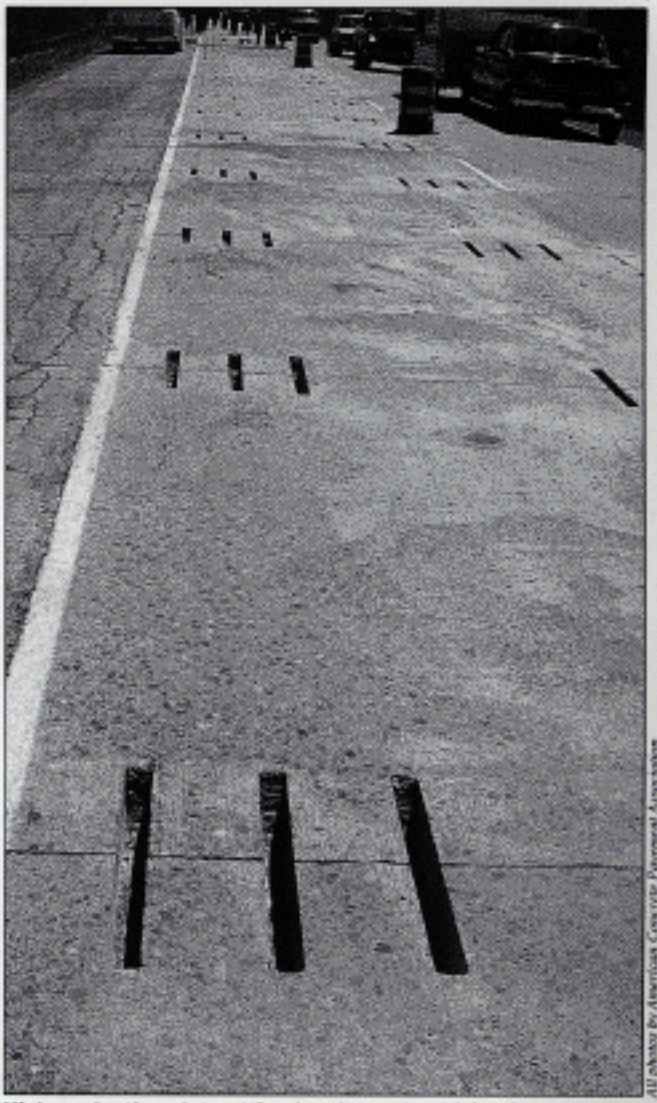
Dowel retrofit restores pavement load transfer

When combined with diamond grinding, it provides a long-lasting solution to faulted joints and cracks

By James W. Mack, P.E.



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High-production slot cutting has been the driving force behind the renewed interest in dowel bar retrofit.

Concrete pavements have been serving the United States well for more than 100 years. The first, built in Bellefontaine, Ohio, in 1893, carried traffic until its 100th anniversary in 1993. Throughout this century of service, concrete pavements have had one primary location of weakness—the joints.

Because concrete shrinks as it gains strength and hardens, joints are placed at certain intervals to control the location and pattern of the cracking. Today, modern pavement jointing details include dowels, proper joint reservoir design, and durable sealants. Proper details, along with regular maintenance programs, have made possible the construction of durable, high-quality joints that help concrete pavements perform for many years.

Unfortunately, many roads built in the past do not contain joints with the proper design features. Pavement designers often placed the joints too far apart and did not use dowels because of underpredicted traffic volumes. Some of these pavements have carried up to three times more traffic than their design. Consequently, they have lost their load transfer capability, which consisted mainly of aggregate interlock. Load transfer is a slab's ability to transfer part of its load to its neighboring slab. The higher the load transfer, the better the pavement performs. Pavements with poor load transfer often suffer from joint faulting.

Until very recently, the two most common practices roadway agencies used to fix roughness and faulting were asphalt overlays and diamond grinding. The problem with these methods is that they cover up or remove the faulting, but do not address the problem of poor load transfer at the joints and cracks. Reflection cracks quickly deteriorate asphalt overlays, and faulting often returns to diamond-ground surfaces. Either way, the life of the improvement rarely exceeds 8 to 10 years.

