Construction Report on the Installation of Retrofit Dowel Bar Test Sections on TH 23
A section of Trunk Highway 23 near Mora, Minnesota, underwent concrete rehabilitation in 1998, which included the installation of retrofit dowel bars over a portion of the project.

The Minnesota Department of Transportation (Mn/DOT) established several different test sections to evaluate the performance of different dowel bar configurations, group materials, and dowel bar lengths. During dowel bar installation, researchers monitored and evaluated construction procedures. They also conducted pavement testing before and after installation of the retrofit dowel bars to determine any immediate improvements to the joint performance.

As expected, early age testing has shown improvements in joint load transfer efficiency after installation of the retrofit dowels. Testing also revealed that the rapid-setting mortar performed better than Mn/DOT’s standard 3U18 patching mix. After only two years, there has been no noticeable differences in ride quality or faulting at the joints between retrofit and nonretrofit joints. Testing of pavements and joint performance will continue on a yearly basis to determine the long-term performance of the retrofit dowels.
CONSTRUCTION REPORT ON THE INSTALLATION OF RETROFIT DOWEL BAR TEST SECTIONS ON TH 23

Construction Report

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EXECUTIVE SUMMARY

Several different test sections were established on a portion of TH 23 near Mora, Minnesota in 1998 to evaluate the performance of the installation of retrofit dowel bars across the joints. The existing pavement is approximately 50 years old; however it is in generally good condition except for the development of faulting at the joints due to a lack of adequate load transfer. These existing conditions made this pavement a good candidate for the installation of retrofit dowel bars.

Test sections were constructed to monitor the performance of various dowel bar configurations, grout types and dowel bar lengths. In one test section dowel bars were configured so that there were three dowels in the outer and inner wheelpaths, three dowels in the outer and two dowels in the inner wheelpath or three dowels in only the outer wheelpath. Another test section is comparing the performance of the Minnesota Department of Transportation (Mn/DOT) standard 3U18 patching mix to a rapid setting mortar mix. The last test section is comparing the performance of dowel bars that are 325 and 375 mm (13 and 15 in.) long.

The pavement section due to undergo dowel bar retrofit was tested to determine load transfer of the joints and the ride quality prior to installation of the dowels and again shortly after completion of the dowel bar installation and diamond grinding. These results were used to determine the immediate improvements obtained from the rehabilitation. These results showed expected improvements in both load transfer and ride quality.

Construction procedures were monitored during the installation of the dowel bars and a discussion of these procedures can be found in the construction report.

Testing and monitoring by means of visual inspections, joint load transfer testing, faulting measurements and ride quality evaluation will continue on a yearly basis.
Testing has been completed in 1999 and 2000. Visual inspections have shown that dowels backfilled with Mn/DOT’s standard 3U18 patching mix have developed shrinkage cracks along the slot walls while the rapid setting mortar has shown good bonding characteristics along the slot surfaces. Joint load transfer measurement, faulting measurements and ride quality measurements have indicated no differences between the performance of any of the test sections thus far.
CHAPTER 1
INTRODUCTION

Minnesota Trunk Highway 23 located between Ogilvie and Mora underwent concrete pavement rehabilitation in the summer of 1998. This pavement section consists of concrete that is nearly 50 years old. This section of pavement was originally constructed in 1952 and consists of undoweled 9-7-9 concrete, 6.7 m (22 ft.) wide with a joint spacing of approximately 4.8 m (16 ft.). Prior to rehabilitation of the 8.89-km (5.53-mile) stretch of concrete pavement, this two-way, two-lane roadway had minimal faulting along the transverse joint near the centerline but substantial faulting near the outer edge of the pavement.

Overall, the concrete was in fairly good condition except for the faulting that occurred at the joints. These conditions made this section of pavement a good candidate for the installation of retrofit dowel bars at the joints. Some of the joints along this section of pavement had joint widths up to 19 mm (0.75 in.). It is likely that these joints have very little load transfer capability. Retrofit dowels will restore the load transfer across the joints. Upon completion of the installation of the dowel bars the surface was diamond ground to remove any faulting that was present. The retrofit dowel bars should greatly reduce any recurrent faulting at the joints.

Three different test sections were set up on this project to investigate the following:

1. Compare the performance of retrofit dowel bars in just the outer wheel path versus both the inner and outer wheel paths. This was done by using various
configurations of dowels in the wheel paths. These configurations include using three dowel bars in the inner and outer wheel paths, three dowel bars in only the outer wheel path, and using three dowel bars in the outer wheel path and two in the inner wheel path. All dowel bars in this section are 375 mm (15 in.) long and 38 mm (1.5 in.) in diameter.

