Performance Monitoring of Joint Load Transfer Restoration

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The most comprehensive load transfer restoration experiment currently in service was constructed on Interstate 10 near Tallahassee, Florida, in 1986. The performance of this experiment has been monitored continuously by the University of Illinois and the Florida Department of Transportation between 1986 and 1992. Fourteen different load transfer restoration treatments were studied. Retrofit dowel factors studied included number of dowels per wheelpath, dowel length, and dowel diameter. Double-V shear device factors studied included core wall grooving and number of devices in the outer and inner wheelpaths. The results of condition surveys, faulting surveys, and falling weight deflectometer deflection load transfer testing of the project are reported. All of the treatments were effective in limiting faulting increases to much lower levels than the faulting increases of the control sections. In addition, they all improved deflection load transfer significantly, and after 5 years in service, deflection load transfer percentages are still similar to initial postconstruction values. The only poor aspect of the project's performance is slab cracking in the vicinity of many retrofit dowels, which appears to be the result of a combination of construction, materials, and climatic factors.

Many jointed concrete pavements have been constructed without mechanical load transfer devices (e.g., dowels) across joints, and significant faulting has occurred on some of these pavements as a result of poor load transfer. Many other jointed concrete pavements have been constructed with dowels, but under heavy traffic the dowels may become loose and significant faulting may result. Transverse cracks in concrete pavements often deteriorate because of poor load transfer.

In an effort to extend the service lives of concrete pavements that exhibit poor load transfer and faulting at joints and cracks, highways agencies have used various devices to restore load transfer. These devices include retrofitted dowels, double-V shear devices, figure-eight devices, and miniature I-beam devices. The devices sometimes are placed in all traffic lanes and sometimes in only the most heavily trafficked (outer) lane. Load transfer restoration is often, but not always, done in conjunction with diamond grinding to remove existing faults at joints and cracks.

The effectiveness of load transfer restoration may be assessed by monitoring the performance of rehabilitated joints and cracks. This monitoring includes measurement of faulting and measurement of deflection load transfer with a heavy-load deflection device such as the falling weight deflectometer (FWD). In addition, condition surveys are useful for identification of device failure and assessment of future maintenance needs.

Previous field studies have demonstrated the ability of retrofit load transfer devices to improve deflection load transfer and thereby delay the recurrence of faulting (*1*). However, very few well-designed field experiments that examine a variety of devices and configurations (i.e., number and layout of devices) are in service on jointed concrete highway pavements. Such experiments are extremely valuable in assessing the performance and cost-effectiveness of pavement rehabilitation techniques such as load transfer restoration.

PROJECT DESCRIPTION

The most comprehensive load transfer restoration experiment currently in service was constructed on Interstate 10 near Tallahassee, Florida, in the fall of 1986. The statistically designed experiment was the result of a collaboration between the Florida Department of Transportation (DOT), the Civil Engineering Department of the University of Illinois at Urbana-Champaign under contract to FHWA, and the Dayton Superior Corporation.

The Florida DOT provided the location and construction control and conducted annual FWD testing and faulting surveys. The University of Illinois provided the experimental design and also conducted faulting surveys, visual performance ratings, and data analyses. Dayton Superior provided the load transfer devices, backfill materials, and some of the specialized equipment required for installation. Other pavement restoration operations done in conjunction with the load transfer restoration were slab replacement, slab undersealing, edge drain installation, and joint resealing. Diamond grinding was not done. The rehabilitation work was done between September and December 1986.

Faulting and deflections at joints on the experimental load transfer restoration project on I-10 have been monitored by the University of Illinois and the Florida DOT between 1986 and 1991 (*2*). This paper presents the results of the analyses of the performance data collected and summarizes the performance of the load transfer restoration experiment. This project offers a rare opportunity for longitudinal study of the progression of faulting and load transfer, which is essential to assessing the long-term performance and cost-effectiveness of this rehabilitation technique.

Project Site

The I-10 experimental project is located on Interstate 10 in Gadsen County, Florida, about 32 to 48 km (20 to 30 mi) east

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of Tallahassee. The project begins at milepost 172 and extends eastward about 0.8 km (0.5 mi). The region has a wet, nonfreezing climate.

The pavement is a 22.9-cm (9-in.) jointed plain concrete pavement on a cement-treated subbase. The subgrade is predominantly silty gravel or sand (AASHTO classification A-2-4), with clay (A-6) and silty gravel or sand backfill (A-2-4) in some locations. The joints were originally constructed without dowels. The joint spacing is 6.1 m (20 ft). The pavement was constructed with asphalt concrete shoulders and without longitudinal edge drains.

The pavement was opened to traffic in November 1978. Between that time and the time of rehabilitation in 1986, the pavement carried approximately 6 million 18-kip (8.1 metric ton) equivalent single-axle loads (ESALs) in the outer traffic lane. Between 1986 and 1991, the pavement carried approximately 7.5 million ESALs.

Load Transfer Device Test Sections

The project was divided into 14 test sections completely replicated in each direction (eastbound and westbound). Each test section consists of nine joints, so a total of 126 joints in each direction are contained in the test sections. Control sections of nine joints each also exist at the beginning and end of the project in each direction. Eight different retrofit dowel configurations and six different precompressed shear device configurations were used. A diagram of the test section layout is shown in Figure 1. The dowel and shear device factorials are shown in Figure 2. Details of the construction activities were provided previously (*2–4*).

The retrofit dowels were fitted with expansion caps on one end, mounted on chairs in parallel slots sawed across the joints, and backfilled with a concrete patching material (tradename HD-50) supplied by Dayton Superior. The positions of the retrofit dowels across the traffic lane for the different configurations are illustrated in Figure 3.

The primary components of the LTD + Plus double -V shear device are two v-shaped plates of stainless steel, welded together and flanged. The interior of the device is filled with polyurethane foam, and the double-V's are wrapped in polyvinyl foam. The double-V's are aligned with the transverse joint to permit horizontal movement of the slabs. The positions of the shear devices across the traffic lane for the different configurations are illustrated in Figure 4.

