by Tom Kuennen, Contributing Editor

Roadbuilders to Get Fresh Look at Two-Lift Concrete Paving

Used routinely with wire mesh for decades, two-lift concrete fell into disuse, but safety and 'green' paving provide new impetus for two-lift paving.

At the Highway D1 project in the Czech Republic, contractor Skanska DS a.s. uses an excavator to place the top layer of concrete mix into a two-lift paver designed by GOMACO, based on a GP-4000 paver. The bottom layer of concrete was dumped directly on the ground, in front of the GP-4000.

Photo courtesy of GOMACO.

Slowly but surely, two-lift construction of portland cement concrete pavements is returning to the United States..

Two-lift construction involves the placement of two wet-on-wet layers of concrete — or bonding of wet to dry layers of concrete — instead of the homogenous single lift most commonly placed in concrete paving.

With two-lift paving, a thick bottom layer contains aggregate of lesser quality, lower durability or strength, locally available aggregate, or more often, recycled aggregate composed of recycled concrete or reclaimed asphalt. A thinner top layer consists of premium aggregate, perhaps non-locally sourced, designed to provide superior resistance to freeze-thaw damage as well as noise reduction and improved traction.

Balancing the environmental and skid-resistant benefits of two-lift paving are inescapable higher costs. Either two concrete pavers or a combination paver, which places two lifts at once, is required, along with two concrete plants nearby, plus added labor and trucking costs. However, the use of secondary materials such as reclaimed crushed concrete pavement or reclaimed asphalt pavement — perhaps sourced on the same project under

In Austria, two-lift concrete paving is achieved with two pavers; the front paver receives the top lift mix via the hopper at right.

Photo courtesy of Hermann Sommer.

construction — can undercut the added costs.

"Two-lift paving has been utilized for some time in Europe," said Sam Tyson, P.E., concrete pavement engineer, Federal Highway Administration Office of Pavement Technology. "The equipment needed for two-lift paving is available in the United States, because instead of using a single paver modified to apply both layers in series, two pavers can be used. In any case, you have to operate two concrete plants as you must supply fresh concrete for the bottom layer and the top surface course right behind it."

One configuration could be a 9-inch bottom layer, topped with a 3-inch surface layer. "Both are structural layers," Tyson told *Better Roads*. "But with the bottom layer, the composition is less critical, so we can incorporate, for example, recycled concrete aggregate from the same project for cost savings and environmental benefits. That might not be satisfactory for the wearing surface, but it would be fully satisfactory for the principal structural portion of the pavement. The 3-inch surface layer would achieve a long-life pavement by means of its superior durability characteristics and its materials would promote skid resistance and noise reduction."

Two-lift paving not new

While two-lift paving is not new to the United States, today's emphasis is new. Between 1950 and 1970, two-lift paving was implemented extensively in many states, including Iowa, Wisconsin, Michigan, Pennsylvania, and Minnesota, to facilitate placement of mesh in Interstate highway construction. But between 1970 and 2000, the U.S. concrete paving industry moved away from a mesh pavement design and significantly shortened the design length of pavement panels, effectively eliminating the need for two-lift paving.

Today's new emphasis on two-lift concrete paving was launched during a panel on long-lived concrete pavement technologies at the January 2007 annual meeting of the Transportation Research Board in Washington, D.C.

The panel followed a May 2006 international fact-finding tour in which two-lift paving was studied. The goal of the long-life concrete pavement scan tour was to learn more about design philosophies, materials requirements, construction practices, and maintenance strategies involved in constructing and managing portland cement concrete pavements with long-life expectancies. Two-lift paving was one of those themes.

Sponsored by the Federal Highway Administration, the American Association of State Highway and Transportation Officials, and the National Cooperative Highway Research Program, the scan team included representatives from state transportation departments, the FHWA, NCHRP, academia, and industry associations.

During that 2007 Transportation Research Board session, Suneel Vanikar, P.E., panel moderator and FHWA concrete group leader, Office of Pavement Technology, said the FHWA would support six to eight two-lift demonstration projects in various parts of the country.

A final report — *Long-Life Concrete Pavements in Europe and Canada* — was issued in August 2007 and explicitly recommends two-lift construction, along with continued research into other concrete topics including higher quality foundations, mix design components, use of a geotextile interlayer in concrete pavements, and exposed aggregate surfaces for enhanced skid resistance and quieter pavements. The report is available from the FHWA Web site; see *For More Information* for downloading information.