2. Compare the performance of the Minnesota Department of Transportation (Mn/DOT) standard 3U18 concrete patching mix to a rapid setting mortar. Standard 3U18 will achieve a compressive strength of 21 MPa (3000 psi) in approximately 12 hours whereas rapid setting mortars typically achieve the same compressive strength in approximately 4 to 5 hours. The contractor was allowed to select the product they wanted to use for the rapid setting mortar as long as it met ASTM C928 “Packaged, Dry, Rapid-Hardening Cementitious Materials for Concrete Repairs.” The product selected was Tamms Speed Crete® 2028 which is able to achieve 21 MPa in approximately 2 to 3 hours. The dowel bars used in this section are 375 mm (15 in.) long and 38 mm (1.5 in.) in diameter. If the rapid setting mortar performs adequately, it could allow for an early opening of a roadway if necessary. It is also believed that the rapid setting mortar may undergo less shrinkage than the 3U18 grout, thus providing a better bond to the slot surfaces.

3. Compare the performance of dowel bars that are 325 mm (13 in.) and 375 mm (15 in.) long. Due to the greater precision of the placement of retrofit dowels, it is possible that a shorter dowel bar, 325 mm (13 in.), may provide adequate
embedment into the pavement on both sides of the joint. This would allow for a shorter slot and require less backfill material resulting in a reduced cost of installation per dowel. Again the dowel bars are 38-mm (1.5-in.) diameter.
CHAPTER 2
TEST LOCATIONS

The following sections will identify the original locations and the layout of the test sections that were previously described. Unless otherwise specified the dowels used are 375 mm (15 in.) long with a diameter of 38 mm (1.5 in.) and the patching material is 3U18 patch mix.

**Test Section 1**

The first test section, which will compare the performance of dowel bars in only the outer wheel path versus dowel bars in both the inner and outer wheel path, is located between R.P. 253+00.100 and R.P. 253+00.556 and encompasses 160 joints. The first 20 joints of this section used three dowel bars in both the inner and outer wheel paths (figure A-1). The next 20 joints were then retrofit with three dowel bars in only the outer wheel path (figure A-2). The next 20 joints were retrofit with two dowel bars in the inner wheel path and three dowel bars in the outer wheel path (figure A-3). The next 20 joints were retrofit with 3 dowel bars in only the outer wheel path again. This sequence was then replicated for the 80 remaining joints in the test section.

**Test Section 2**

The second test section, which will compare the performance of Mn/DOT standard 3U18 concrete versus a rapid setting mortar, is located between R.P. 253+00.556 and R.P.
253+00.784 and encompasses 80 joints. The first 20 joints were to use Speed Crete® to secure the dowels in place. The next 20 joints were to use Mn/DOT 3U18 patch mix to secure the dowels in place. This sequence was then replicated for the remaining 40 joints. The joints in this test section were retrofit with three dowel bars in only the outer wheel path as displayed in figure A-2.

**Test Section 3**

The third test section, which will compare the performance of 325-mm (13-in.) long dowel bars to 375-mm (15-in.) long dowel bars, is located between R.P. 253+00.784 and R.P. 254+00.081. The first 20 joints were retrofit with the 325-mm (13-in.) dowel bars and the second 20 joints were retrofit with the 375-mm (15-in.) dowel bars. This sequence was replicated throughout the remainder of the project, which encompassed approximately 80 more joints. Dowel bars were placed only in the outer wheel path as displayed in figure A-2.

**Control Section**

The control section, which was diamond ground but did not receive retrofit dowels will be the first 20 joints located just west of the retrofit test sections. These joints will be used to determine any improvement in load transfer and reduction in faulting due to the retrofit dowels. The remainder of the roadway west of the retrofit section was also rehabilitated but retrofit load transfer was not installed. The condition of the remainder
of the roadway will be monitored, however, load transfer and faulting will not be measured.
Falling Weight Deflectometer (FWD) testing was performed prior to installation of the dowel bars. Most of the joints exhibited faulting that was typically 6 mm (.25 in.) or more. However, results of the FWD testing prior to installation of the dowels did not provide realistic load transfer values (80-90 percent) as compared to the condition of the pavement. Figures A-4 and A-5 display the results of the FWD testing. These unreasonably high load transfer results are believed to be due, in most part, to the high temperatures at the time the testing was performed. The retrofit dowel research was added while the rehabilitation project was underway so there was not sufficient time to conduct the FWD testing under more favorable temperature conditions. Surface temperatures of the pavement during testing were typically between 43 and 49 degrees Celsius (110 and 120 degrees Fahrenheit). This is near the upper limit of the temperatures the pavement will experience and provides a condition in which the joint width is small and may allow for increased load transfer due to aggregate interlock. In addition, the time of day at which the load transfer was tested, it is likely that the temperature at the top of the pavement was higher than the temperature at the bottom of the pavement. This would cause the slab edges to curl down into the base and produce higher Load Transfer Efficiency (LTE) results than would be expected.

