ROAD SCIENCE

by Tom Kuennen, Contributing Editor

Correcting Problem Concrete Pavements

How to restore rideability and prolong the working life of flawed concrete pavements.

Concrete pavements are noted and specified for their longevity and ease of maintenance. As a result, most ills that befall portland cement concrete pavements are the result of flaws in the initial construction or lack of maintenance inspection.

Photo courtesy of Strong Mfg. Co.

Fortunately, a palette of proven concrete pavement restoration repair options is available to agencies wishing to bring their existing concrete pavements up to optimum standards for rideability, longevity, and customer satisfaction.

Better Roads editors recently reported on CPR practice and acceptance by state DOTs (see *States Talk Strategy on Pavement Restoration, Better Roads,* September 2002, *Concrete Paving Today* Special Section, pp 4a-8a). In this article we take a second look at CPR implementation in the field and look at ways PCC pavements can be constructed to preclude the need for CPR in the first place.

Do it right the first time

"When concrete pavements are done right, they last a long, long time," says Joseph P. Ellis, COMTECH (Construction Maintenance Technology) construction manager, Delaware Department of Transportation in Dover.

"You have to start with a smooth, rideable pavement," Ellis says. "If you don't have a rideable pavement, you will get complaints from the motorists, and the pavement will suffer stresses from large vehicular traffic."

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A long-lived PCC pavement begins with a well-constructed joint system, he says. "PCC pavements can last 30 to 50 years," Ellis says. "You've got to have a good joint system to begin with. But the pavement will only be as good as the maintenance it gets, primarily on the joint system."

Also fundamental to a successful PCC pavement is a permeable base course, Ellis said. "This base

(left) A volumetric mixer custom-blends concrete for the specific needs of this restoration application.

No Secrets to Successful CPR

This failed concrete pavement joint is packed with debris and incompressible matter that will cause great damage in freeze-thaw cycles.

A subgrade failure caused this concrete slab fault from below.

Grinding is used to prepare a longitudinal joint for repair.

Limited spalling at failed joints may be repaired using ultra-fast proprietary patching compounds- in this case, TechCrete.

Photos courtesy of Crafco, Inc.

Incompressible materials entering unsealed joints during winter will play havoc as slabs go back into expansion in the summer months.

course will be more forgiving if you have a bad joint. If you're not going to pursue a strong maintenance program during construction, you'd better have a very good permeable base course that drains penetrating water and any ground water to a functioning underdrain system and outlets." Such a base will remove water from failed joints, but still will not address the problem of incompressible debris entering joints.

Concrete surfaces that are initially rough can be diamond-ground to get a good, rideable surface, but this is not without potential problems. "In Delaware, because of the severe winters we've had, we're seeing some damage to areas of large aggregate exposed by grinding," says Ellis. "Instead of a smooth surface, our plows are hitting the exposed aggregate, and we're getting some pop-outs of aggregate.

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"Built-in drainage problems can erode unstable base material, causing voids below the pavement. This is particularly a problem on bridge approaches where the subgrade hasn't been carefully compacted," Ellis says.

If load transfer between slabs is lacking or failing, slabs then can pump up and down as trucks come and go, actually spurting wet base material out of the sides of the slab. As the base voids enlarge, the slab can completely crack. The remedy is pressure grouting into the void, called slabjacking. But slabjacking is never an issue if the base is constructed properly in the first place.

Additional tips on PCC pavement construction will be found in *Road Science: New Technologies Boost Concrete Pavement Smoothness, Better Roads,* March 2003, pp 36-46.

Inspect, repair PCC joints seasonally

Continuous inspection is required to keep concrete pavements in top shape. "A continuous maintenance and inspection program of joints and seals is needed," Delaware's Ellis says. "As soon as those joint seals begin to fail — there will be isolated failures every year through expansion and contraction, as joint material blows out — you must immediately reseal the joint, especially before material can get down in the joint. Every spring there should be a maintenance inspection program implemented for PCC pavements."

Incompressible materials entering unsealed joints during winter will play havoc as slabs go back into expansion in the summer months. As the slabs cool and contract, they break the adhesion of the joint sealing compound — be it silicone, Neoprene, or hot-pour — and incompressible matter enters. Then as the slab expands, the incompressible matter causes the joint to shatter and deteriorate.

"The faster you can clean and reseal those joints,

Full-Depth Repairs Restore Pavement Rideability, Integrity

Full-depth repair is a CPR technique that restores the structural integrity and rideability to concrete pavements having certain types of distresses, reports the Federal Highway Administration Office of Pavement Technology.