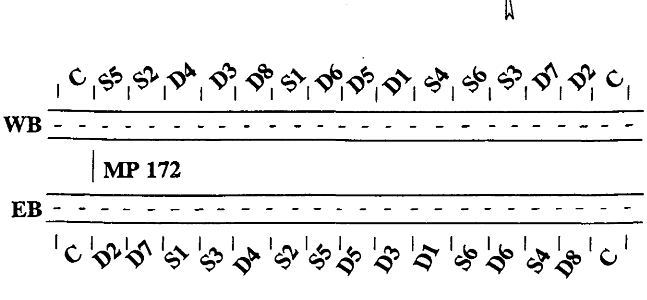

FIGURE 1 I-10 load transfer restoration test section layout.

DOWEL DEVICE FACTORIAL

No. of Dowels In Wheelpath	Three		Five	
Dowel Length (in)	14	18	14	18
Dowel Diameter (in)				
1.0	D1	D5	D2	D6
1.5	D3	D7	D4	D8

1 in = 2.54 cm

SHEAR DEVICE FACTORIAL

Grooving of Core Walls	No		Yes	
No. of Devices In Inner Wheelpath	1	2	1	2
No. of Devices In Outer Wheelpath				
2	S1	S2	S4	S5
3	--	S3	--	S6

FIGURE 2 Retrofit dowel and shear device factorials.

Installation Costs

The following low bid prices were obtained for the dowel and shear device materials and installation:

Device	*1986 Cost ($)*
Dowel	62.00
Shear device	65.00

Device	*1986 Cost per Lane-Kilometer (164 joints) ($)*	*1986 Cost per Lane-Mile (264 joints) ($)*
Dowels		
10 per joint	101,709	163,680
6 per joint	61,025	98,208
Shear devices		
5 per joint	53,315	85,800
4 per joint	42,652	68,640
3 per joint	31,989	51,480

PERFORMANCE MONITORING

Comparison of 1988 and 1991 Survey Results

Examination of past survey results indicate that the retrofit dowels and shear devices exhibited very little distress from the time of construction through 1988. At the time of the 1988 survey, the major distress affecting the retrofit dowels was multiple hairline cracks in the dowel backfill at many locations. Several of these cracks, spaced an inch or more apart, ran across the dowel slot, parallel to the transverse joint.

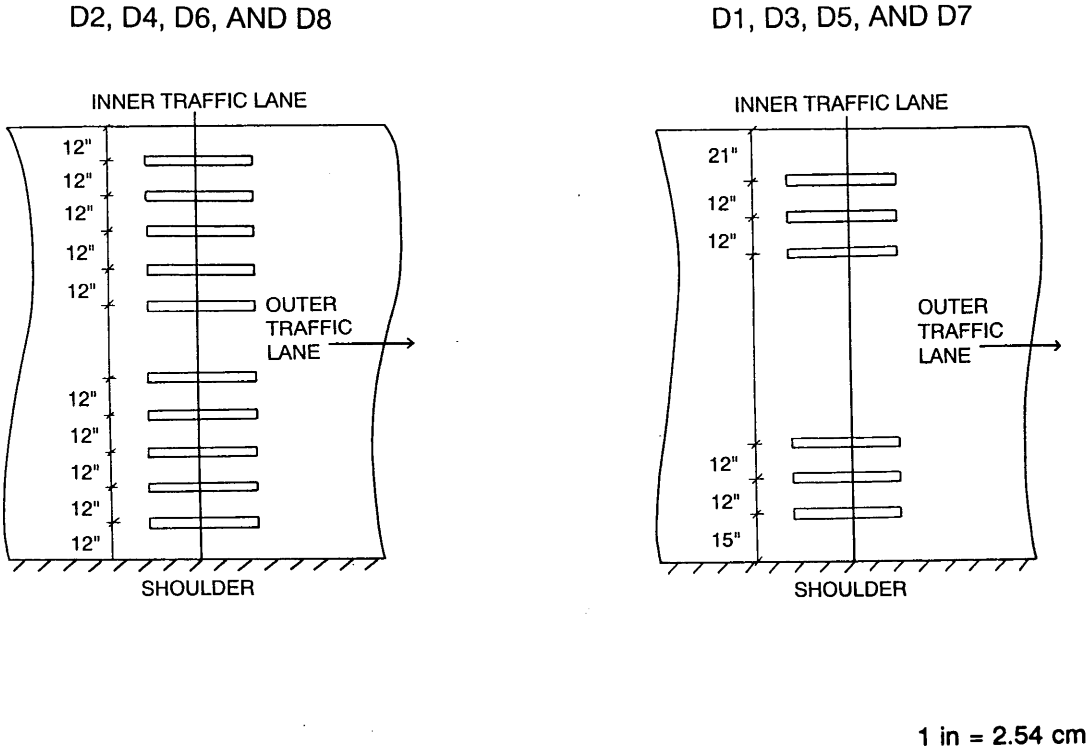

FIGURE 3 Retrofit dowel layouts.

