme	None	No tests because load-transfer unit separated during handling.					
21	Acme	None						
24	Acme	None						

¹ Maximum Load (occurred at movement shown).

² RC-70 or RC-250

³ Dowel coating damaged.

Except for the load on the plastic coated dowel from joint No. 6 the maximum load recorded for these dowels were about one quarter of that measured for the standard dowels. The maximum load on the standard dowels occurred at only about 0.02 in. movement. However, once this load was reached, the load decreased rapidly until the load recorded at 0.50 in. opening was attained. This suggests that the dowels "bond" to the concrete and once this resistance to movement has been overcome the load required to further open the joint decreases sharply.

The plastic coated dowel from joint No. 6 behaved almost like a standard dowel during testing. Later, when the block was opened it was dis-

Figure 10. Pull-out test equipment for dowel bars.

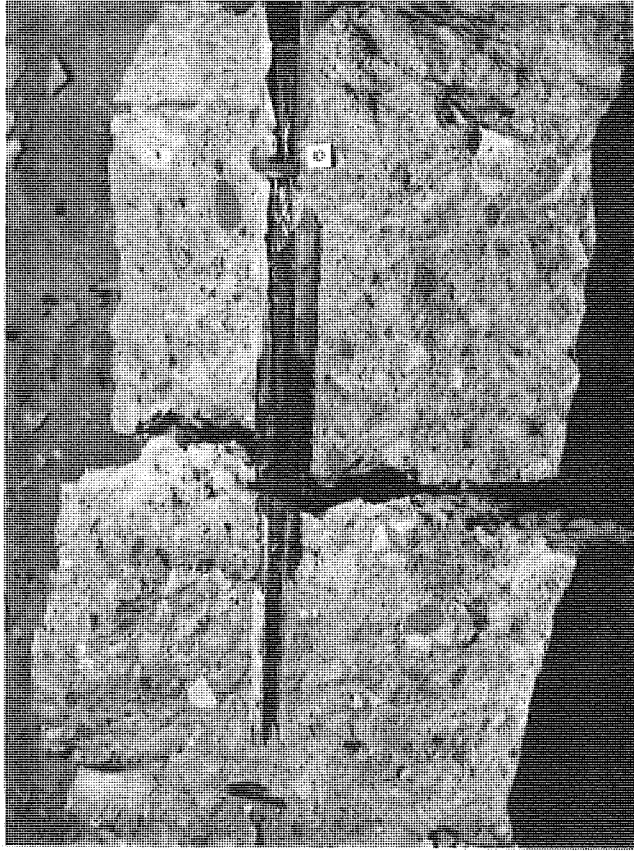
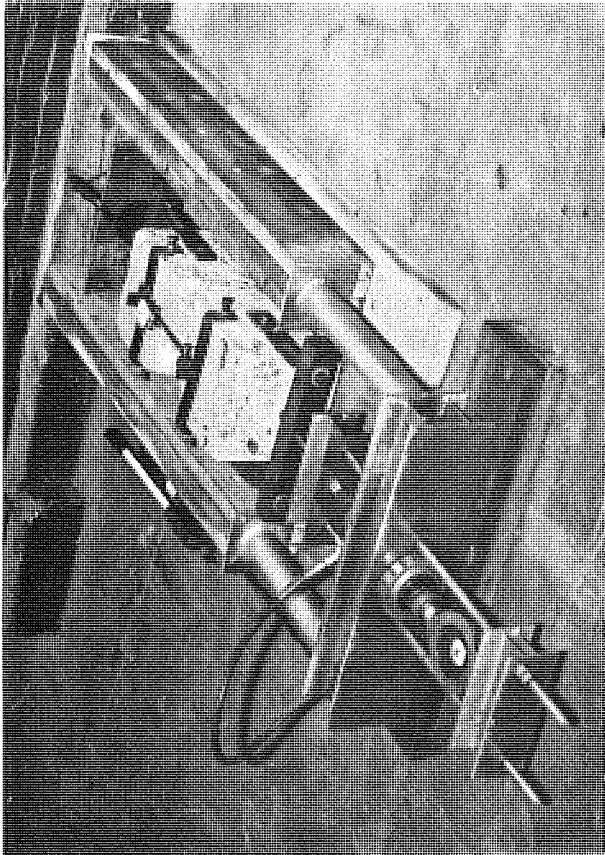
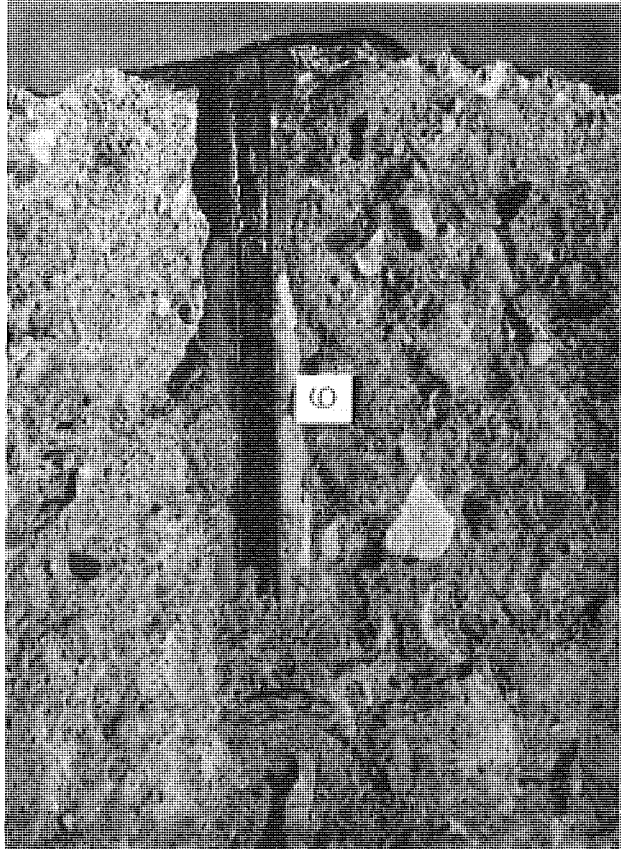


