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Restoring Portland Cement Concrete

MDOT Investigates Dowel Bar Retrofit Procedure for Improving and Preserving Load Transfer at Cracks

.....thump...thump.....thump...thump.....thump...thump.....

This is a sensation that most motorists are familiar with when traveling on concrete pavement. Although this problem is prevalent nationwide, the Michigan Department of Transportation (MDOT) has been looking into ways of addressing it locally. Given the fact that there are concrete pavements in Michigan that have been in service for nearly 100 years, the ability to further prolong the usable life of these pavements is important. This importance is based on both a historical and dollar value. The fact that Michigan has some of the oldest concrete pavement in the nation still in service is a testament to the longevity that is possible with concrete pavement. Add to this the fact that many of these older pavements are located in highly populated metro areas, and the value of keeping them open and in good shape becomes apparent. In a high percentage of the cases, it is often much easier, faster and more cost-effective to repair these pavements rather than replace them. With that in mind, MDOT is continuously looking into ways to repair and maintain concrete pavements to get the longest possible service in the most efficient manner.

The Problem

It's obvious that properly built and maintained concrete pavements can have a serviceable life of well over 50 years. However, as impressive as this performance may seem, there are some historic design factors that can affect the longevity of the concrete.

A problem with some of the older pavements is that in the

past, it was common to have what is now considered long-joint spacing. "The problem with concrete pavement with long-joint spacing is that eventually, mother-nature takes over," states Dr. Thomas Van Dam, Assistant Professor in the Civil and Environmental Engineering Department at Michigan Technological University. "When this happens, you get cracking at mid-panel locations that can eventually turn into working cracks" adds Van Dam. Working cracks refer to transverse cracks that eventually lose their load transfer ability. Load transfer refers to the ability of the slab to pass part of the load from one side of the crack to the adjoining part of the slab on the other side of the crack. This decreased load transfer can in turn lead to other problems. Over time, loading, water, and other roadway contaminants can enter the newly formed crack and eventually corrode and deteriorate the steel reinforcement mesh within the concrete. As a result, there is horizontal movement as the slab reacts to environmental conditions. In colder temperatures



Figure 1: Typical finished Dowel Bar installation

when the concrete contracts, there is no reinforcement to transfer the load, and the spacing of the crack is wide enough that there is no interlocking of the aggregate. As traffic continues to travel across a failing joint, a pumping action can develop between the slabs that in effect, pushes fines and other materials from underneath one slab to the other. This in turn leaves a void, which greatly increases the likelihood of the now unsupported slab to fail.

The “thumps” that people hear and feel as they cross over joints and cracks in concrete is usually caused by the loss of load transfer from one slab to another. As a result, one slab may raise or lower in relation to the adjoining slab. When this happens, the previously flat transition between the two slabs has become a ridge of sorts. This is where the “thumps” typically come from.

Previous Repairs

Up until recently, it was fairly common for agencies to address these crack problems with either full-depth repairs or by applying an asphalt overlay. Although full-depth repairs usually solve the problem, they are fairly costly. The problem with applying an asphalt overlay is that it doesn’t address the underlying problem of the loss of load transfer at the crack. Although asphalt overlays temporarily restore ride quality, reflection cracks can quickly develop up from the concrete crack area through the asphalt. Once this cracking develops in the asphalt, the overlay can quickly deteriorate if further crack filling or sealing operations aren’t undertaken.

A more recent approach to restoring load transfer at cracks in concrete has been with the use of retrofitting dowel bars at crack locations. Dowel bar retrofits, when used in conjunction with diamond grinding, has been shown to restore load transfer at cracks, while improving ride quality. This is an alternative to the accepted repairs mentioned earlier.

This method of repair has been used throughout the country since the early 1990’s, but it has been most extensively used in Washington in that time frame. Given the success that has been reported from other transportation agencies, MDOT began investigating the feasibility of adopting this method of pavement repair. Unlike the other methods of repair that simply mask the problem, dowel bars restore the load transfer abilities by effectively joining the two adjacent sides of the crack together. See Figure 1 for an example of relative placement and appearance of dowel bar retrofit in a roadway.

Installation

The installation of dowel bars is a fairly straightforward process. Once traffic has been properly diverted, installation typically consists of 7 basic steps. These steps outlined below

are taken directly from the *Special Provision for Dowel Bar Retrofit for Load Transfer Across Cracks in PCC Pavement* that was approved on 2/28/2000.