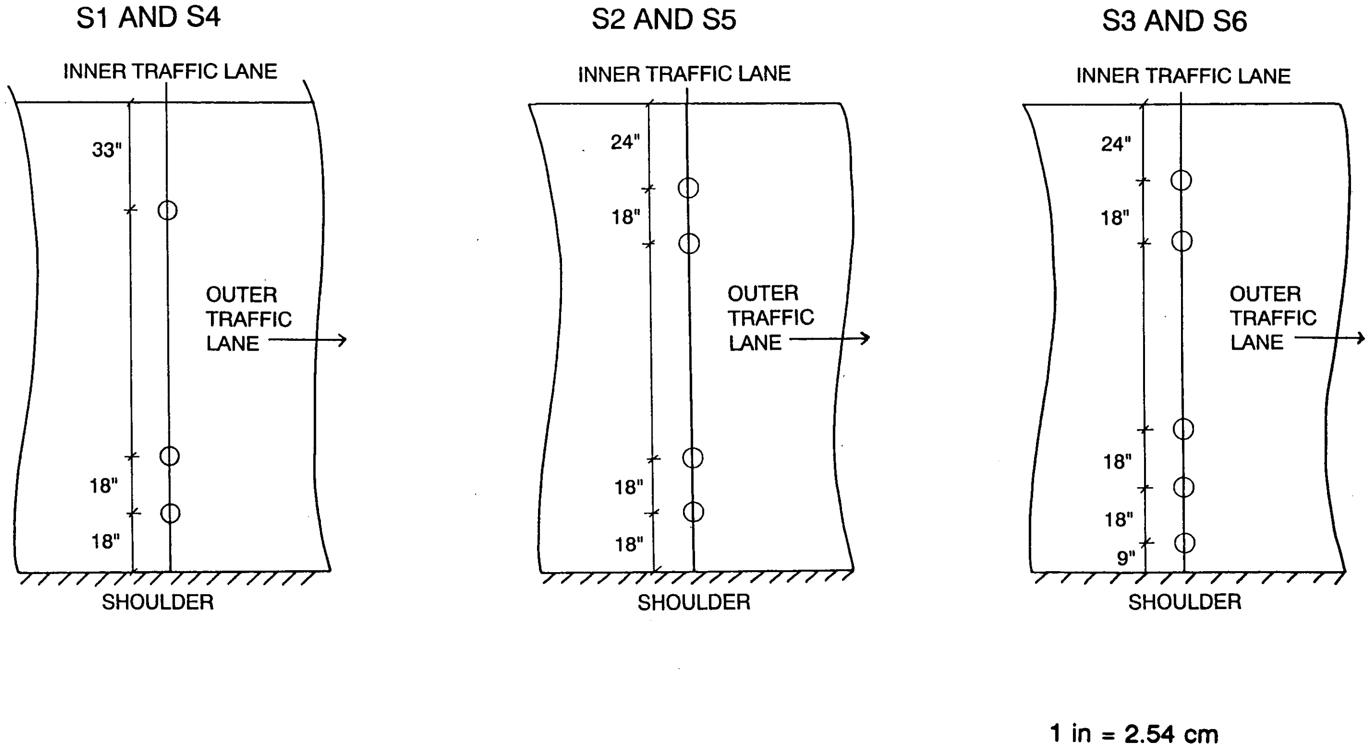

FIGURE 4 Shear device layouts.

These hairline cracks in the dowel backfill were visible during the field survey but were so fine that they are difficult or impossible to see in almost all of the photographs taken at dowel locations in the University of Illinois' (UI) 1988 survey. Neither the field notes nor the photographs from the 1988 UI survey show significant cracking of the slab between the dowel slots or emanating from the dowel slots, although hairline cracks between dowel slots are visible in a few photos.

Between 1988 and 1991, however, the project developed considerable distress, particularly at the retrofit dowels. At many locations, a series of horizontal cracks was observed between the dowel slots, parallel to the joint. Often one or more cracks ran along the side of a dowel slot, and from there extended back into the slab. Some of these slab cracks extended straight from the dowel slot, parallel to the wheelpath, but most of the slab cracks that emanated from dowel slots run diagonally across the slab and intersected the lane edge a few feet from the transverse joint. This type of cracking occurred at dowel installations in both wheelpaths of the traffic lane.

Figure 5 shows Joint 9 in the eastbound D7 test section in 1988 (*top*) and in 1991 (*bottom*). The cracking, which is barely visible in 1988, reached medium severity by 1991.

In the 1988 survey, the most noticeable distress at shear device installations was cracking or spalling in the backfill of about a half dozen of the shear devices. At one device the top inch or more of backfill was spalled out and the metal of the shear device was visible. As noted in the previous section, some shear device installations also had slab cracks emanating from the edge of the core hole. These also developed sometime after the 1988 survey.

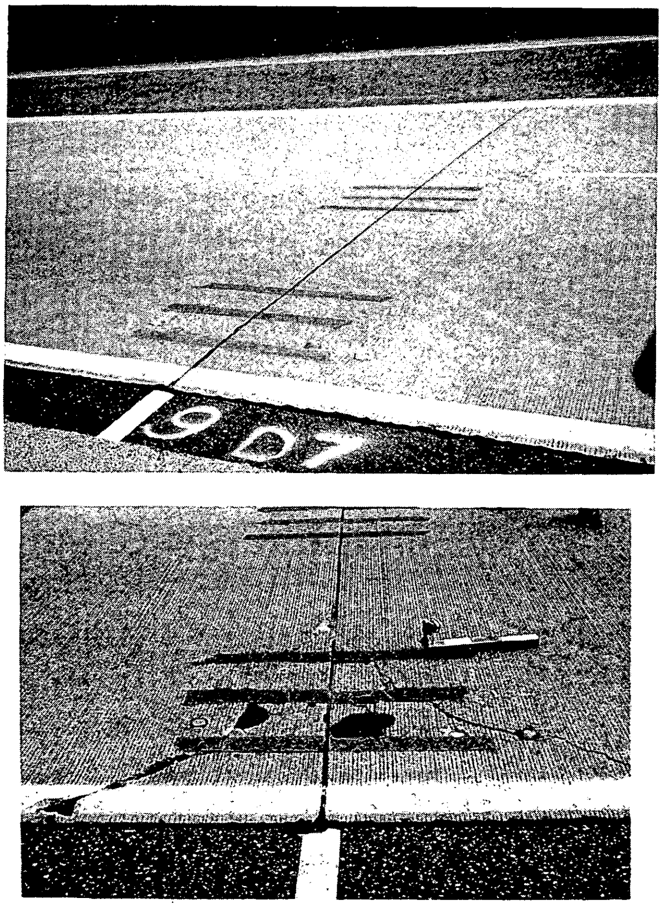

FIGURE 5 Cracking at D7 dowel section, Joint 9 eastbound, 1988 (*top*) and 1991 (*bottom*) surveys.

1991 Condition Survey Results

The number of joints in each section affected by slab cracking or device distress in 1991 is illustrated in Figure 6. For most of the retrofit dowel sections, the slab cracking in the vicinity of the retrofit dowels is more prevalent and more severe in the eastbound direction than in the westbound direction. A striking contrast, for example, is seen between the eastbound and westbound D7 sections. All nine of the eastbound D7 joints have cracking, and this cracking was rated medium or high severity at seven of the nine joints. None of the westbound D7 joints have any cracking. It is worth noting that the eastbound D7 section was one of the first test sections to be constructed (see the test section layout in Figure 1).