Figure A-4 provides a good illustration of how the pavement temperature can affect the load transfer measurements. Initially, when load transfer testing of the joints commenced, the pavement surface temperature was around 29 degrees Celsius (85
degrees Fahrenheit). As can be seen on the graph, LTE is widely scattered anywhere between 20 percent and 90 percent for the first 150 joints. The scatter gradually decreases as the surface temperature continually increases and the joints lock up. The LTE is consistently around 90 percent with very little scatter after approximately joint number 170. The surface temperature from this point on was very warm with temperatures consistently between 46 and 52 degrees Celsius (115 and 125 degrees Fahrenheit). It is fairly safe to assume that if the temperature had remained cooler throughout the testing the latter results would have appeared more like the first 150 joints tested.
CHAPTER 4
CONSTRUCTION

The installation of the dowel bars was performed according to the following procedure:

The slots were first cut parallel to the centerline 64 mm (2.5 in.) wide and to a length and depth adequate for the dowel bar to sit at mid-depth of the pavement (figure A-6). The slot depth was controlled by the 178-mm (7-in.) inside pavement thickness measurement of the slab. The slots were then cleaned out with a chipping hammer to allow the dowel bar assembly to sit parallel to the pavement surface (figure A-7). Once the slots were cleaned out with the chipping hammer, the sides and bottom of the slots were sandblasted to remove any loose debris and sawing residue. The transverse crack at the bottom of the slot was then caulked to prevent any of the grout material from entering the joint (figure A-8). At the same time, the dowel bar assemblies were being prepared by placing groups of three to four compressible styrofoam spacers, each 6 mm (.25 in.) thick, on the dowel bars, fitting the end caps, and attaching the chairs to the dowels (figure A-9). A release agent was not applied to the dowels since the dowels came with a wax based curing compound coating on them to prevent the grout from adhering to the dowels. The end caps were fitted on the dowels to allow for 6 mm (.25 in.) of expansion on both ends of the dowel. The slots were cleaned out with a gas-powered blower just prior to placing the dowel bar assembly into the slot. All the slot surfaces were then coated with a bonding agent comprised of a cement and water slurry having the consistency of a heavy cream. The dowel bar assemblies were then inserted into the slots such that they were parallel with the pavement surface and centered over the transverse crack. Compressible
styrofoam spacers were installed to maintain the joint and fitted tightly along the sides and bottom of the slot to prevent any grout material from entering the joint (figure A-10). Once the dowel assembly was in place, the grout was placed around the dowel and consolidated using a “spud” type vibrator (figure A-11). The surface of the slot was then finished flush with the pavement surface and sprayed with Mn/DOT approved curing compound (figure A-12). Appendix B shows the special provisions and plan sheets used for retrofit dowel bar installation.

The grout used to secure the dowel bar assemblies into place was the Mn/DOT standard 3U18 concrete patching mix for a majority of the project. Aggregate used in the patching mix was 50 percent gravel pearock with a 10-mm (.375-in.) topsize and 50 percent concrete sand. The batch weights used for the patching mix are listed in table 4.1. The grout was mixed using a paddle mixer and a batch size of 0.19 cubic meters (0.25 cubic yards). Information on the batching sequence was not recorded during construction.

| Type I Cement | 42 kg (93 lbs.) |
| Fine Aggregate | 68 kg (150 lbs.) |
| Coarse Aggregate | 70 kg (154 lbs.) |
| Water | 15 kg (33 lbs.) |
| Air Entrainment | 103 ml (3.5 oz.) |

The grout used for the remaining slots was Tamms Speed Crete® 2028, which is a rapid setting mortar. The mix was extended by adding the maximum allowed 22.7 kg (50 pounds) of 10-mm (.375-in.) pea gravel per 22.7-kg (50-pound) bag of mortar mix as stated on the instructions listed on the bag of mortar. All mix instructions on the mortar
bag were followed when mixing the Speed Crete® 2028. The maximum recommended amount of water, 2.4 L (5 pints), per 22.7-kg (50-pound) bag of mortar mix was used. The mixing sequence used was as follows:

1) Add the measured quantity of water to the mixer.
2) Add any pea gravel to be used to the mix.
3) Start mixer.
4) Add Speed Crete® 2028.
5) Mix for a minimum of 4 minutes. The mix may seem stiff at first but relaxes after 4-5 minutes of mixing. Do not add additional water to loosen the mix.

Although, according to the manufacturer, Speed Crete® 2028 does not require curing, the slots were still sprayed with curing compound to reduce the likelihood of shrinkage cracking.