However, recent improvements in concrete pavement restoration techniques have provided a better solution to the problem of poor load transfer. Dowel bar retrofit is an operation in which slots are cut into the concrete across the joints and cracks, and dowels are placed in the slots to restore the

Figure 1. **The machine above saws the edges of all six dowel slots at one time. The machine below saws three slots at a time. After sawing, traffic can be returned to the pavement until the fins between the sawcuts are removed.**

load transfer. When combined with diamond grinding, dowel retrofit increases the load transfer capabilities and structural capacity of the pavement and removes its roughness.

Dowel bar retrofit is a relatively simple procedure that consists of five main operations:

1. Cutting the slots
2. Preparing the slots
3. Placing the dowel bars
4. Backfilling the slots
5. Opening the pavement to traffic

Cutting the slots

Advancements in slot-cutting equipment have been the driving force behind the renewed interest in dowel bar retrofit. Manufacturers have developed two types of equipment that are capable of cutting slots quickly and efficiently: the diamond-saw slot cutter and the modified milling machine. Of the two, the diamond-saw slot cutter is the most reliable and proven method, while the modified milling machine has been used only experimentally.

Diamond-saw slot cutting. In diamond-saw slot cutting, multiple sawcuts are made that form the edges of the slots. The cutting operation leaves fins in between the sawcuts that must be removed. Currently, there are machines that are capable of cutting either three slots (one wheel path) or six slots (two wheel paths) in one pass (Figure 1).

To cut the slots, the saw head is placed before the joint or crack, then plunged into the concrete and advanced across the joint or crack. Typically, the saw operator must make more than one plunge to cut the slot to its required depth. The plunging and moving back and forth across the repair area creates a flat bottom along the slot that is used to keep the dowel in proper alignment. The slot must be long enough to allow the dowel to sit at the bottom of the slot without its ends hitting the curves of the sawcuts. Typically, this requires the surface length of the sawcut to be 3 feet for an 18-inch-long dowel bar. After sawing, traffic can be returned to the pavement until the fins are removed.

Modified milling machine. When milling the slots, the modified milling machine is placed before the joint or crack, then plunged into the concrete and moved across the repair area. The advantage of milling is that it creates the slot in one pass and does not leave concrete fins that need to be broken out. However, because the milling operation creates open slots, you can't allow traffic on the pavement; you must complete the entire dowel retrofit operation in one stage.

Some agencies have raised concerns about the milling process causing microcracking at the slot edges and fractures at the crack or joint faces. They suspect that the microcracks and fractures may decrease the long-term durability of the dowel retrofit. Presently, the Indiana Department of Transportation is investigating the possible detrimental side effects of milling the slots.

When creating the slots, it is essential that they are cut parallel to the center line of the pavement. This keeps the dowels in proper alignment