For the three shear device treatments without core wall grooving (S1, S2, and S3), slab cracking or device distress is more prevalent in the westbound sections than in the eastbound sections. For the remaining three shear device treatments, the distress levels in the two directions were very similar.

Slab cracking is not limited to the retrofit dowels: a few shear devices also have cracks emanating from their core holes straight back into the slab or diagonally to the slab edge. However, the more prevalent distresses at shear devices were sealant failure, debonding, cracking, or spalling of the backfill on one or both sides of the joint, and/or device failure (broken metal). A total of 18 shear devices in the eastbound direction (18 of 216 total, or 8 percent) and 20 shear devices in the westbound direction (9 percent) showed some distress.

Possible Causes of Retrofit Dowel Distress

Two hypotheses are suggested for the cause of the slab cracking at the retrofit dowels on the Florida I-10 project. One hypothesis is that the dowels are locked up, preventing joints from opening in response to falling temperatures. This would cause high tensile stresses in the dowel backfill material and the surrounding concrete slab.

Two factors point to the likelihood of dowel lock-up as the cause of the cracking. The first factor is the frequent occurrence of cracking at dowel installations in both wheelpaths, which suggests that whatever is causing the cracking is acting across the full slab width, and not just at the outer slab edge. This would be true of longitudinal contraction caused by falling temperatures. However, if the cracking were caused by corner deflections and nonuniform support, one would expect the cracking to be confined largely to the outer wheelpath.

The second factor is the likely decrease in ambient temperatures during construction. The test sections were constructed sequentially, beginning at the west end of the eastbound lane in late September, when daytime temperatures were about 26°C (80°F) and nighttime temperatures were in

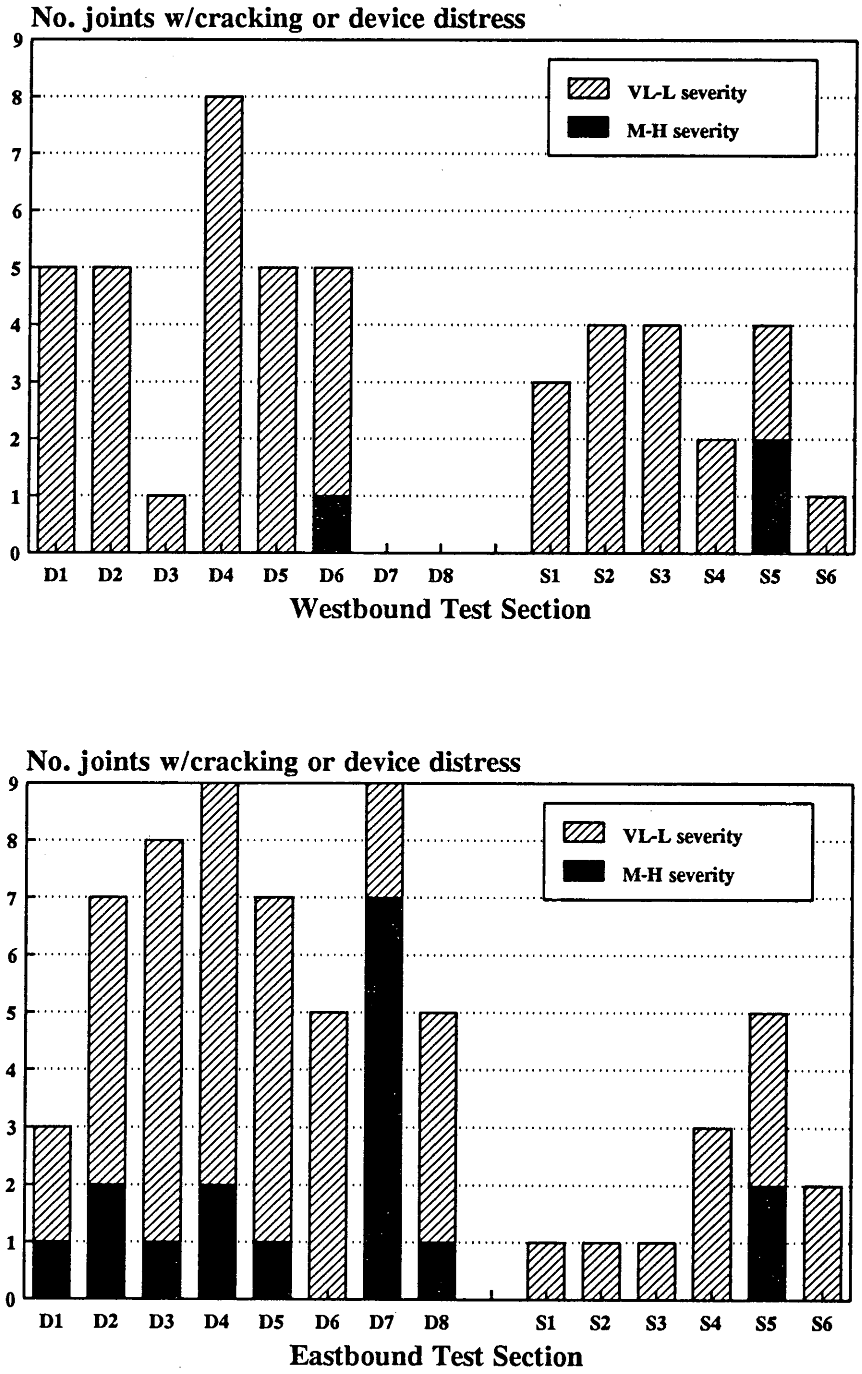

FIGURE 6 Number of joints with slab cracking or device distress.

the range of 10°C to 15°C (50°F to 60°F). Construction of the eastbound sections continued in order, followed by the westbound sections. Construction of the last westbound test sections was completed around mid-December.

It is likely that ambient daytime temperatures were lower during the westbound construction and that, as a result, the joints were open wider when the dowels were installed, and thus lower tensile stresses were induced in the backfill and slabs by further slab contraction in January. This suggestion is consistent with the greater extent and severity of cracking in the eastbound sections than in the westbound sections.