Air content and slump measurements of the 3U18 patch mix were taken at various times throughout the installation of the dowels. The air content and slump were consistently around 7 percent and 25 mm (1 in.) respectively for the 3U18 patch mix. The Speed Crete® 2028 had an air content and slump of 6.2 percent and 63 mm (2.5 in.), respectively. Table 4.2 provides a summary of all air content and slump measurements. In addition, concrete cylinders 152 mm x 305 mm (6 in. x 12 in.) were cast to measure the compressive strength of the grout after 1, 7 and 28 days of curing. Additional cylinders were cast for the Speed Crete® 2028 to also measure compressive strength after 3 hours of curing. All concrete specimens were moist cured until the time of testing.
Compressive strength was measured based on an average of three tests. Table 4.3 lists the results of the compressive strength testing performed.

### Table 4.2 Air content and slump measurements of patching mixes

<table>
<thead>
<tr>
<th>Mix</th>
<th>Air Content, %</th>
<th>Slump, mm (in.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mn/DOT 3U18</td>
<td>7.2</td>
<td>25 (1.0)</td>
</tr>
<tr>
<td></td>
<td>7.0</td>
<td>25 (1.0)</td>
</tr>
<tr>
<td></td>
<td>7.4</td>
<td>25 (1.0)</td>
</tr>
<tr>
<td></td>
<td>7.4</td>
<td>19 (0.75)</td>
</tr>
<tr>
<td>Tamms Speed Crete® 2028</td>
<td>6.2</td>
<td>63 (2.5)</td>
</tr>
</tbody>
</table>

### Table 4.3 Compressive strength of patching mixes

<table>
<thead>
<tr>
<th>Mix</th>
<th>Age</th>
<th>Compressive Strength, MPa (psi)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mn/DOT 3U18</td>
<td>1-day</td>
<td>27.1 (3929)</td>
</tr>
<tr>
<td></td>
<td>7-day</td>
<td>41.2 (5987)</td>
</tr>
<tr>
<td></td>
<td>28-day</td>
<td>46.1 (6688)*</td>
</tr>
<tr>
<td>Tamms Speed Crete® 2028</td>
<td>3-hour</td>
<td>27.5 (3993)</td>
</tr>
<tr>
<td></td>
<td>1-day</td>
<td>33.0 (4796)</td>
</tr>
<tr>
<td></td>
<td>7-day</td>
<td>42.7 (6191)**</td>
</tr>
<tr>
<td></td>
<td>28-day</td>
<td>42.7 (6195)</td>
</tr>
</tbody>
</table>

* Average of nine compressive strength tests  
** Average of two compressive strength tests

In addition to the installation of the dowel bars, partial depth and full depth repairs were made where necessary throughout the project. Upon completion of the installation of the dowels and all necessary concrete repairs, the entire concrete surface was diamond ground to remove any faulting that was present and improve the ride quality. Once the surface was diamond ground, all the joints were resealed with silicone sealant to prevent the infiltration of water and incompressible material.
CHAPTER 5
FIELD MODIFICATIONS AND OBSERVATIONS

There are several modifications and observations that were made throughout the installation of the dowel bars that deviated from what was addressed earlier in this report or which may be considered improper construction practices. The following sections will discuss the observations that were made throughout the construction that were inconsistent with the original workplan.

Test section layout

In general, the test sections were layed out as stated earlier in this report. However some slight modifications were made to the layout of test section 2. The intended layout of test section 2 was to install dowel bars in 20 joints using Speed Crete®, then install dowel bars in 20 joints using Mn/DOT 3U18 patch mix, and then do one replication of this. Due to the necessary adjustments to the mixer (i.e. cleaning, batching sequence, etc.) and perfecting the technique to place and finish the material, it was decided to place all of the Speed Crete® at once. Therefore dowel bars were installed in 40 consecutive joints using Speed Crete® and then in 40 consecutive joints using Mn/DOT 3U18 patch mix. This should not provide significant problems but should be noted however for future testing and monitoring.
Construction Observations

During the installation of the dowels there were several different construction practices that were noted and corrected early in the process. A list of these procedures follows along with the complications that may have resulted and any corrective actions taken.

1) Inadequate removal of concrete material in the slots – There were several occasions where the bottom of the slot was not cleaned out adequately to provide a level surface for the dowel bar assembly to sit. If not corrected, the dowel bar could cause the joint to lock up and result in cracking or failure of the patch. Any slots identified with this problem were cleaned out again with a chipping hammer to provide a level surface.

2) Improper caulking of slots – Although the bottoms of the slots were caulked adequately, the sides of the slots were not caulked at all for a majority of the project. Instead of caulking the sides of the slots, additional spacers were used to cover the joint crack along the sides of the slots. There still were several instances where the spacers were unable to completely close off the crack from the grout material. If grout material is able to enter the cracks, especially if the grout is placed in cooler weather, it is possible that as the panels expand in warmer weather that either spalling may occur at the joint or the joint may blow-up. Two measures were taken in an effort to correct this problem. The first was to require that the cracks on the sides of the slots be caulked to prevent any grout from entering the crack. This, however, was not
enforced until late in the project. Second, the contractor was required to
return to the project and resaw the joints all the way down to the depth of the
dowel bar in an effort to remove any material that may have entered the crack.

