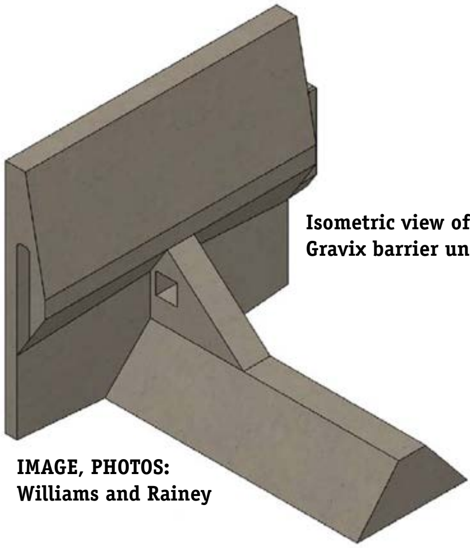
Precast barriers, double tee girders get look at TRB 2016



Isometric view of precast Gravix barrier unit

IMAGE, PHOTOS: Williams and Rainey

During the second week of January, the epicenter of the transportation world was Washington, D.C. and the 95th annual meeting of the Transportation Research Board. Over 12,000 transportation professionals from around the world came to see more than 5,000 presentations in nearly 800 sessions and workshops.

Concrete Products was there. Here are summaries of some of the most pertinent peer-reviewed technical papers in precast/prestressed concrete presented at TRB. Next issue we will look at new research in ready-mixed concrete and cast-in-place structures. For more information about the 2017 meeting, or to obtain the full 2016 meeting papers, visit www.trb.org.

TTI TESTS SHOW NEW-DESIGN BARRIER MEETS AASHTO SPECS

A new-design, modular precast concrete traffic barrier with supporting wall units has potential for use in transportation infrastructure, based on test results presented at TRB. Testing showed the Gravix TL-4 barrier met all the strength and safety performance criteria of AASHTO's Manual for Assessing Safety Hardware (MASH) TL-4 specs, say William F. Williams, P.E., associate research engineer, Texas Transportation Institute (TTI), and Thomas Rainey, P.E., president, Earth Wall Products, Marietta, Ga., in their paper, Design & Full Scale Testing of Gravix Modular Barrier and Retaining Wall System.

This product presents potential savings in construction, as it relies on on-site backfill, rather than material trucked in. "Gravix is an earth retaining wall system that was created to meet the need for a retaining wall system that makes use of on-site backfill, vs. bringing in select or off site select fill for backfill behind retaining walls," the authors note.

The Gravix traffic barrier unit was designed to handle a MASH TL-4 impact load that is used as the top unit when constructing a wall with a roadway above. "A conventional traffic barrier would consist of a cast in place moment slab or an extensive cast in place or precast foundation," Williams and Rainey observe. "With the perpendicular stem acting as a moment slab, capturing the weight of the backfill will help resist the impact forces. The adjacent units are joined together by a tongue and groove connection which allows the units to share the impact force as well as to maintain alignment and prevent snags or misalignment."

The units vary in stem depth dependent upon the wall height as well as surcharge, and a typical wall section has the longest units at the bottom, getting shorter as they are stacked vertically. "The units incorporate a triangular section in the stem that allows the weight of the backfill to bear on the units below, transferring downward pressure, which results in a stabilizing effect of the wall units," note Williams and Rainey. "In combination, the units will create a coherent gravity mass designed to resist overturning, sliding and bearing failure."

For this project, TTI crash-tested a barier unit consisting of a 36-in. high single slope traffic barrier. The modular units were 8 ft. long and 7 ft. high. In anticipation of the test, extensive analysis was performed to design the steel reinforcement and concrete geometry required to resist the anticipated impact load.

"The units are precast concrete, a good sustainability material, providing one of the longest design lives for buried structures," Williams and Rainey say.

During tests, the Gravix TL-4 barrier met all the strength and safety performance criteria. "The vehicle did not override or penetrate through the barrier, and therefore met all the performance requirements for MAST TL-4 Specifications," the authors conclude. Further improvements were made to the barrier system by improving the strength and the gap tolerance of the tongue and groove connection. The tongue thickness was increased by 1/2-in., which will further reduce the permanent deformation that was observed (3/4-inch) in the crash test.

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Installation of Gravix barrier prior to testing

Barrier withstands truck hit during TTI tests

F-SHAPE TEMP BARRIERS GET RETROFIT STIFFENING

For years, the classic precast Jersey-shape temporary concrete barrier (TCB) was the standard for reliable work zone worker protection, but the newer F-shape is a refinement of the Jersey TCB that further limits vehicle damage, as its lower-sloped face better redirects vehicles under low-impact conditions.

"Temporary barriers are segmented units which are attached end-to-end by a load-bearing connection," say Robert W. Bielenberg, M.S.M.E., Ronald K. Faller, Ph.D., P.E., Jennifer D. Schmidt, Ph.D., P.E., and John D. Reid, Ph.D. Midwest Roadside Safety Facility, University of Nebraska-Lincoln; and Erik Emerson, P.E., Wisconsin Department of Transportation, in their 2016 technical paper, Development of a Retrofit, Low Deflection Temporary Concrete Barrier System.