Figure 11. Damaged plastic coated dowel. The plastic coating was split the full length of bar.

Figure 12. Top half of block with damaged bar. Concrete was found to have filled the gap in the plastic coating indicating that the split had occurred prior to concrete pouring.



covered that the plastic coating had split and was open about $3/8$ in. for the length of the bar (Fig. 11). It was also noted that the movement had occurred between the bar and plastic coating rather than between the plastic and the concrete. The cause of the damage to the plastic coating is not known, but it was evident from the concrete removed from the dowel that the split had occurred prior to concrete pouring; the concrete having filled the gap in the coating (Fig. 12).

For the undamaged plastic coated dowels, the maximum load occurred at about 0.25 in. movement, and then remained at that value until the test was discontinued at 0.50 in. movement. Unlike the standard dowels, the plastic coated dowels do not appear to require a high initial load to induce movement. Examination of the exposed dowels showed that the movement in both cases had occurred partially between concrete and coating and between coating and bar. For the joint No. 9 dowel the concrete-plastic coating movement was $3/8$ in. and the coating-bar movement was $1/8$ in. and for the other dowel these same movements were $1/8$ and $3/8$ in., respectively (Fig. 13).

As noted in Table 1 the Acme dowels were not tested because the units came apart during handling. From the design of this type of load transfer device it is clear that the restraint of movement would be very little since the maximum engagement of the unit is only $1-1/2$ in. Figure 14 shows the male and female half of the sample removed from joint No. 24.

Transverse Slab Cracking

Transverse cracks in slabs longer than about 10 ft are expected to occur. In reinforced concrete slabs, the steel prevents the cracks from opening more than a few hundredths of an inch. As long as the steel is intact the cracks present no problem. However, when the steel fractures, the cracks open and are infiltrated by incompressible material which results in additional compressive forces in the pavement during expansion and contributes to joint failures.