In summer 2007, a *Scan Team Implementation Plan* recommended that two-lift concrete paving in the United States be pursued in the context of exposed aggregate surfaces in the top layer for noise reduction, combined with the use of recycled concrete in the lower layer for economical and environmental reasons.

Development of two-lift concrete paving now is spearheaded by the FHWA's *Highways for LIFE* program. The program will disburse funding for the state demonstration projects, with the Federal Highway Administration providing technical assistance to

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states for two-lift concrete paving. Also last summer, *Highways for Life* produced a video conference on two-lift paving in a joint effort with the National Concrete Pavement Technology Center at Iowa State University, and the FHWA's Office of Pavement Technology. Drawing participants from across the country, the live video conference featured presentations on the May 2006 scanning tour.

"In the countries visited, concrete pavement means long life," said scanning tour participant Tom Cackler, director of the National Concrete Pavement Technology Center, at the video conference. Also featured was a presentation by Dr. Hermann Sommer, chair of the Committee for Specifications for Concrete Pavements and Soil Stabilization in Austria, which has extensive experience in using two-lift technology.

On the Skanska project, the four-track GP-4000 was equipped with an In-the-Pan Dowel Bar Insertion system, and G21 technology, which allowed the machine to be controlled by a stringless 3-D machine-control system. Paving widths on the D1 project in the Czech Republic ranged from 35 to 40 feet, with a total thickness of the two-lift slab of 12 inches.

Photo courtesy of GOMACO.

Two lift is 'green' construction

"Two-lift construction contributes to the green highway concept," said video conference participant Charles Goodspeed, faculty liaison of the Transportation Technology Transfer Center at the University of New Hampshire. The use of recycled materials for much of the aggregate — in the thicker, lower lift — minimizes the need for high-quality new aggregate and cuts down on landfill waste, he said. "We're using fewer resources and minimizing the truck traffic and fuel costs required to haul new aggregate," said Goodspeed.

Austria, Belgium, the Netherlands, Germany, and the United Kingdom all are using two-lift paving. Austria started using two-lift concrete paving in 1991. "We consider the long-term performance very satisfactory," said Sommer.

In Austria, he said, two mixing plants and two pavers are used, with the two pavers positioned 13 to 16 feet apart. The top lift is placed before the bottom lift starts to dry, with up to a half hour between the placement of the layers. Best practices described by Sommer include making the top layer as thin as possible, using shallow milling to ensure a good bond with the subbase, and curing immediately after brushing to prevent cracks. "The efficiency of the curing compounds is very important," said Sommer. Austria also uses an exposed aggregate surface to reduce pavement noise. Sommer noted that the cost of two-lift paving has not been significantly higher in Austria.

Michigan's 1993 project

The Kansas DOT is planning a two-lift project on I-70 this year, and the Washington State DOT is planning a project in the Spokane area. But this century's look at two-lift paving was preceded in 1993 by a project involving two-lift paving on the Chrysler Expressway in downtown Detroit.

The total project involved the reconstruction of 2.3 miles of I-75 (Chrysler Freeway) between I-375 and I-94 (Edsel Ford Freeway). The so-called European two-lift pavement design was used for approximately

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1 mile of the northbound section. The remaining portion of the northbound section was constructed using a standard 1993 MDOT pavement design. As a result, the approximately 1 mile of test pavement could be directly compared with approximately 1 mile of a standard pavement design.

This project was spurred by a 1992 FHWA scanning tour of European concrete pavements, and was placed in conjunction with the 1993 national convention of AASHTO in Detroit.

Crushed, recycled concrete aggregate obtained on-site and used on the less-critical lower lift of two-lift concrete paving will lower costs and reduce the cost differential between two-lift and one-lift concrete paving.

Photo by Tom Kuennen.

Tough, durable aggregate, when exposed on the surface of the more-critical top course mix design as used in Austria, will suppress tire pavement noise and enhance skid resistance.

Photo courtesy of Hermann Sommer.

The Michigan DOT elaborated on the major differences between the two designs. The two-lift pavement demo project structural section consisted of 10 inches of two-layer concrete pavement with a special exposed aggregate surface texture, doweled transverse joints at a 15-foot spacing, 6-inch lean concrete base with 6-inch underdrains, and 16 inches of aggregate subbase placed on an existing prepared subgrade. The top-layer wearing surface was composed of a special concrete mix incorporating an extra-hard aggregate, which was left exposed in the finished pavement surface.