"They are designed to protect equipment and workers in the work zone, to prevent errant vehicles from leaving the traveled way, and to safely redirect those vehicles impacting the barrier," the authors write. "Often, temporary barriers are used in applications where it is desired that their deflection during vehicular impacts be limited. During bridge construction, temporary barriers are often placed adjacent to the edge of a bridge deck in order to provide adequate lane width. Freestanding temporary barriers used in these types of installations pose a potential safety hazard to errant vehicles as there is a risk for the barrier segments to be propelled off of the bridge."

Also, as most highway pavement work zones are restricted in lateral width, it's desirable to minimize the deflection of temporary barriers to minimize required buffer distance, and optimize the space and number of lanes available for traffic. Normally, Jersey or the refined F-shape barriers utilize tie-down systems, which anchor barriers to the roadway surface, Bielenberg, Schmidt, Faller, Reid and Emerson observe. But these require alteration of the road or bridge surface, and also pose the risk of damaging the pavement during a severe impact event.

In response, the Wisconsin DOT looked for a retrofit method for limiting barrier deflection without the need for additional tie-down anchors. WisDOT also desired the safety performance of the new low-deflection TCB system meet the Test Level 3 (TL-3) safety requirements published in AASHTO's Manual for Assessing Safety Hardware (MASH). The research effort developed a stiffening mechanism to reduce the deflection of temporary concrete barriers without requiring anchorage of the barrier segments to the road sur-

PHOTOS: Bielenberg, Schmidt, Faller, Reid and Emerson

Low-deflection F-shape barrier retrofit system test was composed of 16 12.5-ft.-long F-shaped temporary concrete barriers installed with the back of the barrier segments offset 24 inches from a simulated bridge deck edge.

face, and was developed for use with the Midwest Pooled Fund States 12.5-ft long, F-shape, precast TCB. This new, low-deflection system is designed to be retrofitted to an existing F-shape TCB and not require anchoring to the roadway surface.

"After considering several alternatives, the researchers selected a low-deflection TCB design focused on a steel cap plate bolted across the TCB joint and continuous steel tubes running along the sides of the barrier segments," write Bielenberg, Schmidt, Faller, Reid and Emerson. "It was anticipated that combination of the steel cap and the tubes would be effective at limiting barrier deflection through composite action, and the continuous tubes would provide for increased vehicle stability by presenting a more vertical impact face."

Ultimately, the barrier system test installation was composed of 16 12.5-ft.-long F-shaped TCB installed with the back of the barrier segments offset 24 inches from a simulated bridge deck edge. This initial barrier system consisted of a cap plate bolted across the TCB joint and continuous tubes running along the sides of the barriers that would limit unit deflection and provide for increased vehicle stability by providing a more vertical face during vehicle impact.

An initial full-scale crash test was conducted on this low-deflection TCB design. The impacting vehicle was safely and smoothly redirected in the test and all of the barrier segments were safely retained on the edge of the bridge deck with a peak dynamic lateral deflection of 43 inches. Via simulation tests, additional attachment points between the tubes and the TCB were developed to further stiffen the barrier system. Another full-scale crash then was conducted on this revised, low-deflection TCB design. The impacting vehicle was safely and smoothly redirected in the test, and all of the barrier segments were safely retained on the edge of the bridge deck, with a peak dynamic lateral deflection of the barrier system at 40.7 inches.

The latter test suggested that the low-deflection TCB design was limited by the TCB segment capacity, and that further redesign of the retrofit deflection reducing system would have negligible benefit without additional deflection limiting mechanisms or barrier reinforcement changes.

"[T]here may be a desire to adapt the low-deflection TCB system developed in this research to other TCB designs," Bielenberg, Schmidt, Faller, Reid and Emerson say. "It is believed that this design could be adapted to other systems with some additional considerations with respect to barrier segment capacity, joint design, barrier geometry and other factors."

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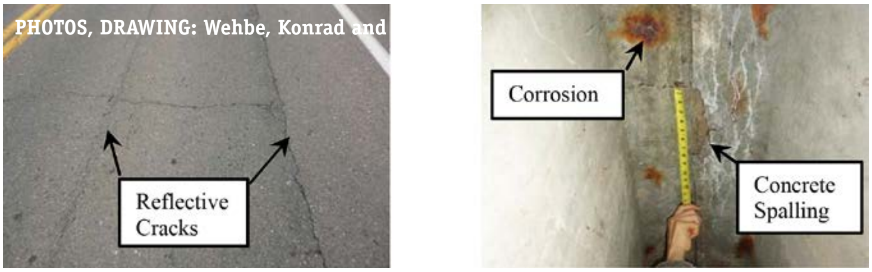
NEW JOINT DETAILING IMPROVES DOUBLE-TEE GIRDER PERFORMANCE

A new longitudinal joint detailing design for popular double-tee concrete girders in South Dakota bridges quells water intrusion and enhances girder performance, say Nadim Wehbe, South Dakota State University-Brookings; Michael Konrad, Kiewit Engineering Co., Omaha; and Aaron Breyfogle, South Dakota Department of Transportation, in their TRB paper, Joint Detailing Between Double Tee Bridge Girders for Improved Serviceability and Strength.