"[Full-depth repair] involves making lane-width, full-depth saw cuts to remove the deteriorated concrete down to the base, repairing the disturbed base, installing load-transfer devices, and refilling the excavated area with new concrete," the FHWA says. "It is an effective, permanent treatment to repair pavement distresses, particularly those that occur at or near joints and cracks."

By removing and replacing isolated areas of deterioration, full-depth repairs may delay or stop further deterioration and restore the pavement close to its original condition. Distresses that can be addressed using full-depth repairs include transverse cracking, corner breaks, longitudinal cracking, deteriorated joints, D-Cracking, blowups, and punchouts.

"With good design and construction practices, full-depth repairs should perform for as long as the surrounding concrete slabs," the FHWA reports. But certain factors need attention, including joint design and load transfer; selection of repair locations and boundaries; material selection; preparation of repair area; concrete placement and finishing; "o" joint sealing, and the future curing and opening to traffic.

The FHWA outlines eight steps in the construction and installation of full-depth repairs:

- Define repair boundaries area.
- Saw old concrete.
- Remove old concrete.

the longer your pavement will last," Ellis says. "If you let it go one season, and the slab goes back to expansion with debris in the joint, you've got a failure. Once a joint starts failing, the whole pavement can start to fail. And once that area is weakened, you've lost the rideability and the long-term viability of the pavement structure."

Curing concrete ills

When concrete pavements spall or become rough, when slabs fault, or when joints crumble, a host of pavement repair options is available to pavement owners.

Gathered under the umbrella of concrete pavement restoration, these repairs are effective at bringing a pavement back to initial or even improved smoothness, while prolonging pavement life.

On the downside, these repairs can be labor-intensive, time-consuming, and intrusive to motorists due to lane closures. And even if a pavement is to be overlaid with hot mix asphalt, CPR may be required to repair the future base, lest those pavement ills reflect upward and ruin the asphalt friction course.

It's for those reasons that the industry emphasizes building a concrete pavement right the first time, thus minimizing the need for restoration work in years hence.

The practices that constitute CPR include repairing portions of a concrete pavement with the type of joint specified; diamond grinding pavement to spec; resawing and sealing existing longitudinal pavement joints; and sawing, cleaning, and sealing cracks in concrete pavements.

Photo courtesy of Crafco, Inc.

A so-called "hot lance" is used to clean and prepare the base of a spall prior to patching.

The equipment used for restoration is evolving year after year. For example, some of the acceptability of CPR has resulted from research undertaken in the 1990s by the FHWA, says Angel Correa, P.E., pavement design engineer, FHWA's Southern Resource Center, Atlanta.

"In the early 1990s the Washington State DOT investigated alternative ways of rehabilitating older concrete pavements," Correa says. "The Wisconsin DOT was encouraged by the FHWA to consider the use of dowels for restoring load transfer in existing concrete pavements." In 1992 Wisconsin constructed short experimental sections to evaluate the technique, and achieved favorable results, he says.

- Prepare patch area.
- Provide load transfer.
- Place and finish concrete.
- Cure and insulate concrete.
- Saw and seal joints.

"Before removing deteriorated concrete, isolate the area from adjacent concrete and shoulder materials using full-depth saw cuts," the FHWA says. "The full-depth cuts separate the segment of deteriorated concrete and allow room for its removal with minimal damage to surrounding materials." The FHWA suggests diamond-bladed saws are preferable for full-depth transverse cuts.

After removing the old concrete and loose material, the area is ready for subbase preparation. If removal operations damage the subbase, it may be necessary to add and compact new subbase material.

"Automatic dowel-drilling rigs are preferable to single, hand-held drills," the FHWA says. "It is difficult to drill consistent holes using hand-held drills because they are heavy and do not have an alignment guide or jig."

Dowels may be held in place with grout or epoxies. For epoxy injection, the wand on the installation unit should contain an auger-type mixing spindle that mixes the two-part epoxy. "Prefabricated epoxy cartridges are available that supply enough material for one or two holes; a more cost-effective system for large projects uses a pressurized injection system from bulk epoxy containers," the FHWA says.

The final step is to form or saw transverse and longitudinal joint sealant reservoirs at the patch boundaries.

More information, including field photography, is available at *www.fhwa.dot.gov/pavement/full.htm*.

The precast process also greatly reduces construction variability, assuring uniform thickness and material quality.