The factors that cause transverse cracks include; initial concrete shrinkage, temperature and moisture changes, slab warping, loads, base conditions, and joint movement restraint. Aside from subbase friction, joint movements are restrained by the amount of force required to produce sliding of dowels in the concrete. As the restraint increases during the age of the pavement some of the joints freeze and this creates additional tensile stress in the steel which, in conjunction with corrosion, causes fracture of the steel. Since the Acme and plastic coated dowels offer little restraint

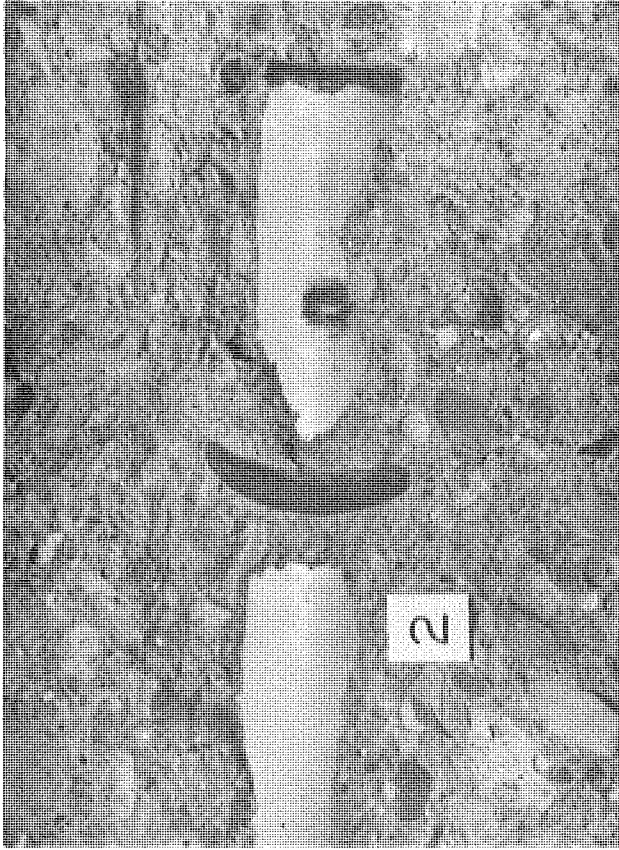
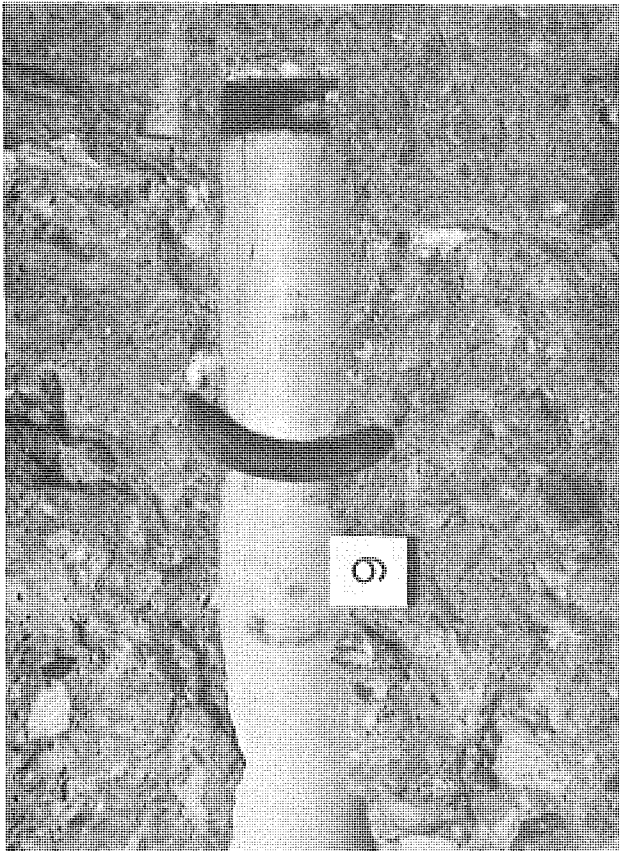


Figure 13. Movement of plastic coated dowels was found to take place both between concrete and plastic and between plastic and bar. Of the 1/2-in. movement the two bars were subjected to, 3/8 in. and 1/8 in. occurred between concrete and plastic (left) and (top right), respectively.