Dowel lock-up, if it occurred, may have been caused by development of bond between the backfill material and the epoxy-coated dowels. A thin coating of motor oil or some other lubricant is typically used on retrofit dowels to prevent the backfill material from bonding to the dowel. Because the dowels were epoxy coated and because the HD-50 backfill was a high-strength patching material (mean flexural strengths of 3238 kPa (470 psi) at 2 hr, 4134 kPa (600 psi) at 24 hr, and 9646 kPa (1,400 psi) at 28 days (R. E. Nelson and G. O. Schumacher, personal communication, 1986), a relatively strong bond could have developed between the two since no bondbreaker was used.

Dowel misalignment may also have played a part in locking up the transverse joints. Either the dowel slots or the dowels themselves may have been misaligned, so that the dowels were not positioned parallel to each other and perpendicular to the transverse joint, within the tolerances specified. This would explain the particularly badly deteriorated joints in the eastbound direction where construction started—where the dowel slots were marked individually, before the contractor started using a template to mark all the dowel slots together. However, the same type of cracking is evident, albeit at lower severities, in the westbound lane where the template was used.

A second hypothesis is that high tensile stresses could have developed from a combination of heavy traffic loads, curling at the corners, and the presence of either voids or a nonuniform and stiff grout beneath the slab corners. Stresses in the corner region of the slab under truck wheel loads may be dramatically increased by the presence of the dowel slots, and the corners of the dowel slots may become points of stress concentration.

The slab cracking at retrofit dowels, which appears to have occurred throughout the project, may have been caused by either a combination of the two mechanisms described above, or by some other unknown cause. It is important to note that this type of distress is not typical of retrofit dowels (*1*). It is strongly recommended that some deteriorated dowel installations be removed for further inspection.

Faulting Survey Results

Since diamond grinding was not done on this product, the effectiveness of the load transfer restoration must be measured not in terms of actual faulting measurements, but rather by increases relative to initial faulting measurements. Preconstruction faulting measurements were taken on all joints, using a faultmeter provided by the University of Illinois. This same device has been used for several previous studies, including the NCHRP 1-19 (COPES) study (*5*), and an FHWA study of diamond grinding, retrofit load transfer, and other rehabilitation techniques in several states (*1*). A description of the faultmeter and its use was given previously (*4*).

The initial faulting data taken in 1986 represent the average of two to four readings taken at each joint 30.5 cm (12 in.) from the edge. Joint faulting varied considerably along the project (coefficients of variation were 60 and 62 percent, respectively), and the eastbound average faulting was higher than the westbound average [0.262 cm versus 0.221 cm (0.103 in. versus 0.087 in.)].

Subsequent joint faulting measurements were taken by UI personnel in April 1987, November 1987, November 1988, and October 1991. As before, the faulting value obtained for each joint was determined from two to four readings. For each individual joint, the increase in faulting was determined by subtracting the fault measurement obtained from the preconstruction (October 1986) fault measurement. For each test section, the average faulting was determined by averaging the faulting measurements for the nine joints in the test section, and the average increase in faulting was determined by averaging the fault increases for the nine joints in the test section.

The percent change in average faulting between 1986 and 1991 is illustrated in Figure 7. The 50 percent change for control joints represents the average for all joints in the project's four control sections (36 joints total). The percent changes shown for the various load transfer treatments represent the average of the percent changes for the treatment sections in both directions (18 joints total). The percent change in control section faulting has been much greater than that in any of the load transfer treatments.

Figure 8 illustrates the effects of the retrofit dowel factors and shear device factors studied on faulting performance. In each category the percent change in faulting is much less than the 50 percent change in control section faulting.

The number of dowels does not appear to have been significant: sections with three dowels per wheelpath (D1, D3, D5, and D7) and sections with five dowels per wheelpath (D2, D4, D6, and D8) both had similarly small increases in faulting.

Figure 8 suggests that dowel length may have been significant: the average faulting change of sections with 45.7-cm (18-in.) dowel bars was positive, whereas the average faulting change of sections with 35.6-cm (14-in.) dowel bars was negative. However, these results were actually mixed by section. Of the treatments with 35.6-cm (14-in.) dowels (D1, D2, D3, and D4), one of four showed a percentage increase in mean faulting, and two of four showed a positive average increase in faulting. Similarly, of the treatments with 45.7-cm (18-in.) dowels (D5, D6, D7, and D8), two of four showed a percentage increase in mean faulting and two of four showed a positive average increase in faulting.

The most significant factor in retrofit dowel faulting performance appears to have been dowel diameter. All of the sections with 2.5-cm (1-in.) dowels (D1, D2, D5, and D6) showed a percentage increase in mean faulting and a positive average increase in faulting. All of the sections with 3.8-cm (1.5-in.) dowels (D3, D4, D7, and D8) showed no positive percentage increase in mean faulting, and only D3 showed a slight positive average increase in faulting.

Grooving of the core walls does not appear to have been significant: neither the sections without grooved core walls (S1, S2, and S3) nor the sections with grooved core walls (S4, S5, and S6) showed an overall average percentage increase in faulting. In each group, one treatment (S1 and S4, respectively) showed slight faulting increases, and the other two treatments (S2 and S3 and S5 and S6) did not show positive changes.

Of the three shear device patterns used, the only one to show an increase in faulting was the weakest pattern (two devices in the outer wheelpath and one in the inner wheelpath for S1 and S4). Both of the other patterns (two devices in each wheelpath for S2 and S5 and three devices in the outer wheelpath and two in the inner wheelpath for S3 and S6) showed no positive increases in mean faulting.