The typical 1993 MDOT section consisted of 11 inches of single-layer concrete pavement with standard surface texture (transverse tining into the plastic concrete), doweled transverse joints at a 41-foot spacing, 4 inches of open-graded drainage course with 6-inch underdrains, and 12 inches of sand subbase placed on existing prepared subgrade.

The department indicated that the cost of constructing the test section was $87.76 ($128.19 in 2007 dollars) per square yard; the cost of the standard section was $37.58 ($54.89 in 1997) per square yard.

"The department believes that the two-lift method was the primary reason the contractor-bid costs for constructing the test section were significantly higher than for the standard design section," reported a Michigan House Fiscal Agency memo to the Michigan House Appropriations Subcommittee in May 2005. "To place two concrete mixes wet on wet, the contractor had to set up two paving plants and use two paving crews, resulting in additional labor and equipment costs. The department believes that other elements affecting the cost of the test section included the use of an enhanced base and premium quality joint seals."

Since construction, the department has monitored the performance of the test and control sections. The last formal study appears to be a report prepared by Michigan State University under contract with the department. The report, dated May 2000, was titled *Cost Effectiveness of European Pavement Demonstration Project: I-75 Detroit*. The report found that neither the test section nor the control section showed enough pavement distress to estimate the remaining service life.

"In other words, after seven years, neither section showed distress trends that would allow the researchers to predict how long either section would last," the House Fiscal memo said. "The department continues to make visual surveys of the sections and has found that both sections show little material or structural distress. There is currently no evidence from the I-75 study to indicate that the European pavement test design as used on I-75 is worth the additional construction costs."

According to *High Performance Concrete Pavement: Technical Summary of Results from Test and Evaluation Project 30*, from the FHWA Office of Technology Applications, February 2006, "the cost of the European demonstration project was about 234% more than the Michigan standard section, which would not be typical for standard construction. The Michigan DOT estimates that the costs for the European section would have to be less than 17% more than the standard Michigan section to be cost competitive."

Supporters counter that use of recycled materials — perhaps site-sourced — in the thicker lower lift will counterbalance the cost premium.

GOMACO develops two-lift system

That the added cost of two-lift paving mitigates against its use is acknowledged by the concrete industry. "Certain cost, mix design, and construction concerns are inhibiting the use of two-lift paving," stated Iowa State's National Concrete Pavement Technology Center in a September 2004 flyer, *Reassessing Two-Lift Paving*. "Currently, the greatest resistance to this technique is economic. Two-lift paving often requires the use of two plants, two slipform machines, and a special haul road, all of which add to the cost of the paving project."

Nonetheless it urged research to develop a knowledge base that could come into use as circumstances changed. "If current trends continue and two-lift paving is not further researched and demonstrated, the concrete paving industry won't have enough experience to adequately take advantage of two-lift construction when it becomes cost-effective or otherwise beneficial to do so," NCPTC said.

In addition to extensive use of reclaimed materials in the lower lift, one way of lowering costs is to eliminate the second paver. GOMACO Corporation already has developed a product that can be added to a GP-4000 paver, which recently saw use in the Czech Republic.

In the Czech Republic, Skanska DS a.s., found two-lift pavement was a requirement on its first project, Highway D1. The typical method for two-layer pavement in the country requires two separate machines. A paver leads laying down the first layer of concrete, a placer/spreader follows spreading out

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the second concrete mix, and a second paver follows behind paving the top layer of concrete with a mid-mount dowel bar insertion system.

Officials from Skanska had observed that version of two-lift paving and wanted a more efficient way for their project. They began discussions with GOMACO about a GP-4000 paver with a two-lift system incorporated on a single paver.

GOMACO's two-lift system fits underneath the paver. No extra extensions or paving machines are needed. Skanska ultimately purchased a GP-4000 with the two-lift paving system. The paver is also equipped with an In-the-Pan Dowel Bar Inserter and Leica stringless control system.

Using GOMACO equipment for two-lift paving, Skanska was achieving an average smoothness reading of 0.08 inches per 13.1 feet on the Planograph testing system, half of the project's 0.16-inch specification.