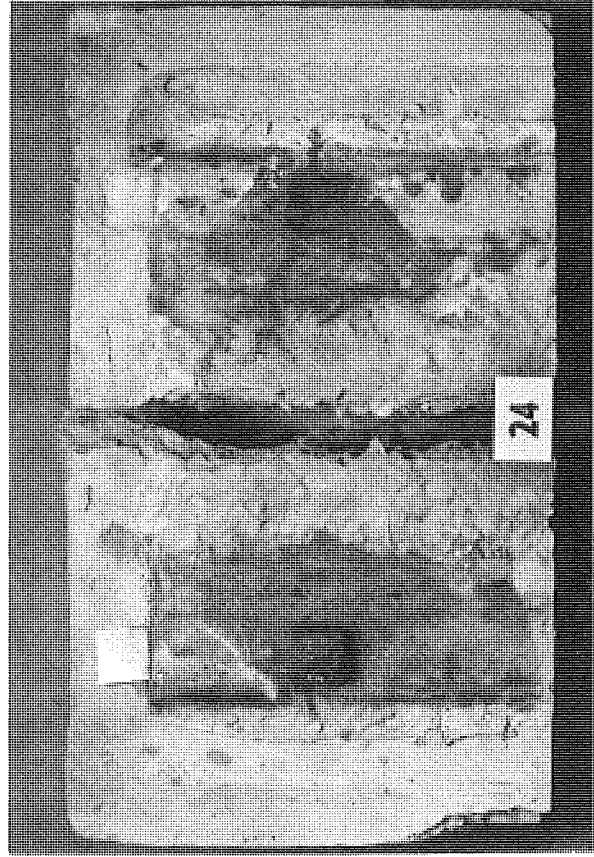


Figure 14. Condition of Acme dowel assembly as removed from pavement. Because of short engagement, the block came apart during handling and no pull-out tests could be conducted.

to movement compared to standard dowels, annual surveys are conducted to determine the effect of load transfer type on the cracking and eventual fracture of the reinforcement.

Figure 15 shows frequency distributions of the number of transverse cracks per roadway slab for the years 1970 through 1973 for each of the three test sections. Basically, the formation of cracks has followed the same pattern in each test section. After one year of traffic most slabs had no cracks. This has gradually changed during the past four years so that in 1973 there are only a few slabs without cracks. Presently, the number of slabs with two, three, and four cracks are about equal in each section. Although it is too early to make conclusions in regard to the effect of load transfer devices on slab cracking it appears that dowel restraint has little effect on slab cracking during the first few years of pavement life.

Joint Groove Spalling

The effect of joint groove spalling on the performance of load transfer devices is difficult to ascertain. Small shallow spalls that do not release the compression in the neoprene seals have little effect on the amount of moisture entering the joint. However, when spalls relieve the compression in the seal, moisture would have free access to the joint at the spall location and would probably accelerate corrosion of the dowels. Thus severe spalling could contribute to earlier freezing of the joints and the accumulation of rust on the dowels could possibly cause tensile failure spalls over the bars.

After four years of service the estimated average length of interior groove spall per joint was 10, 9, and 8 in. in the standard, Acme, and plastic coated dowel sections, respectively. The average spall length was 2 in., the average width $3/4$ in., and the average depth $1/2$ in. On the basis of the joint surveys, it appears that the amount of spalling that has occurred to date does not have any serious effect on the performance of the different types of load transfer unit.

Load Transfer

Nighttime load-deflection tests were conducted at three contraction joints in each of the experimental sections on December 4, 1969. The same three joints in each section were subjected to daytime tests on December 21, 1973. The change to daytime tests was made to eliminate the traffic hazards created by nighttime lane closures.