Deflection Survey Results

Deflection testing and deflection data analyses were conducted by the Florida DOT before and after installation of

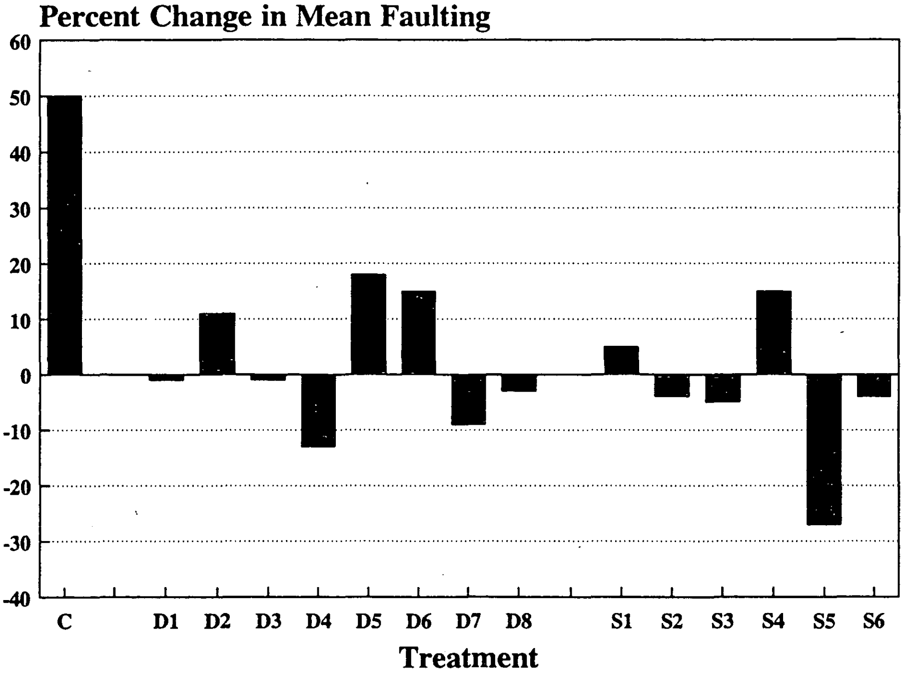

FIGURE 7 Percent change in mean faulting of control sections and load transfer and restoration treatments.

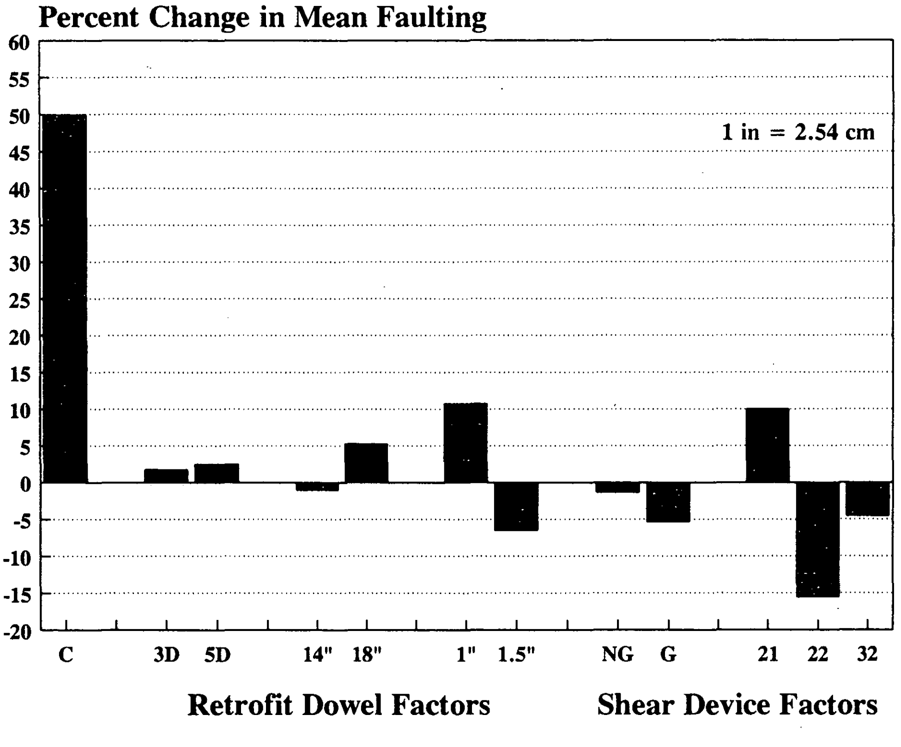

FIGURE 8 Effect of retrofit dowel and shear device factors on faulting.

the load transfer devices, using an FWD. The deflection testing was typically done between the hours of 11:30 p.m. and 2:30 a.m. when slab temperature gradients were low (*6*). The load plate used for testing was 30 cm (11.8 in.) in diameter, with a deflection sensor at the center of the load plate, 30.5 cm (12 in.) behind the load plate, and 30.5, 61, 91.5, 122, and 152.5 cm (12, 24, 36, 48, and 60 in.) ahead of the load plate. For the purpose of joint load transfer measurement, the FWD load plate was centered in the outer wheelpath approximately 30.5 cm (12 in.) from the longitudinal slab edge, with the edge of the plate close to the transverse joint, so that the joint was approximately midway between the load plate sensor and the sensor 30.5 cm (12 in.) behind the load plate sensor.

The deflection load transfer efficiency of each joint was computed from the ratio of the deflection on the unloaded side to deflection of the loaded side. Before installation of the dowels and shear devices, load transfer was very poor (less than 10 percent in most sections) throughout the project. The retrofit dowels improved load transfer substantially: up to 50 to 80 percent. More than 50 percent generally would be considered good load transfer, and more than 70 percent generally would be considered very good load transfer. The shear devices achieved smaller increased in load transfer: up to 20 to 55 percent, which might be considered fair to poor.

Deflection testing was conducted again by the Florida DOT in early 1992. The load transfer efficiencies of the various test sections are compared with the load transfer efficiencies in 1986 in Figure 9. In general, the results are similar.

The load transfer efficiencies of most of the retrofit dowel sections in 1992 are within 15 percent of their 1986 values. Most of the westbound dowel sections actually have higher mean load transfer efficiencies now, whereas most of the eastbound dowel sections have lower load transfer efficiencies now. In one eastbound dowel section (D7), joint load transfer measurements were not taken, presumably because of excessive joint deterioration.