1. Slot Cutting - The slots shall be cut using a drum-type carbide machine or a diamond-bladed saw machine. The machine shall be capable of cutting a minimum of three slots simultaneously that are centered over the crack. Three slots will be made in each wheel path across each crack designated by the Engineer as shown in Figure 2. They shall be cut parallel to each other and with the longitudinal joints to the dimensions shown in Figure 3. Slots shall also be centered over the crack or as directed by the Engineer. If the crack wanders, the slots shall be cut to have at least 150 mm of the dowel bar on each side of the crack.

If a minimum of 150 mm of dowel bar on each side of the crack is not achieved, payment for that slot shall be as follows:

<u>Length Provided</u>	<u>% of bid price</u>
Less than 150 mm but more than 75 mm	50
Less than 75 mm	0

The Contractor shall mark the cracks along their length so that the slot cutter can see them to properly place the slots. The transverse distance from the shoulder or longitudinal joint to the first slot may be increased by up to 50 mm if the longitudinal portion of the reinforcing mesh is inhibiting the removal of the slot concrete to the desired depth or width.

2. Removal of Concrete - The concrete remaining in the slots after sawing shall be removed with chipping hammers no greater than 13.6 kg. Concrete shall be removed in such a manner so as to prevent any pavement fractures caused by the removal operations.