3) Misalignment of spacers and grout in joints – There were several slots where
the spacers were not aligned with the existing joint in order to maintain it or
where grout was allowed into the joint (figure A-13). This problem was
addressed early on the first day of construction. A review of the project a few
weeks later showed the situation had not been completely eliminated as the
number of spacers being used to maintain the joint was reduced down to two
per dowel instead of three or four perhaps to save approximately $0.25 to
$0.50 per slot. This could lead to spalling at the joint or possibly cause the
joint to blow up. Again, the contractor was required to return to the project
and resaw the joints all the way down to the depth of the dowel bar in order to
remove the grout that was allowed into the joint and to reestablish the joints
where the spacers were misaligned.
CHAPTER 6
POST-CONSTRUCTION TEST RESULTS

Shortly after the dowel bars were installed and the surface was diamond ground, a visual inspection of the pavement was conducted. Several areas of minor spalling along the edges of some of the partial depth repairs and dowel bar slots were identified. However, the overall condition of the pavement after the installation of the dowel bars appeared to be good.

During the fall after the dowel bar installation was complete all the joints and midpanel cracks were again tested to determine load transfer efficiency. In addition several joints that were not retrofit with dowels were tested. The testing was performed in November when temperatures were much cooler than the pre-construction testing. The pavement temperature during the testing was around 35 degrees Fahrenheit. The results this time were much more reasonable as the joints without dowel bars had a load transfer efficiency between 20 and approximately 50 percent with an average load transfer of 41 percent and standard deviation of 17 percent. The joints retrofit with dowels maintained an average load transfer efficiency of 79 percent with a standard deviation of 5.3 percent. Figures A-14 and A-15 display the results of the FWD testing.

The pavement management unit did testing along this section of highway in 1997 prior to rehabilitation and again in October of 1998 shortly after the completion of the retrofit work at the request of the research office. This testing was performed to determine the present serviceability rating (PSR), a measure of ride quality, and faulting present along the pavement using their Pathway data collection van. PSR was determined by
converting International Roughness Index (IRI) values that were obtained from the data collected. PSR is based on a scale of 0 to 5 with higher values indicating a smoother ride. Faulting measurements were obtained directly from the data collected. Table 6.1 provides the results obtained from this testing. These results indicate that the PSR improved and faulting was essentially eliminated upon completion of the retrofit and diamond grinding of the surface. This was also true for portions of the concrete pavement that received diamond grinding but no retrofit dowels. This would be expected since the testing was performed shortly after the rehabilitation of the pavement before any recurrent faulting was able to develop. This will provide a good baseline to monitor the performance of the dowel bars. One point of concern however was the minimal improvement in the PSR values. It is felt that the measured improvement does not adequately reflect the actual improvement in the ride quality due to the retrofit dowels and diamond grinding. It is the opinion of the researchers that the improvement in ride quality is far greater than the measured results indicate, however, it is not known why the results did not reflect this improvement. As a result, profilograph data was obtained after diamond grinding the pavement to provide further information on the smoothness of the pavement. The average profile roughness index (PRI) was 2.00 in./mi. This value indicates that a smooth pavement was achieved from the dowel bar retrofit and diamond grinding. These results are more indicative of the improvement in ride that were believed to have been attained by installation of the dowel bars and diamond grinding.
Table 6.1 Pavement condition measurements

<table>
<thead>
<tr>
<th>Section</th>
<th>Testing Date</th>
<th>PSR, left wheel path</th>
<th>PSR, right wheel path</th>
<th>PSR, average</th>
<th>0.04”-0.19”</th>
<th>0.19”-0.49”</th>
<th>0.49”-2.00”</th>
</tr>
</thead>
<tbody>
<tr>
<td>No Dowels</td>
<td>7/17/97</td>
<td>2.4</td>
<td>1.8</td>
<td>2.1</td>
<td>174</td>
<td>80</td>
<td>0</td>
</tr>
<tr>
<td>Retrofit Dowels</td>
<td>10/27/98</td>
<td>2.8</td>
<td>2.8</td>
<td>2.8</td>
<td>6</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>No Dowels</td>
<td>7/17/97</td>
<td>2.4</td>
<td>1.9</td>
<td>2.1</td>
<td>173</td>
<td>167</td>
<td>0</td>
</tr>
<tr>
<td>Retrofit Dowels</td>
<td>10/27/98</td>
<td>2.8</td>
<td>2.8</td>
<td>2.8</td>
<td>13</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

* the number of faults in the left wheel path were measured over a 1-mile undoweled section and the 1-mile test section that was retrofit with dowels