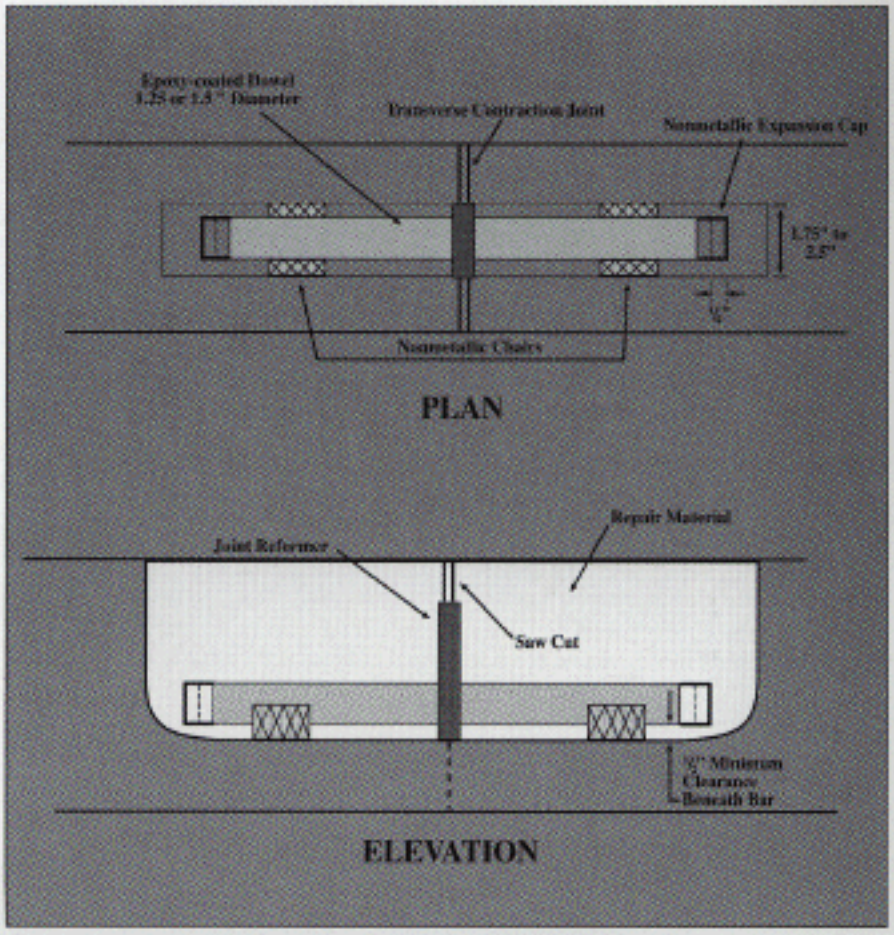

Figure 2. **Plan and elevation views of dowel retrofit details.**

and prevents them from locking up or tying the pavement together. Slots are cut between 1¼ and 2½ inches wide and slightly deeper than half the slab depth. This puts the dowel at the slab mid-depth after placement (Figure 2).

The most effective slot pattern appears to be three slots per wheel path. The outside wheel path dowels should start 12 to 18 inches in from the pavement edge and be separated by 12 to 15 inches. The inside wheel path dowels should start 18 to 24 inches in from the center line and be separated by 12 to 15 inches (Figure 3).

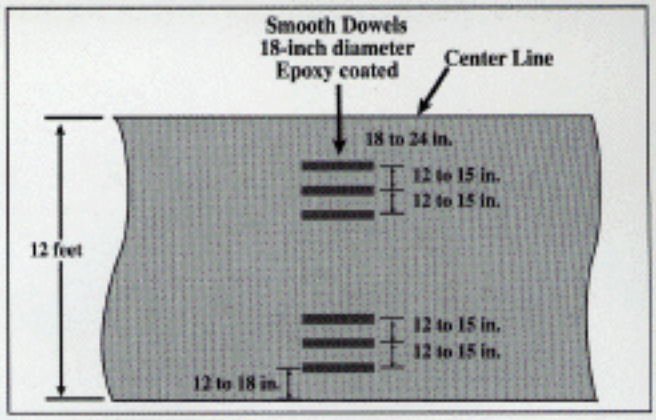

Figure 3. **Three slots per wheel path is a typical slot pattern.**

Preparing the slots

If the slots are sawed, slot preparation consists of removing the fins, flattening the bottom of the slots, cleaning the slots, and caulking the joints or cracks. If a milling machine is used, slot preparation consists of cleaning the slots and caulking the joints or cracks.

To remove the fins after sawing, use a hand-held jackhammer no heavier than 30 pounds to chip out the concrete. Larger jackhammers may break through the concrete, which will then require a full-depth repair. One technique to remove the fins is to place the jackhammer at the end of the fin and jackhammer down and along the bottom of the sawcuts (Figure 4). Another is to place the jackhammer along the side of the slot and break off the fin. Either way, with some practice, most workers can remove a fin in two or three large pieces.

After removing the fins, flatten the bottom with a small hammerhead bit mounted on the jackhammer. This removes rocks and stubble from the slot bottom. Rocks and stubble can prevent proper dowel alignment by keeping the dowel from sitting level. They can also prevent the patching material from completely encasing the dowel. Improper dowel alignment and incomplete encasement can result in pavement lockup or dowel socketing. Pavement lockup is the inability of the joint or crack to open and close with temperature changes. Dowel socketing is the widening of the dowel hole, which leads to loss of load transfer.