Precast Slabs: Hassle-Free Full-Depth Pavement Repairs

Precast slabs for full-depth concrete repairs may speed construction, with attendant reduction in road-user delays and work-zone exposure, says Neeraj Buch, Michigan State University, Vernon Barnhart, Michigan DOT, and Rahul Kowli, MSU, in their January 2003 Transportation Research Board paper, *"Pre-Cast Concrete Slabs as Full-Depth Repairs."*

Dr. Buch stressed to *Better Roads* editors that their work is a preliminary investigation into the utility of precast slabs for concrete pavement repairs, and more study is needed. Nonetheless, their work is an indicator of the ways restoration may become more widespread as fast-paced field alternates to existing procedures become available.

In October 2001 and summer 2002, Michigan State University, in cooperation with the Michigan DOT, installed 21 precast full-depth patches along I-94 BL (Benton Harbor) and I-196 (South Haven) in southwestern Michigan. The installation will be studied over time to judge its performance.

The use of precast PCC panels has the potential to address the key issues of urban pavement renewal such as minimized construction time and reduced user delay costs, and enhanced long-term pavement performance.

Precast concrete panels eliminate the time required in the field for PCC curing, as well as offering excellent quality concrete batched in factory conditions, with high strength, low shrinkage, and superior durability. Ideal factory conditions also provide control of built-in curling, eliminating slabs with excessive built-in curling. The precast process also greatly reduces construction variability, assuring uniform thickness and material quality.

"Precast concrete repair can satisfy the service life requirements by avoiding material-induced distress, but at higher installation costs," they wrote. "However, previous cost comparisons did not consider user delay or future maintenance. Today most [states] mandate a life cycle cost analysis and inclusion of user costs when pavement preservation options are considered."

Then, in 1992 an FHWA special project (SP 204) was undertaken to encourage industry to develop equipment for economically constructing slots for retrofit load transfer. "Tests conducted in 1993 and 1994 proved this technology successful," says Correa.

"As a result of the FHWA-sponsored evaluations, many states are now using dowel bar retrofit," Correa says. Several state DOTs are also now routinely performing load transfer restoration using smooth dowel bars as part of their concrete pavement maintenance or rehabilitation programs.

"Diamond sawing equipment has been used on regular construction or maintenance projects in Kansas, Puerto Rico, Washington state, and North and South Dakota," Correa continues. "The carbide-milling equipment has been used on regular construction projects in New Jersey, West Virginia, and Minnesota."

New materials help

Also, new technologies in materials are making restoration more palatable to state DOTs and the driving public by reducing highway user delays. These materials include fast-setting, proprietary products which make it possible to repair concrete spall and potholes in less than an hour.

"We have been looking at these materials and feel they are beneficial," Delaware's Ellis says, "but we have found that preparation is critical to every one of the products."

For spall repair work with one such product, crews cut about 3 inches around the spall making a square-edged saw cut to 1-inch depth. Using 60-pound air hammers, users can chip out the damaged concrete down to sound material. The patch is cleaned out and air-blasted to remove moisture and fines.

A supplied primer is placed in the patch area, and after a 5- to 10-minute wait, patching compound from a melter is poured in the patch with buckets, or for larger patches, placed in the patch directly from the pot. Finally, a specified, high-performance aggregate is placed over the patching material before the material has cooled to a firm consistency.

This particular product, TechCrete, is a hot-applied, polymer-modified, resin-based flexible concrete-repair material which can be used to repair cracks, spalls, pop-outs, failed joints, and most types of defects in concrete surfaces up to a maximum depth of 8 inches. It is marketed by Crafco.

Beyond spall repair

Beyond spall or pothole repair, removal of deteriorated concrete requires full-depth sawing, often in multiple passes within the same operation, though sometimes in one pass.

Transverse saw cuts are made in a straight line at a right angle to the centerline of the pavement. The longitudinal joints adjacent to other lanes, ramps, shoulders, or curb and gutter are sawed full depth.

Pavement surfaces ought to be flushed with water immediately after sawing to remove all slurry. Concrete between narrowly spaced saw cuts at the end of a slab may be removed with hammers and hand tools. However, sawed slabs ought to be lifted without disturbing the base by using cables or chains attached to a backhoe, wheel loader, or backhoe-loader.

Load transfer essential

As pavement loads pass from existing concrete pavement to patches or newly placed slabs, uneven movement of pavement against slabs will result. Therefore common practice requires use of dowels or "deformed" tie bars across transverse joints, which permits common movement of pavement and repair slab as the load transfers from one to the other.

Minnesota requires that load-transfer dowel bars be epoxy-coated to resist chloride attack.