Another visual inspection of the test sections was performed in February 1999. It was observed that a majority of the slots using 3U18 patching mix had shrinkage cracks along one of the slot edges at the interface of the patching mix and the slot wall (figure A-16). The Speed Crete\textsuperscript{®} patch mix, however, showed very little cracking along the edges of the slots. Several cores were taken in the spring at locations where cracks were present in the 3U18 patching mix to determine how well the patching material bonded to the slot wall. These cores verified the presence of shrinkage cracking along the full depth of the slot wall (figure A-17). Cores were also taken at locations where there was no cracking and the Speed Crete\textsuperscript{®} was used, again to determine the bonding between the patching mix and slot wall. These cores showed very good bond between the Speed Crete\textsuperscript{®} and all the slot surfaces (figure A-18).
CHAPTER 7
ONGOING TESTING AND MONITORING

The test sections on TH 23 have undergone FWD testing in 1999 and 2000 to determine the load transfer capability of the joints. In addition, faulting measurements were taken in 1999. The following sections will update the most recent findings from these test sections.

Joint Load Transfer

FWD testing at the joints has been performed in 1999 and 2000 to determine the load transfer capability of the different test sections over time. Thus far all the retrofit test sections have performed well with average load transfer values falling between 72 and 79 percent for all the test sections. These values are comparable to those taken right after completion of the retrofit dowel installation. The joints that were not retrofit have had lower and highly variable load transfer results. The average load transfer for these joints has been between 28 and 53 percent. Figure 7.1 shows the load transfer history of the various test sections between 1999 and 2000.

Faulting

Faulting measurements were conducted in 1999, however, they were not collected in 2000 due to time constraints. The faulting measurements in 1999 did not indicate any recurrent faulting at that point. While measurements were not taken in 2000, it is
expected that there would be very little change in the faulting from 1999. These measurements will resume again in the fall of 2001.

![Load Transfer History by Test Section](image)

Figure 7.1 Load Transfer of the Test Sections

**Ride Quality**

As stated earlier, the minimal improvement in PSR value shortly after the completion of the retrofit was not believed to have reflected the actual improvement in ride due to the rehabilitation efforts. Results of the ride measurement taken in 1999 indicate a much improved ride quality as compared to the results obtained right after rehabilitation. These ride results are more indicative of the expectations after retrofitting and grinding. This noticeable improvement in the ride quality indicates it is likely that the initial measurements obtained right after completion of the retrofit did not properly indicate the
actual improvement in ride quality. Table 7.1 shows the results of all the ride testing conducted thus far.

<table>
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<th>Joint Type</th>
<th>1997*</th>
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<td>2.1</td>
<td>2.8</td>
<td>3.8</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Undoweled</td>
<td>2.1</td>
<td>2.8</td>
<td>3.6</td>
</tr>
<tr>
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<td>Doweled</td>
<td>-</td>
<td>-</td>
<td>3.7</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Undoweled</td>
<td>-</td>
<td>-</td>
<td>3.6</td>
</tr>
</tbody>
</table>

*prior to dowel bar retrofit
Currently, there has been no significant difference between the performance of the different retrofit test sections or the control section. The only noticeable difference between the doweled and undoweled sections is the joint load transfer, which is expected. After only two years, the undoweled section has not shown any recurrent faulting and the ride quality is comparable to the doweled sections.

Monitoring of the test sections will continue on a yearly basis to determine the joint load transfer, faulting and ride quality over time. Visual inspections will also continue to be performed to determine the development of any deterioration.
APPENDIX A

CONSTRUCTION PICTURES, DOWEL LAYOUTS
AND LOAD TRANSFER RESULTS
Figure A-1. Dowel bar configuration, 3 inner wheel path and 3 outer wheel path
Figure A-2. Dowel bar configuration, 3 outer wheel path
Figure A-3. Dowel bar configuration, 2 inner wheel path and 3 outer wheel path
Figure A-4. Eastbound T.H. 23 LTE results before retrofit

Figure A-5. Westbound T.H. 23 LTE results before retrofit
Figure A-6. Saw cuts for slots

Figure A-7. Concrete fin between saw cuts is cleaned out with a chipping hammer
Figure A-8. Caulking along crack on the bottom of the slot
Figure A-9. Dowel bar assembly

Figure A-10. Alignment of spacers with existing joint
Figure A-11. Placement and consolidation of patching material

Figure A-12. Spraying curing compound on finished slots
Figure A-13. Misalignment of spacers and grout in joint

Figure A-14. Eastbound T.H. 23 LTE results after retrofit
Figure A-15. Westbound T.H. 23 LTE results after retrofit

Figure A-16. Cracks along sides of slot
Figure A-17. Core from retrofit with 3U18 patch mix

Shrinkage crack along slot wall
Figure A-18. Core from retrofit with Speed Crete®

Good bond along slot
APPENDIX B

SPECIAL PROVISIONS FOR EPOXY COATED DOWEL BAR RETROFIT
The following are special provisions and plans sheets from a previous retrofit dowel bar rehabilitation project. Except for some minor changes to coincide with the details of this project, they are basically the same provisions used for this project.