Dowel length does not appear to have any significant effect on load transfer efficiency: pairwise comparisons of sections in each direction with 35.6-cm (14-in.) versus 45.7-cm (18-in.) dowels show similar results in most cases. The number of dowels has some significance: pairwise comparisons show that in most cases, sections with five dowels per wheelpath have slightly higher load transfer efficiencies than sections with three dowels per wheelpath. An exception to this is D5 (three dowels) versus D6 (five dowels). In both directions the D5 section has a slightly higher mean load transfer efficiency than the D6 section. Dowel diameter also appears to be significant: in most cases in both directions, the section with 3.8-cm (1.5-in.) dowels has higher load transfer than the section with 2.5-cm (1-in.) dowels. An exception is eastbound D2 [2.5-cm (1-in.) dowels], which has higher load transfer than eastbound D4 [3.8-cm (1.5-in.) dowels].

The load transfer efficiencies of most of the shear device sections in 1992 are within about 10 percent of their 1986 values. Two eastbound sections (S2 and S5) appear to have dropped to fairly low load transfer levels (less than 20 percent). Sections without grooved core walls do not have significantly different load efficiencies than corresponding sections with grooved core walls. In the westbound direction, the load transfer efficiency improves with increasing number of devices: Sections S1 and S4 (2/1 device pattern) have the lowest load transfer levels, Sections S2 and S5 (2/2 device pattern) have higher load transfer, and Sections S3 and S6 (3/2 device pattern) have the highest load transfer. This trend is not repeated in the eastbound direction, however. The 2/2 pattern actually shows the lowest load transfer. It is interesting to note that the trend of higher load transfer with more devices was present in both directions, for both grooved and nongrooved core walls, initially after construction.

Figure 10 illustrates sample load versus deflection plots for representative joints in two dowel sections and two shear sections. The dowelled joints show lower deflections at each load level than the shear joints. Between the two dowelled joints shown, the joint with 3.8-cm (1.5-in.) dowels shows lower deflections than the joint with 2.5-cm (1-in.) dowels. Between the two shear device joints shown, the one with three devices in the outer wheelpath shows lower deflections than the one with two devices in the outer wheelpath.

The trends illustrated in Figure 10 are typical of the load-versus-deflection behavior of joints throughout the project, although there is significant variation from joint to joint within each test section. In general, joints with 3.8-cm (1.5-in.) dowels had about 30 percent lower corner deflections than joints with 2.5-cm (1-in.) dowels. Other retrofit dowel factors did not have any significant effect on corner deflections. Overall, dowelled joints had about 30 percent lower corner deflections than joints with shear devices. Joints with 3.8-cm (1.5-in.) dowels had about 38 percent lower corner deflections than joints with shear devices.

CONCLUSIONS

Condition Results

This pavement section was in very good condition for the first 3 years after installation of the load transfer devices in 1986. Sometime between 1988 and 1991, a considerable amount of cracking developed, mostly at joints with retrofit dowels. This cracking may have been caused by stress concentrations at dowel slot corners or by joint lock-up as a result of a lack of bondbreaker, dowel misalignment, or some other cause. The eastbound direction has many deteriorated joints that must be repaired, and the westbound direction has many joints with lower-severity cracking that is expected to deteriorate in the future.

The deterioration of the retrofit dowel installations, which is not at all typical of retrofit dowel behavior on other projects, has greatly reduced the performance life of the load transfer restoration work. Further investigation of the causes of the dowelled joint deterioration is strongly encouraged.

Faulting Results

All of the load transfer restoration treatments investigated in this project were effective, in combination with undersealing and edge drain retrofitting, in limiting faulting increases to much lower levels than the faulting increases of the control