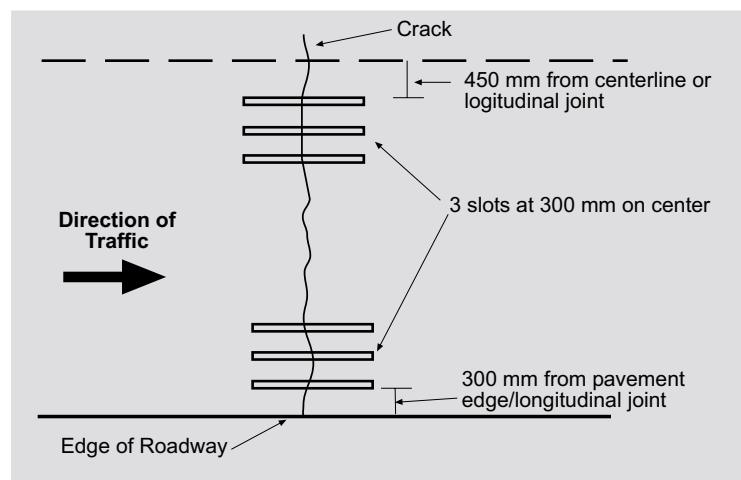


Figure 2: Location of Dowel Bars in relation to the roadway

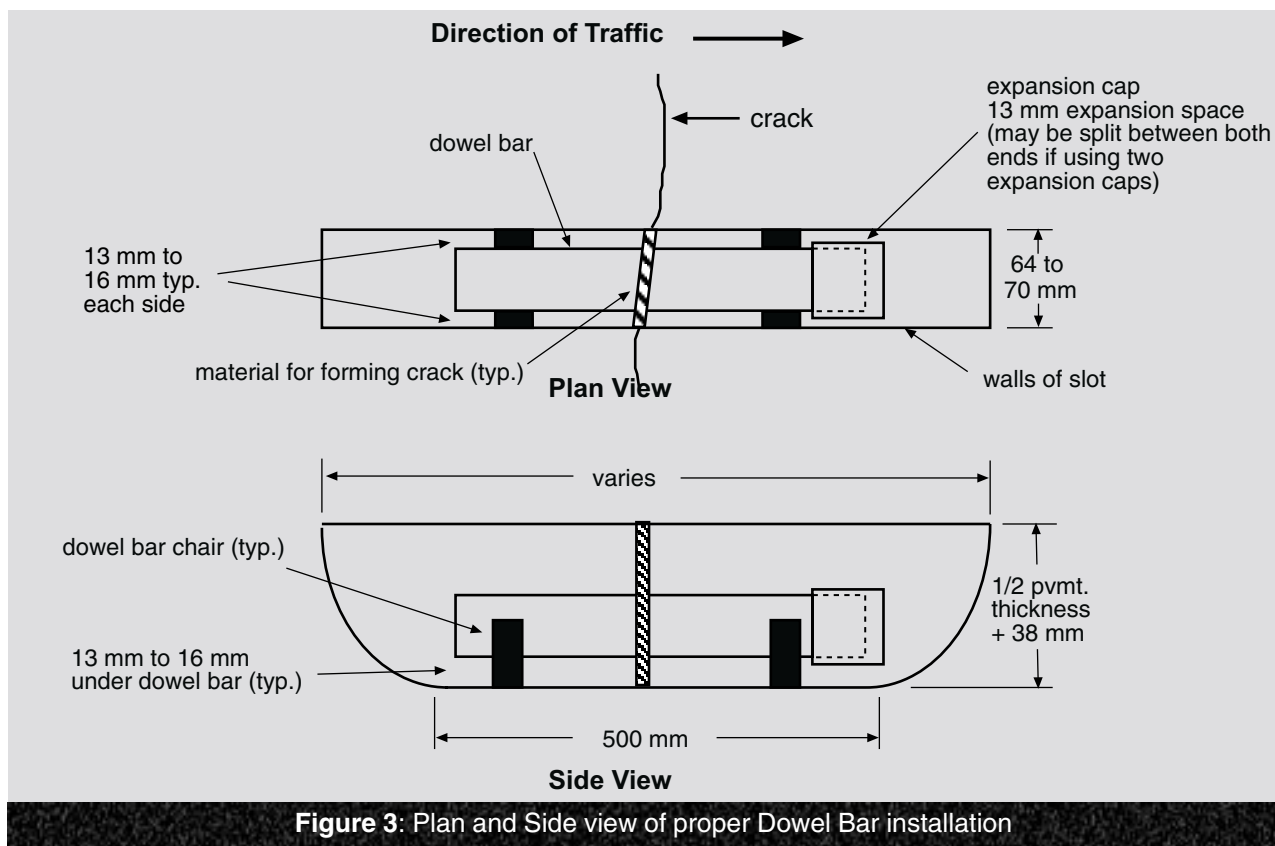


Figure 3: Plan and Side view of proper Dowel Bar installation

3. Spall Repair - Minor spalls, as defined in Subsection 602.03.P of the *1996 Standard Specifications for Construction*, shall be repaired using the patching material used to backfill the slot. Intermediate and major spalls shall be repaired according to Subsection 602.03.P.

4. Slot Cleaning - Any loose concrete shall be vacuumed or removed from the slot and all surfaces shall be dry, abrasive blast cleaned. Any exposed steel shall be blast cleaned to remove any rust or laitance. Immediately prior to placement of the dowels and patching material, the slots shall be final cleaned with moisture-free, oil-free compressed air having a minimum pressure of 620 kPa.

5. Dowel Bar Placement - After final cleaning, the crack shall be sealed with a bond breaker tape or joint sealant to prevent the patching material from entering the crack. The chairs shall be made and situated for the dowel bars to be aligned in the center of the slot, horizontal, and lay 13 mm to 16 mm off the bottom of the slot. When aligned correctly, dowels shall be true to the pavement surface and parallel to the pavement centerline. When using one expansion cap, it shall be fitted on the trailing end of the dowel bar as shown in Figure 3. Total expansion capability, whether using one cap or two, shall be 13 mm. Please refer to Figure 4 for an example of dowel bars with one expansion cap, placed on chairs and ready for installation into the slots.

The compressible material shall be placed to form

the crack across the slot for cracks 6 mm or wider. The material shall be cut so that it is a minimum of 6 mm below the existing surface so as not to interfere with the finishing of the slot surface. It shall also be cut to the width of the slot +6 mm/-0 mm to provide a tight fit against the slot sidewalls. It shall be angled if necessary to align the crack on either side of the slot.

The bond release agent shall be applied over the entire dowel bar by hand prior to placing the dowel bar in the chairs. Any bond release agent spilled on any slot surface shall be immediately cleaned off.

6. Patching - The patching material shall be mixed with a portable or mobile mixer. The patching material shall be extended, by weight of the cement, with 26A aggregate up to a maximum extension rate as specified in the QPL, and placed according to the manufacturer's recommendations. The patching material shall then be consolidated using a hand-held vibrator if recommended by the manufacturer. The surface of the patch shall be finished flush with the surrounding concrete and cured according to manufacturer's recommendations, even if diamond-grinding of the concrete surface is to occur afterward.