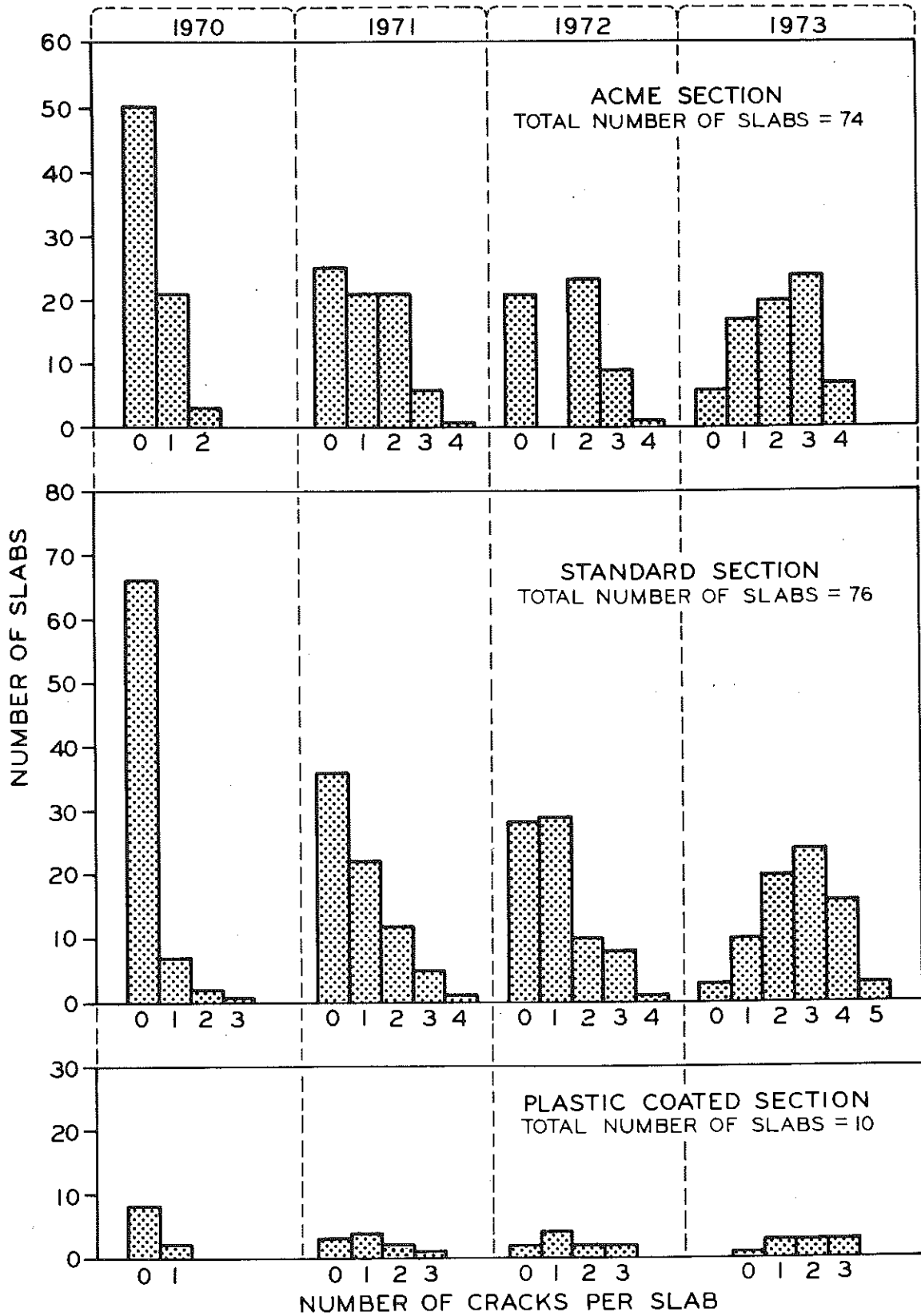


Figure 15. Frequency distribution of number of cracks per slab.