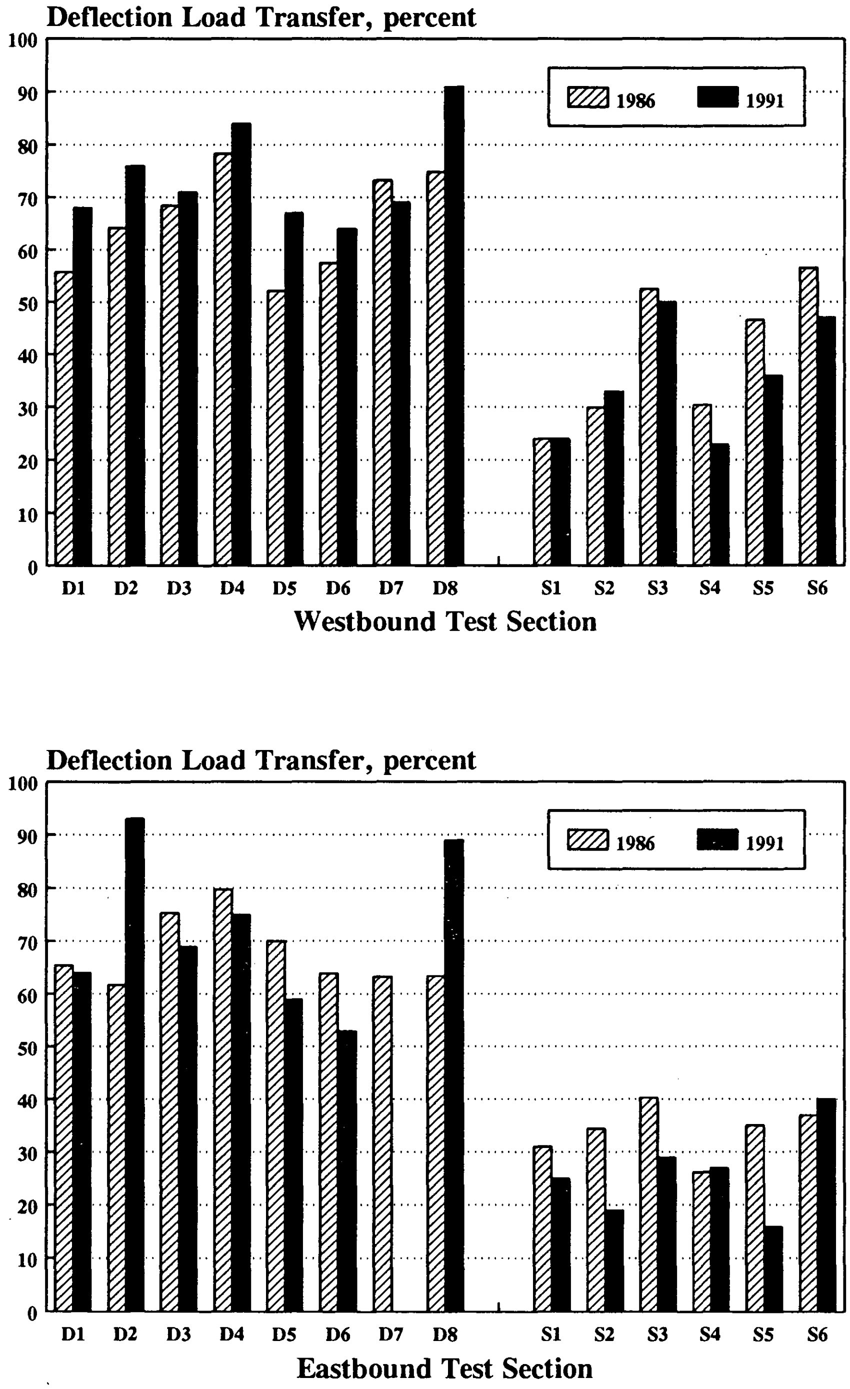

FIGURE 9 Comparison of 1986 and 1991 delection load transfer efficiencies in test sections.

sections. Several sections actually showed a negative change in faulting from 1986 to 1991, which, within the range of random variation, may be interpreted for practical purposes as prohibiting any increase in faulting. In addition, faulting was not measured at joints that were deteriorated enough to prohibit a valid faulting measurement.

Three dowels per wheelpath and five dowels per wheelpath performed equally well in terms of faulting. Dowel length had mixed results on faulting. Dowel diameter appeared to significantly affect faulting: sections with dowel bars 2.5 cm (1 in.) in diameter showed increases in faulting, whereas sections with dowel bars 3.8 cm (1.5 in.) in diameter did not.

Grooving core walls did not appear to have any significant effect on faulting of joints with Double-V shear devices. Of the three shear device patterns investigated, the weakest one (two devices in the other wheelpath and one in the inner

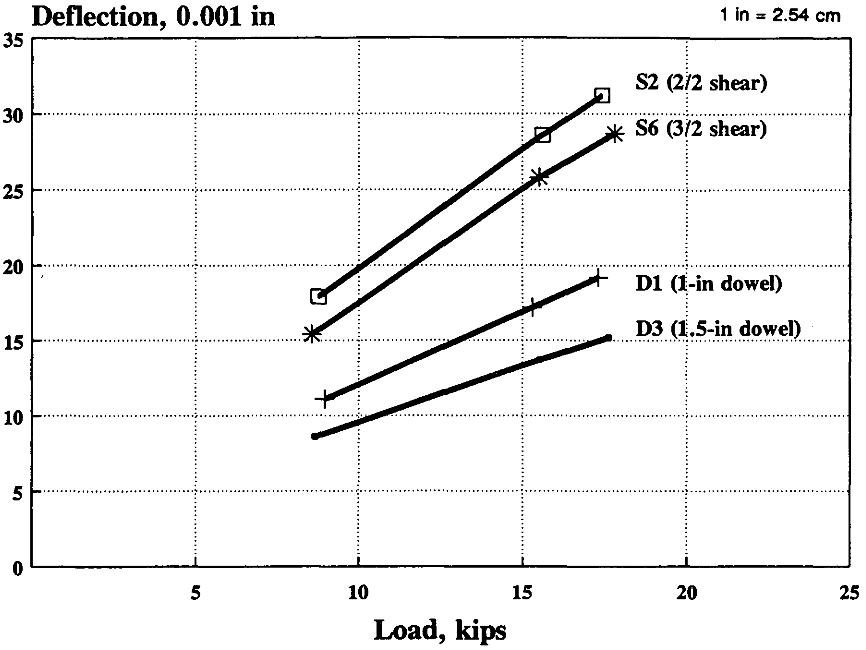

FIGURE 10 Example of load-versus-deflection results at slab corners for dowels and shear devices.

wheelpath) showed an increase in faulting, whereas the other two patterns (two devices per wheelpath, and three in the outer wheelpath, two in the inner wheelpath) did not show an increase.

Deflection Results

Before installation of the load transfer devices, the undowelled joints of this project had very poor deflection load transfer efficiency (less than 10 percent for most test sections). The retrofit dowels improved load transfer dramatically, to between 50 and 80 percent. The shear devices produced more modest load transfer improvements, to between 20 and 55 percent. After more than 5 years in service, both the retrofit dowels and the shear devices exhibit load transfer efficiencies that are similar to those measured initially after installation.

In most but not all cases, sections with five dowels per wheelpath had slightly higher load transfer efficiencies than sections with three dowels per wheelpath. Similarly, in most but not all cases, sections with 3.8-cm (1.5-in.) dowels had slightly higher load transfer efficiencies than sections with 2.5-cm (1-in.) dowels. Dowel length did not appear to affect load transfer efficiency.

Grooving core walls did not appear to affect the load transfer efficiency of joints with shear devices. Joints with three shear devices in the outer wheelpath and two devices in the inner wheelpath had the highest load transfer efficiencies. Only the 3/2 pattern appeared to be able to achieve load transfer efficiencies in the range of 50 percent, and then only in one direction on the project. The shear device pattern with the lowest load transfer efficiency was not consistent by direction.

Joints with 3.8-cm (1.5-in.) dowels had about 30 percent lower corner deflections than joints with 2.5-cm (1-in.) dowels. Other retrofit dowel factors did not have any significant effect on corner deflections. Overall, dowelled joints had about 30 percent lower corner deflections than joints with shear devices. Joints with 3.8-cm (1.5-in.) dowels had about 38 percent lower corner deflections than joints with shear devices.

Despite the fact that joints with retrofit dowels have higher load transfer efficiencies and lower corner deflections than joints with shear devices, the dowels and shear devices appear to have been about equally effective in controlling faulting. However, the higher load transfer and lower corner deflections achieved by retrofit dowels may benefit pavement performance in other ways (i.e., reduction of slab stresses caused by corner loads).

ACKNOWLEDGMENTS

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