Prior to construction, the Contractor shall produce a trial batch of the patching concrete to a slump or consistency approved by the Engineer. The trial batch shall be proportioned and mixed at the maximum water/cement ratio recommended by the manufacturer and the

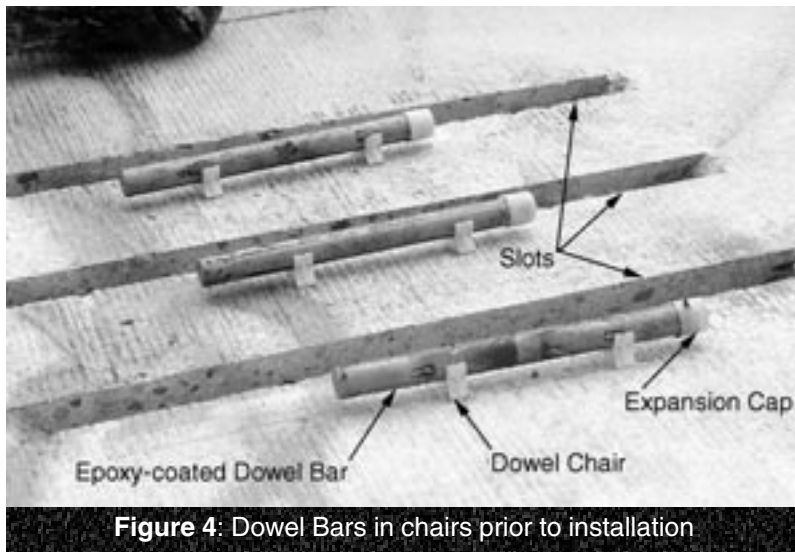


Figure 4: Dowel Bars in chairs prior to installation

maximum aggregate extension rate as specified in the QPL. During construction, patching concrete that the Engineer determines to be not uniform with the approved slump or consistency, shall either be discharged into a separate container and hand mixed to the specified uniform consistency or rejected and discarded at the Contractor's expense.

The slot walls and bottom must be dry before placement of the patching material, unless otherwise recommended by the manufacturer.

The Department reserves the right to sample the patching material and conduct strength testing to verify that the mixture is meeting the requirements stated below.

<u>Age of Sample</u>	<u>Minimum Strength</u>
2 hrs.	13.8 MPa
4 hrs.	17.2 MPa
28 days	31.0 MPa

7. Opening to Traffic - The patching material shall be cured for a minimum of four hours, or as directed by the Engineer, before placing any vehicle loads on the repair.

Candidate Selection

The installation of dowel bars is particularly well-suited for concretes that have a significant remaining structural

life, and little joint deterioration. If the slab has a short remaining service life, or if it exhibits a substantial amount of deficiencies like excessive cracking or spalling, then a more involved resurfacing alternative will most likely have to be used. Typical selection criteria for the use of dowel bar retrofits include a history of crack faulting and spalling in a particular pavement design, or cracks that are starting to demonstrate cracking and/or spalling.

Future Plans

As of the summer of 2000, MDOT has installed dowel bars to restore load transfer at seven locations throughout the state. The first test installations were installed in 1997, and yearly monitoring has shown

that the majority of the retrofits are performing as expected. There have been a few problems at a couple locations with spalling of the patching material. This was more of an aesthetic problem, as the retrofits were still performing their function of load transfer. The slots that exhibited this spalling have since been repaired. There were also a problem with a couple projects where the set of slots, usually in the right wheel path, had cracks originating from the ends of the slots to the shoulders. The whole set would then get punched down up to 50 mm creating a pothole or sinkhole-type situation. This problem will be addressed through full-depth repairs, and possible causes for the condition are being investigated.

All of the installations are monitored yearly to ensure proper performance. Of the installations thus far, the cost of installation for the dowel bars is roughly 1/3 the price of a full-depth repair.

MDOT is planning to continue dowel bar retrofits in the future. It is proving to be a relatively inexpensive way to not only maintain or restore ride quality, but to increase the overall performance of the concrete pavements through the improvement of load transfer ability. If things go as planned, the common "thump" may be a thing of the past.

Contact Information

For more information regarding Michigan's experience with load transfer restoration using dowel bar retrofits, or the special provision mentioned earlier in this report, please contact Mike Eacker, Construction & Technology Division, MDOT at (517) 322-5673, or via email at EACKERM@mdot.state.mi.us. In addition, there is also the *Concrete Pavement Rehabilitation - Guide for Load Transfer Restoration*, published by the Federal Highway Administration, publication no. FHWA-SA-97-103 that is available by calling the Local Technical Assistance Program at Michigan Technological University at (906) 487-2102.

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Research Writer/Editor Scott Bershing