Using 60-pound air hammers, users can chip out the damaged concrete down to sound material.

To accommodate the dowels, the faces of the existing pavement are drilled — sometimes by hand, but more often with a drilling attachment or even dedicated machine — to permit insertion of the dowel bars. Load transfer device holes must be drilled to the proper depth, diameter, and alignment.

For these larger slab replacements, fast setting, accelerated cements are indicated. When fresh concrete finally is placed in the open cavity, it should be cast in one, continuous full-depth operation. Concrete should be consolidated using a vibrator, with attention given to consolidating the concrete around dowel bars or other load transfer devices.

The PCC patch surface should be struck off flush with the existing pavement surface with a screed, either vibratory or rolling. Floating instead of striking off with a screed may not be acceptable to all states.

Transverse texturing of the repair surface likely will be required, usually to conform to the texture of the adjacent pavement.

When needed — especially during summer months — curing compound must be applied immediately after any free water has evaporated from the surface.

Sawing and sealing joints

After a full slab patch is placed, sawcuts made in pavements or shoulders by overcutting ought to be

Photo courtesy of Crafco, Inc.

Hand work with a pneumatic hammer is needed to prepare this smaller spall for repair.

The transverse and longitudinal joints are resawed over the existing joint groove to produce a finished joint with two freshly sawed faces.

A failed joint is sawed in preparation for replacement.

cleaned and then sealed. These joints typically are sealed with hot-poured sealant after all CPR, spall repair, and pavement texturing or profiling is done.

The transverse and longitudinal joints are resawed over the existing joint groove to produce a finished joint with two freshly sawed faces. Immediately following the sawing operation, the joint groove may be flushed to remove slurry and debris from the joint groove. After final cleaning of the joints, a backer rod is inserted into the joint to provide a 1:1 width-to-depth ratio of the hot-poured sealant. The backer rod conserves expensive sealant, saving money for taxpayers.

More information on pavement sawing and drilling is available from the Concrete Sawing & Drilling Association, 10901D Roosevelt Blvd. N, Suite 100, St. Petersburg, Florida, 33716, *www.csda.org*.

Diamond grinding smooths way

Despite the fore-mentioned cautions about pop-outs, diamond grinding is a method of smoothing rough concrete pavement and correcting roughness due to minor concrete slab faulting.

Typically, diamond grinding equipment employs diamond blades mounted on a self-propelled machine specifically designed for grinding and texturing pavement. The equipment should not damage the underlying surface of the pavement, nor should it cause raveling or fracture of aggregate, spalls, or otherwise impair existing transverse or longitudinal joints.

Grindings residue and leftover water are typically vacuumed with equipment that can extract slurry grindings from the pavement, preventing fugitive dust.

Grinding typically is undertaken in a longitudinal direction, and begins and ends perpendicular to the pavement centerline. The area ground must not be polished or slick, and grinding must not be undertaken when danger of water freezing is present.

The Portland Cement Association and its allies, the International Grooving & Grinding Association and the American Concrete Pavement Association, note that diamond grinding can repair distresses such as:

- Removal of transverse joint and crack faulting (most common reason for grinding).
- Smoothing out built-in or construction roughness.
- Texturing of a polished concrete surface to improve friction.
- Removal of wheel path rutting caused by studded tire wear.
- Reducing noise level caused by tire-pavement interaction.
- Removal of permanent upward slab warping at joints.
- Improvement of transverse slope to improve surface drainage.

Diamond grinding involves removing a thin layer (4-6 mm) at the surface of hardened portland cement concrete using closely spaced diamond saw blades. "The blade assembly cuts tiny grooves in the pavement surface, providing texture as it smooths down surface irregularities," PCA says.

Grindings residue and leftover water are typically vacuumed with equipment that can extract slurry grindings from the pavement, preventing fugitive dust.

More information is available from IGGA, 126 Mansion St., P.O. Box 58, Coxsackie, N.Y., 12051, *www.igga.net;* and from the ACPA, 5420 Old Orchard Road, Suite A100, Skokie, Illinois, 60077, *www.pavement.com*.

Streamlining CPR

In the future, the industry is working toward a streamlined restoration process that will use state-of-the-art equipment and high-performance materials, so that a mile-a-day restoration can be common practice, according to a forward looking essay penned by industry experts affiliated with the Transportation Research Board at the turn of the century.

Until then, agency owners and concrete contractors will have to do the best they can to build concrete pavements right the first time to preclude the concrete pavement restoration that may otherwise follow. **BR**