The slot must be clean when placing the dowel and patching material. Otherwise, the patch material may not bond to the slot sides. To clean the slot, sandblast the sides and bottom, then airblast them. To determine if the slot is clean, wipe your hand along the slot sides and bottom. If there is laitance or dust on your hand, the slot is not clean and will need to be recleaned.

The final step in slot preparation is caulking the joint or crack on the bottom and sides of the slot. This keeps the patching material from entering the joint or crack. If the patching material gets into the joint, point bearing stresses can develop when the joint closes, causing spalling and possibly failing the repair.

Placing the dowels

The dowels used for retrofitting are the same as those used for new concrete pavement construction, with a few modifications. Their minimum length is 14 inches. They must be long enough to have at least 6 inches on each side of the joint or crack being repaired when placed in the slot. However, due to construction and field variability, most agencies have used 18-inch-long dowels in their major repair projects. The minimum dowel diameter is either 1¼ or 1½ inches, depending on the slab thickness. Finally, the dowels should be epoxy-coated over the entire bar, including the ends, to prevent the corrosion that can cause the pavement to lock up.

Before placing it into the slot, fit the dowel with a ¼-inch nonmetallic expansion cap, a plastic foam or filler-board joint reformer, and nonmetallic chairs (Figure 5). Placed on one end or both ends of the dowel, expansion caps allow the joint to open and close after installation. Placed at the dowel midpoint, the plastic foam joint reformer also allows slab movement by keeping patching material out of the joint. Nonmetallic chairs are placed at each end of the dowel to lift the dowel ½ inch off the slot bottom and ½ inch away from the saw kerf ends. A ½-inch clearance at the bottom and sides of the dowel ensures that the patch material will be able to completely encapsulate the dowel. It is important to use nonmetallic chairs and endcaps on the dowels. Otherwise, the dowel may corrode and cause pavement lockup.

Before placing the dowel in the

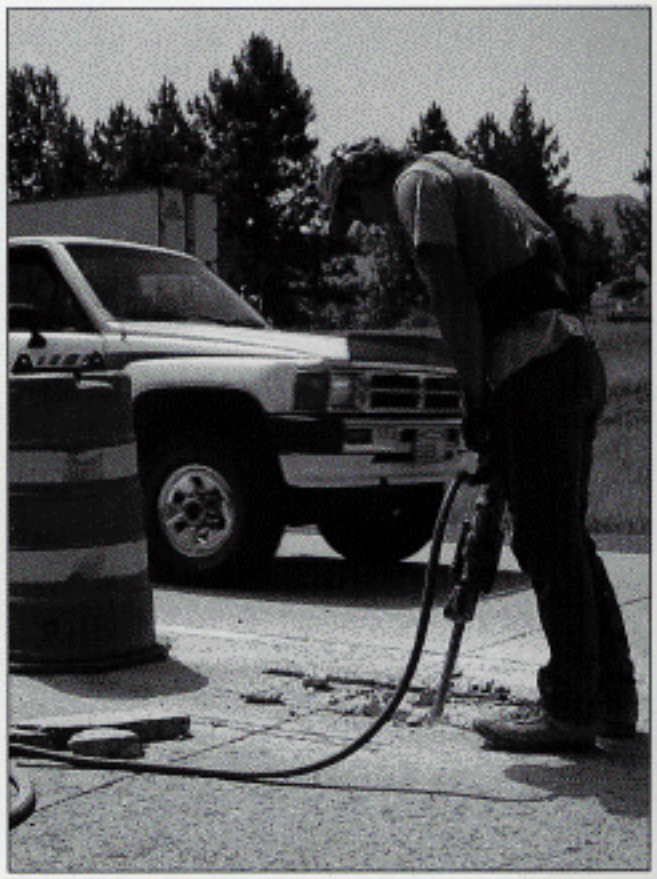
Figure 4. **One technique to remove the fins is to place the jackhammer at the end of the fin and jackhammer down and along the bottom of the sawcuts. With some practice, most workers can remove a fin in two or three large pieces.**

slot, cover it with a debonding agent such as form oil or grease so that it can move within the patch after it has hardened. However, make sure that no oil or grease falls onto any of the slot surfaces. Oil or grease will keep the patch material from bonding to the slot, which could cause the patch to fail. Some agencies have tried placing a sleeve over the dowel, but this is not recommended. Sleeves build an inherent looseness into the slot that could cause the dowel to socket and fail.