A single axle load of 18,000 lb was moved across the joint at creep speed with the outside tire being 12 in. from the pavement edge. Deflection measurements were made 2 in. each side of the joint centerline, 1 in. from the pavement edge, and three trials were made at each joint. The 1969 measurements were made with linear variable differential transformers and recorded on a Sanborn Oscillograph. In 1973, direct current differential transformers and a direct writing Brush recorder were used to measure the deflection.

The deflection measurements of the loaded and unloaded side obtained in each test section were averaged to obtain one value for each type of load transfer device. Figure 16 shows the average deflection across a joint of each type. The low values recorded for the daytime tests reflect the difference in warping condition of the pavement at the time the two tests were conducted.

The load-transfer effectiveness is defined as the ratio of the deflections of the unloaded side of the joint to the loaded side. As expected, and as can be seen on Figure 16, the unloaded side of the joints always deflected less than the loaded side which indicate none of the devices are 100 percent effective in transferring load. On the basis of the recorded deflections, the load transfer effectiveness of the standard assemblies have dropped from 94 percent in 1969 to 89 percent in 1973. The effectiveness of the Acme assemblies has declined from 94 percent to 77 percent during the past four years, whereas for the plastic coated dowels there was no change from the 83 percent obtained in 1969. The results indicate that the standard and plastic coated dowels are performing better with respect to load transfer than the Acme units.

Corrosion of Dowels

The dowels removed from the concrete sample blocks were examined for corrosion. Figure 17 shows the condition of the standard dowels; as can be seen, rusting has commenced. The affected portion of the bars was at the joint centerline and is about 1 in. long. The deepest penetration, 1/8 in., was measured on bar No. 30. A depth of 1/16 in. was measured on both bar Nos. 22 and 26.

The plastic coated dowels removed from joint Nos. 2 and 9 did not exhibit any signs of corrosion (Fig. 18). The plastic coating was stained in the joint crack area but was without creases or cracks. Figure 19 shows the bar removed from joint No. 6, where, as previously mentioned, the plastic coating had split prior to concrete pouring. As a result the bar had corroded in the joint crack area to a depth of 1/8 in.