Photo courtesy of GOMACO.

"The two layers are a general requirement for this highway," said Josef Richter, production/technical manager of Skanska. "The difference between the two concrete mix designs is mostly the size and quality of the aggregate. The upper layer has a maximum aggregate size of 0.9 inches, while the bottom has a maximum of 1.25 inches. The mix contains both air entrainment and plasticizers. Aeration is the basic requirement for frost resistance and to resist against chemical sanding."

Not two, but one concrete batch plant was used for both concrete mix designs. Concrete was mixed at a 2:1 batching ratio, with two loads of the bottom concrete mix batched versus just one of the thinner top layer.

Concrete was hauled to the paving site by dump trucks with a hauling capacity of 25 tons. Trucks dumped directly onto the grade for the bottom layer or lift of the roadway. Augers on the front paving pan spread the material, vibration was applied consolidating the bottom layer and the second mold finished the top layer of concrete.

An excavator running in front of the paver emptied concrete out of the trucks for the top layer. The excavator placed the concrete into a specially designed hopper on the front of the GP-4000 paver. The concrete was conveyed from the hopper into a top-layer paving chamber and was spread with an auger across the width of the pavement. The vibrators in the top layer paving chamber ran parallel to the face of the paving pan. Their placement ensured the top layer of concrete was properly consolidated without mixing it into the bottom layer of concrete and changing both mix designs. Vibrators placed along the width of the pan provided proper consolidation to the edge.

The two layers were slipformed simultaneously underneath the length of the paver. The arrangement guaranteed a good bond between the two layers because of the freshness of the two layers of concrete.

Paving widths varied between 35.3 feet and 40.2 feet, depending on project specifications. Producing the two different mix designs from a single plant with double drums limited their daily production, which averaged approximately 1,312 feet per day.

HfL popularizes proven technologies

The FHWA's *Highways for LIFE* program is not intended to make breakthroughs in engineering technology; instead it's intended to spotlight existing or new proven technologies that should be more widely known or used.

"One of our goals is to make the use of some lesser-used existing technologies more widespread," said Mary Huie, *Highways for LIFE* program coordinator. "We want to promote the implementation of advanced technologies, and we work as a technology transfer program. We want to share technological information and best practices on proven technologies with states."

An overarching goal of *Highways for Life* is to promote technologies that will reduce traffic congestion caused by construction, so among its focus technologies are prefabricated bridges, and precast concrete pavements. "If we can replace a bridge deck overnight using elements that were prefabricated elsewhere, it can cut out a lot of congestion, compared to ongoing construction day after day," Huie told *Better Roads*.

Under the *Highways for Life* program, the FHWA may fund up to 15 projects a year that use innovative design or construction approaches to cut construction congestion while enhancing safety, quality, and user satisfaction.

So far, the FHWA has awarded grants to 16 states for projects that include such innovations as prefabricated pavement slabs and bridges, full road closures, traffic maintenance technologies, and contractor incentives.

To qualify for incentive funding, projects must use innovations that are readily available but that the state department of transportation has never or rarely used. Even if the innovation or technology has been used in other states, if it's new to the state applying for funding, the project is eligible for consideration. Project applications also must specify performance goals such as safety, construction congestion, quality, and user satisfaction.

Prefab bridge replacements

One such effort was the overnight replacement of a bridge on I-4 in Florida, which was the subject of an workshop. "Every *Highways for Life* project we select, we prefer to showcase the innovations in some sort of industry event," Huie said. "The event showcases the technology and shares it with others in and outside the state."

Another such project was the 2007 replacement of a bridge in Utah using self-propelled modular transporters. There, *Highways for Life* funding helped the Utah DOT use innovations on the $6.6-million bridge project to reduce construction congestion and build a smoother, quieter, longer-lasting bridge.

Prefabricated bridge elements and systems may be manufactured on-site or off-site, under controlled conditions, and brought to the job location ready to install. Use of prefabricated bridge elements and systems minimizes traffic impacts of bridge construction projects, improves construction zone safety, makes construction less disruptive for the environment, makes bridge designs more constructible, and can increase quality and lower life-cycle costs.

Also, prefabrication of bridge elements and systems can be accomplished in a controlled environment without concern for jobsite limitations, which increases quality and can lower costs. Prefab bridge elements especially tend to reduce costs where use of sophisticated techniques would be needed for cast-in-place, such as in long water crossings, or higher structures, like multi-level interchanges.