EPOXY-COATED DOWEL BAR RETROFIT

Qualification of Workers

It is crucial that quality workmanship be performed on Concrete Rehabilitation Pavement Projects. Therefore, all Contractors, supervisors, foremen, sub-foremen and other key personnel such as operators, finishers, steel setters, sandblasters, joint sealers, etc., involved in the field supervision and/or actual rehabilitation operations, exclusive of delivery work, shall be required to attend, within five working days of being employed on the project, a Concrete Pavement Rehabilitation Session. These sessions, consisting of a short slide/tape presentation, will be made available for viewing prior to the start of work on the project at the Contractors local field office and/or through the Project Engineer. Verification of attendance at one of these sessions shall satisfy this requirement for all subsequent projects in this calendar year.

Description

This work shall consist of installing 1-1/2 inch diameter x 15 inch long and 1-1/2 inch diameter x 18-inch long epoxy-coated dowel bars into existing portland cement concrete pavement.

The site is a one-mile segment of roadway that will be divided into 5 sections, each of which will contain approximately 40 mid-panel cracks to be repaired. The first twenty panels of each section will utilize 1-1/2 inch x 15 inch dowel bars to provide load transfer at the mid panel cracks. The second twenty panels of each section will utilize 1-1/2 inch x 18 inch dowel bars to provide load transfer at the mid panel cracks. The sections will contain variations in layout. Each section will vary in the number and location of the epoxy-coated dowel bars.

Materials

The release agent shall be a liquid membrane-forming compound that conforms to the requirements of Section 3902 of the Mn/DOT Standard Specifications for Construction.
Caulking filler shall be silicone sealant. The Contractor shall obtain approval prior to use.

Epoxy-Coated dowel bars shall be in accordance with Section 3302 of the Mn/DOT Standard Specifications for Construction.

Dowel bars shall be plain steel bars of the dimensions shown in the Plans, and shall be epoxy-coated on 100% of all surfaces including ends.

The dowel bars shall have tight fitting end caps made of non-metallic materials that will allow for a 1/4-inch movement of the bar at each end. The contractor shall submit to the engineer sample end caps and obtain approval of them prior to use. The contractor is advised that ordering of the end caps prior to their approval by the engineer is at the contractor’s risk and shall not be a basis for additional compensation.

The 1/4-inch thick foam core board filler material shall be a closed cell foam faced with poster board material on each side commonly referred to as foam core board. The contractor shall submit to the Engineer a sample of the material and obtain approval prior to use.

Twenty percent of the total cement concrete pavement removed, in each of the five sections for the purpose of installing retrofitted dowel bars, shall be replaced with Burke 928 Fast-Patch, Fosroc-Patch 10-60, Five Star Highway Patch or CTS Rapid Set DOT. The engineer will approve the grout material on the basis of the name brand. The remaining eighty percent of the total cement concrete pavement removed shall be replaced with Mn/DOT concrete mix grade 3U18, mix design obtained from the Mn/DOT Concrete Office.

Accelerators should generally not be used when the ambient air temperature exceeds 80 degrees F. If accelerators are used, they must be used with caution (contact concrete engineering).

The air content for grade 3U18 concrete shall be 6.5 percent plus or minus 1.5 percent. Specification 2461.4A4b shall be adjusted accordingly based on the 6.5 percent target value.

The CA-8 gradation in table 3137-1 of the specifications shall be modified to read 55 to 95% passing the #4 sieve.

B1 Immediately after final finishing, all concrete shall be cured in accordance with spec. 2531.3g2 "membrane curing method." The material shall meet specification 3754 except as noted in specification 2301.3m regarding extreme service cure. Hudson sprayers may be allowed if the
coverage rate is doubled and the curing material is from an agitated source.

Chairs for supporting and holding the dowel bar in place shall be completely epoxy coated in accordance with AASHTO M 294, or made out of non-metallic materials. The contractor shall submit to the engineer for approval a sample of the chairs and obtain approval of them prior to use. The contractor is advised that ordering of chairs prior to their approval by the engineer is at the contractors risk and shall not be a basis for additional compensation.

**Construction Requirements**

The contractor shall install the dowel bars in the existing cement concrete pavement as shown in the Plans and in accordance with the following specifications:

1. Saw cut slots in the pavement as required to place the center of the dowel at mid-depth in the concrete slab. Multiple saw cuts parallel to the centerline may be required to properly remove material from the slot.

2. To prevent damage to the existing pavement designated to remain any jack hammers used to break loose the concrete shall have a weight less than 30 pounds.

3. All exposed surfaces and cracks in the slot shall be sandblasted and cleaned of saw slurry and any release agent prior to installation of the dowel.