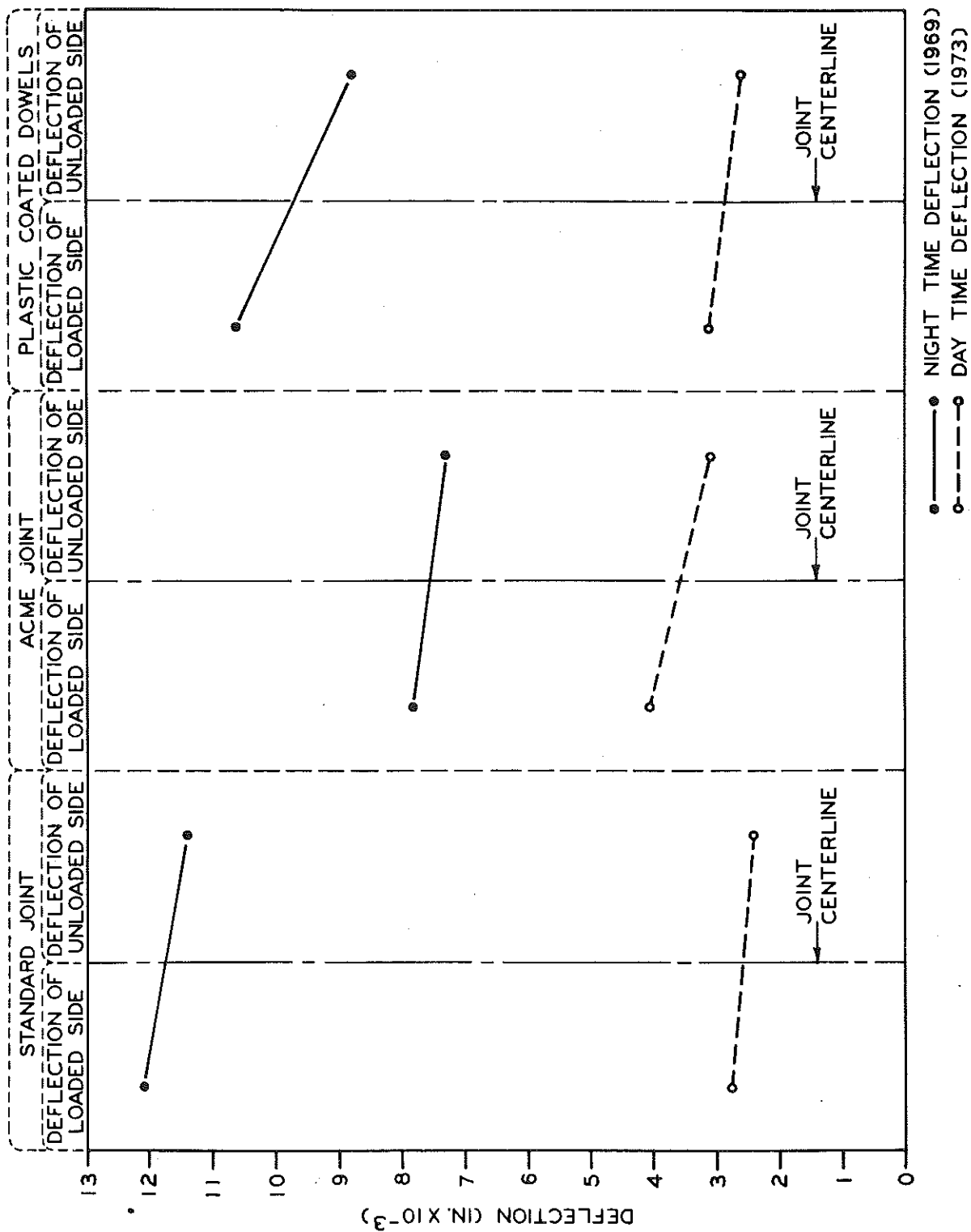


Figure 16. Deflection at joints in each test section.



Figure 18. Plastic coated dowels after four years service show no corrosion.

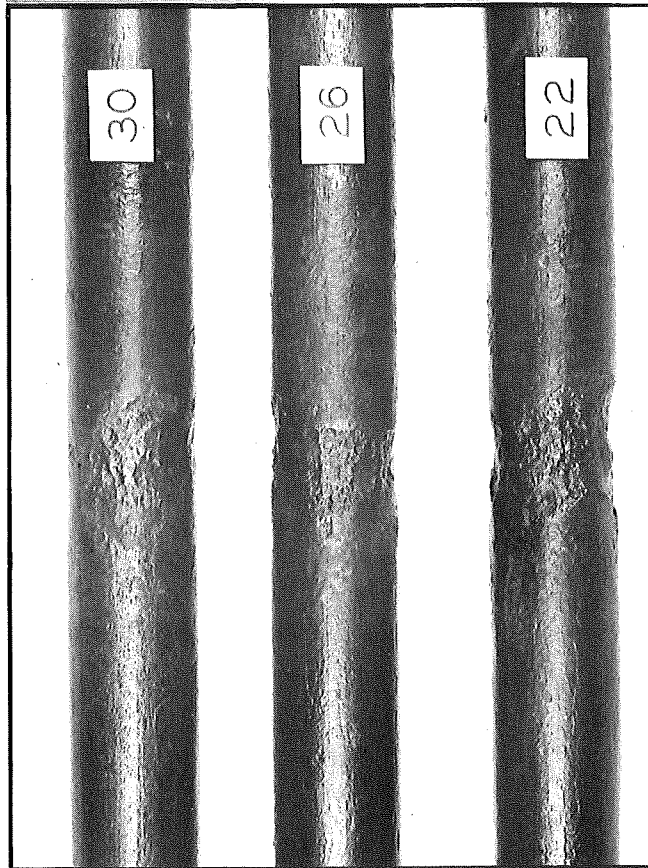


Figure 17. Corrosion of standard dowels after four years of service.