To insert the dowel properly, place it so that the chair legs are in the sawcut kerfs at the bottom of the slot. This maintains proper dowel alignment by keeping the dowel horizontal and parallel to the pavement center line and surface. The joint reformer should be over the joint or crack with half of the dowel on each side of the joint. The legs and sides of the chairs should also be snug against the slot wall. This keeps the dowel from moving and becoming misaligned during placement of the patch material.

Backfilling the slots

Generally, any material that works for a partial-depth repair should work as a patch material for a dowel retrofit. The patch material should have thermal properties similar to concrete and have little or no shrinkage. It should also set and develop strength quickly so the repair can support traffic as soon as possible.

Several state agencies have used both fast-track concrete mixes and proprietary mixes successfully. The fast-track concrete mixes usually contain Type III cement, accelerators, and aluminum powder. Accelerators shorten the concrete set time and aluminum powder reduces its shrinkage. However, be careful when using chloride accelerators. Too much chloride accelerator may cause the dowel bar to corrode. For proprietary mixes to perform well, you need to follow the manufacturer's recommendations closely. For both the fast-track concrete and proprietary mixes, use a maximum aggregate size of ⅜ inch. This helps ensure that the dowel bar is completely encased by the patch material.

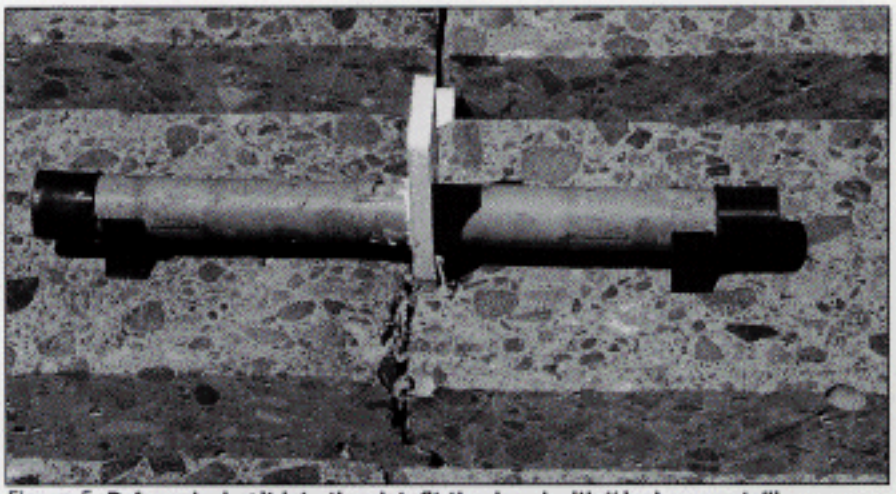

Figure 5. **Before placing it into the slot, fit the dowel with ¼-inch nonmetallic expansion caps, a plastic foam or filler-board joint reformer, and nonmetallic chairs.**

To place the patch material, shovel the concrete into the slot and consolidate it in the slot and around the dowel bar with a spud vibrator. Be careful not to hit the dowel bar with the vibrator when placing the patch material. This may knock the dowel out of alignment. After consolidating the concrete, you may want to put a curing compound on the patch, depending on the weather conditions. Although hot and windy conditions will probably require a curing compound, cool, calm conditions will not. The finish of the patch usually is not crucial since the entire pavement surface is usually diamond ground shortly after the dowel retrofit is complete.

Opening to traffic

You can allow traffic back onto the dowel retrofit when the patch material has gained adequate strength. Recent fast-track studies have shown that the minimum compressive strength required to open a repair to traffic is about 2000 psi for a slab that is 8 inches thick or greater. Most fast-track concrete mixes and proprietary mixes can gain this strength within two to six hours after placement. A recent dowel retrofit job in Washington state used a patch material that reached 4000 psi compressive strength in about two hours. Once the dowel retrofit is complete and open to traffic, the entire pavement should be diamond ground. This will remove the joint faulting and imperfections left after the patching procedure and restore the rideability of the roadway.

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