Using normal construction techniques on the bridge project would have affected traffic flow on I-215 and Utah S.R. 266 for up to nine months. Using accelerated bridge construction techniques such as prefabrication cut construction time to five months, and traffic impact to only two weeks.

The new superstructure was constructed offsite and the new substructure was built under the existing bridge while it remained in service. Once the new substructure was complete, the existing structure was removed and the new superstructure was moved into place with self-propelled modular transporters.

The interstate was closed to traffic from 6 p.m. Friday to 6 a.m. Monday in late October 2007 for removal and replacement of the bridge structure. The new bridge was ready for traffic by Monday morning rush hour. About 20 out-of-state transportation professionals and hundreds of local residents turned out to observe the weekend bridge move. The visuals of the event were so spectacular that the replacement was covered by CNN.

For motorists using the bridge, the impact included a two-week closure while crews removed the existing structure, set the new structure in place, and prepared the bridge for traffic. For interstate traffic, the impact was even less. Traffic lanes under the bridge remained open while the new substructure was constructed next to the interstate.

HfL: Precast pavement slabs

Like the prefab bridge replacements, precast concrete pavement slabs comprise an HfL focus area, because they too are a tested technology that can greatly reduce traffic congestion.

"Precast pavement slabs are a vanguard technology which has been proven in the field," FHWA's Tyson told *Better Roads*. "The Office of Pavement Technology has demonstrated in four states — Texas, California, Missouri, and Iowa — the use of precast slabs for pavement rehabilitation and reconstruction. That led right into the HfL interest and recognition that we had proven technology, ready for implementation, but that many states still were not aware of it."

Use of value-added products like precast slabs represents a higher cost, so their use is limited to places in which unique circumstances make them the best choice in reducing user delays. For example, they have been used by toll authorities to replace broken slabs approaching existing toll plazas. By eliminating days of slab replacement, the tollway satisfies toll patrons by reducing work zone delays.

"The special circumstances are traffic, traffic, and traffic," Tyson said. "The reason that states are considering the slabs for use is not lower first cost, but slabs as a long-life solution to pavement rehabilitation or construction where traffic demands require that lane closures be restricted to nighttimes or weekends. Quite a bit of pavement rehab can be accomplished in those work windows, on projects such as intersections and turning lanes. Virginia is in the process of designing a ramp application from I-66 west of D.C. onto U.S. 50 west. It's a 3,900-foot ramp and the initial and end portions will be done with precast, and the intermediate portions with rapid-setting concrete." **BR**

Precast concrete slabs (placed in pavement) figure into high-speed rehabilitation of toll plaza approaches for the Illinois State Toll Highway Authority in suburban Chicago.

Photo courtesy of ISTHA.

For More Information

Visit these sites for more information about the topics discussed in this article:

■ *Long-Life Concrete Pavements in Europe and Canada* (FHWA-PL-07-027), a report on the scanning study sponsored by the FHWA, the American Association of State Highway and Transportation Officials, and the National Cooperative Highway Research Program is available at *international.fhwa.dot.gov/pubs/pl07027/index.cfm*. It includes the scan team's observations and recommendations on two-lift paving.

■ The FHWA and Iowa State University held a June 2007 video conference on two-lift paving, including presentations on its use in the United States and Europe. For a DVD, e-mail the Highways for LIFE office at *HfLT@fhwa.dot.gov*.

■ Documents from the video conference are available from the Web site of the Concrete Pavement Technology Center at Iowa State University. For a variety of source documents — including technical documents and training materials — visit *www.cptechcenter.org/projects/two-lift-paving/*.

■ General information about the FHWA's *Highways for Life* program is available at *www.fhwa.dot.gov/hfl/*. Specific info about HfL's individual programs is downloadable at *www.fhwa.dot.gov/hfl/browsetopics.cfm*.

■ Prefabricated bridge elements and systems is one of the FHWA's *Priorities, Market-Ready Technologies and Innovations*. More information is available at the R&T Web site, *www.fhwa.dot.gov/crt*.

■ The February 2006 report, *High Performance Concrete Pavements: Technical Summary of Results from Test and Evaluation Project 30*, with a review of test section performances, may be found at *www.fhwa.dot.gov/pavement/concrete/hpcp/techsumm.pdf*.