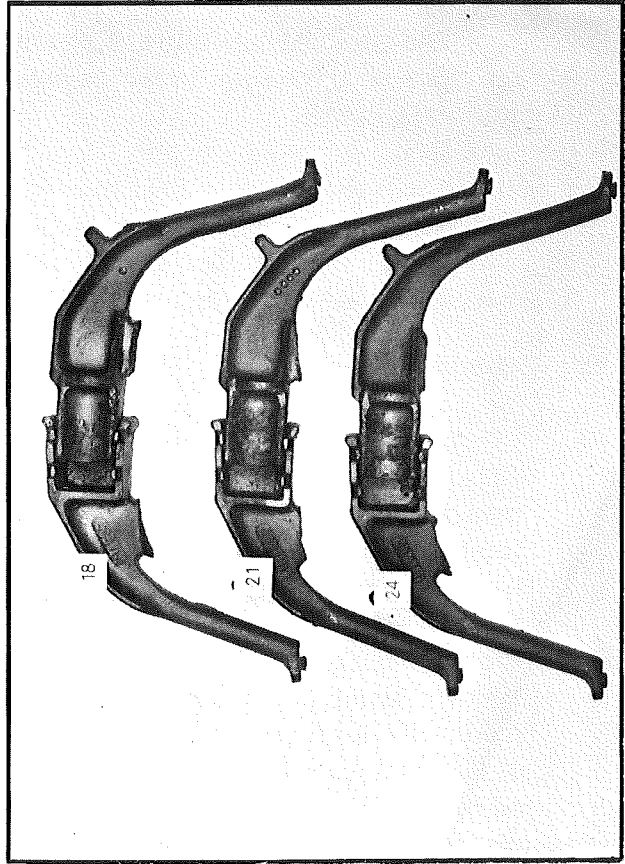


Figure 19. Plastic coated dowel with damaged coating shows corrosion in joint crack area.

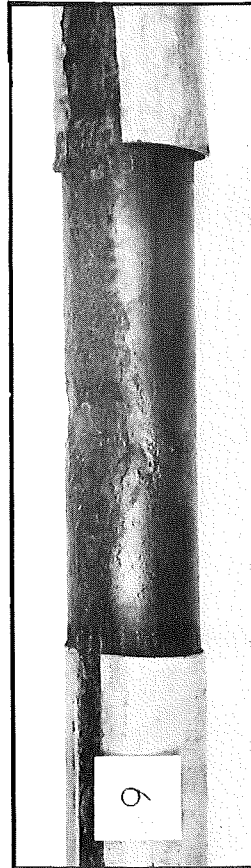


Figure 20. Acme dowel units show very little corrosion compared to standard dowels after equal length of service.

The three Acme units are shown in Figure 20. Although each unit showed signs of corrosion in the engagement area, the loss of metal by rusting was very small.

From the result of the corrosion examination, it appears that quite extensive corrosion occurs in standard dowels, Acme units corrode to a good deal lesser extent, and plastic coated dowels with undamaged coating do not corrode at all after four years of service.

Conclusions

After four years of service there is not sufficient evidence to make definite conclusions as to which load transfer device gives the best performance. With respect to joint movement, transverse crack formation, and joint groove spalling the three load transfer types appear to be about equal in performance. The pull-out tests indicate that Acme assemblies offer least resistance to movement and standard assemblies require the greatest force to initiate joint movements. Assemblies with plastic coated dowels require about one-fourth of the force of a standard assembly. From the load-deflection test results it appears that the load transfer effectiveness of the standard assembly is best, followed by the assembly with plastic coated bars, and the Acme assembly showing the poorest performance. The plastic coated dowels with undamaged coating did not show any sign of corrosion, whereas the Acme devices were showing some evidence of rusting and the standard dowels exhibited extensive corrosion.