4. Dowel bars shall be lightly coated with a release agent prior to placement, and placed in a chair that will provide a minimum of 1/2 inch clearance between the bottom of the dowel and bottom of the slot. The dowel bars shall be placed to the depth as shown in the plans, parallel to the centerline, and parallel to the pavement surface of the lower panel at the transverse joint, all to a tolerance of 1/4 inch.

The chair design shall hold the dowel bar tight in place during placement of the grouting material. Any chair design that may allow movement of the bar during the placement of grout will be rejected by the Engineer. If for any reason the above situation occurs, any effects shall not be a basis for extra compensation.
5. Immediately prior to placement of the dowel bar and filler material, the contractor shall caulk the existing transverse joint crack as shown in the Plans. The caulking shall also be placed to provide a smooth level surface and tight fit for the foam core board filler material to the bottom of the slot. The transverse joint crack shall be caulked sufficiently to satisfy the above requirements and to prevent any of the grouting material from entering the joint crack at the bottom or the sides of the slot.

6. A 1/4 inch thick foam core board filler material, as approved by the engineer, shall be placed at the middle of the dowel to maintain the transverse joint as shown in the Plans. The filler material shall fit tight around the dowel and to the bottom and edges of the slot. The filler material shall be capable of remaining in a vertical position and tight to all edges during placement of the grout. If for any reason the filler material shifts during placement of the grout, the work shall be rejected and redone at the contractor’s expense. If for any reason the above situation occurs, any effect shall not be a basis for extra compensation.

7. The existing crack shall be maintained by saw cutting the surface with a hand pushed single blade saw, then sealed with a joint sealant filler conforming to the requirements of Section 3723 of the Mn/DOT Standard Specifications for Construction. The initial cut width shall be 1/8 inch and the depth shall be 1 1/2 inches deep, and 2 1/2 feet long centered over the three retrofit epoxy-coated dowel bars. Where only two retrofit epoxy-coated dowel bars are placed per wheelpath, The initial cut width shall be 1/8 inch and the depth shall be 1 1/2 inches deep, and 1 1/2 feet long centered over the two retrofit epoxy-coated dowel bars. The joint shall be sawed within 24 hours after placement of the grout. Immediately after sawing, all joints shall be thoroughly cleaned by water flushing. The final cross section of the crack shall conform to the detail shown on the Standard Plate Crack Repair (Type A-3A) included in Mn/DOT’s current Concrete Pavement Rehabilitation Standards.

8. Any damage to the pavement or shoulder due to the contractor’s operation shall be repaired by the contractor at no cost to the Contracting Agency.
Alternate Methods

The contractor may propose for the engineer's evaluation an alternative method of cutting the retrofit slot and placing the dowel. The contractor shall demonstrate on site the proposed alternate method. The contractor is advised that the rejection of any proposed alternate method shall not be basis for additional compensation and/or contract time.

Measurement

The dowel bars will be measured per each for each bar installed.

Payment

The unit contract price per each for "1 1/2 Inch x 15 Inch Epoxy-Coated Dowel Bar Retrofit" and "1 1/2 Inch x 18 Inch Epoxy-Coated Dowel Bar Retrofit" shall be full payment to complete the work as specified including chairs and end caps.

<table>
<thead>
<tr>
<th>Item No:</th>
<th>Item</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>0301.610</td>
<td>Dowel Bar Retrofit (1-1/2&quot; x 15&quot;)</td>
<td>Each</td>
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<tr>
<td>0301.610</td>
<td>Dowel Bar Retrofit (1-1/2&quot; x 18&quot;)</td>
<td>Each</td>
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</table>
Construction procedures for retrofitted dowel bar installation using diamond saw blades to construct slot.

**Figure B-1. Retrofit construction procedure**

**STEP 1 - SAW SLOT FOR EACH DOWEL BAR**

- **Depth to position dowel at midsection of slab**
- **5 1/4"**
- **As required for dowel placement**

**STEP 2 - REMOVE CONCRETE TO FORM KERF AND RINSE AND DRY.**

- **Material to be removed using lightweight (less than 30 lb.) hammer**

**STEP 3 - SAND BLAST AND VACUUM CLEAN SLOT**

**STEP 4 - SEAL ALL THREE SIDES OF SLOT. SEAL CRACKS AND JOINTS**

- **Caulking seal**

**STEP 5 - PLACE AND ALIGN DOWEL BARS AND JOINT FILLER MATERIAL**

- **Filler material to maintain crack**
- **Bond breaker on dowel**
- **Expansion cap (required)**

**STEP 6 - PLACE REPAIR MATERIAL**

- **1/2" slab depth**
- **1/2" clearance**
- **Low slump 3U18**
- **Use expansion cap - clear plastic w/ 1/4" relief space**

1 SEE SPECIAL PROVISIONS FOR MATERIAL AND CONSTRUCTION DETAILS.
Construction procedures for retrofitted dowel bar installation

Figure B-2. Slot layout and dowel placement