"Precast/prestressed double tee bridge girders are widely used for accelerated bridge construction on local roads in South Dakota," the authors note. Deteriorated joints allow moisture and de-icing chemicals to reach the deck reinforcement, leading to premature corrosion of reinforcing steel and spalling of concrete, they add. Detailing of longitudinal joints between precast bridge girders for adequate shear transfer remains a major concern especially in "decked" precast girders, such as double tee members, which do not require cast-in-place bridge decks.

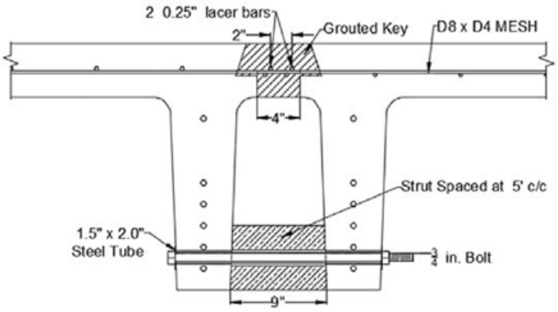
The conventional joint detailing used for double tee girder bridges in South Dakota consists of discrete welded connections spaced along a grouted longitudinal joint (shear keyway) between adjacent girders, Wehbe, Konrad and Breyfogle observe. A common issue among existing double tee bridges is that the longitudinal joints deteriorate with time, most likely due to inadequate shear connection between adjacent girders. It is only a matter of time before the grout begins to crack along the joint, creating a path for moisture and de-icing chemicals to reach the steel reinforcement in the deck, and leading to corrosion, concrete spalling, and structural degradation of the bridge.



Deterioration of double tee bridge girders at longitudinal joints.

To see if the structural performance of conventional and proposed longitudinal joints between precast double tee bridge girders could be improved, both versions were examined experimentally under cyclic and monotonic loading. For the proposed specimen's joint details, the longitudinal joint was 4 in. wider than that of the conventional specimen, and was reinforced with overlapping 4 x 8-D8.0 X D4.0 welded wire mesh that extended from the deck reinforcement for a distance of 6 in., with the wire mesh extension provided during fabrication of the girders.

"Thus, the joint reinforcement consisted of 0.319 in.-diameter deformed wires spaced at 4 in. center-to-center, for a total steel



Proposed specimen joint details for double tee girders.

area of 0.24 in. per sq. ft.," the authors write. "Two 0.25 in.-diameter longitudinal bars (lacer bars) were added to the overlapping mesh in order to develop the joint reinforcement."

According to AASHTO, two longitudinal wires spaced at least 2 inches apart are sufficient to develop the deformed wire in the transverse direction. The longitudinal joint was then grouted the entire length of the girder using non-shrink grout with a specified minimum compressive strength of 4,500 psi. Longitudinal joint construction required temporary plywood at the bottom while grout was being placed. The proposed specimen was tested with and without an option to restrain the rotation of the girders relative to one another.

The restraint was accomplished by means of a diaphragm assembly placed between interior stems of adjacent girders. The assembly consisted of a 6- x 12-in. concrete cylinder strut to restrain the closing of the gap at the bottom of the 18 stem, and a 3/4-in.-diameter tie bolt to restrain widening of the gap between the stems. The cylinder ends were chamfered to allow for a snug fit between the stems. A 1-in.-diameter PVC sleeve at the center of the concrete cylinder allowed for placement of the tie bolt through the cylinder. Galvanized steel sleeves in the stems allowed for passage of the steel bolts. The diaphragm assemblies were placed at 5 feet on center along the length of the girder.

"The proposed continuous joint with overlapping steel mesh reinforcement in a grouted shear keyway exhibited substantially improved serviceability and strength performance characteristics over the conventional grouted joint with discrete welded connections," write Wehbe, Konrad and Breyfogle. "The proposed joint mitigated water leakage through the joint. Water leakage through the conventional joint started at 19,500 and 15,000 load cycles for Fatigue II and Fatigue I loads, respectively, whereas the proposed joint remained water tight under 800,000 cycles of combined Fatigue I and Fatigue II loading."

The proposed joint almost eliminated stiffness degradation due to fatigue. Under fatigue loading, the conventional joint deteriorated rapidly resulting in significant stiffness degradation, while the proposed joint remained essentially intact and had negligible effect on stiffness. For Fatigue II loading, the stiffness degradation rate of the conventional specimen was 26 times that of the proposed specimen.

"The proposed joint enhanced the continuity between adjacent girders," Wehbe, Konrad and Breyfogle conclude. "The enhanced continuity was manifested by higher flexural strength, increased load transfer across the joint, and more uniform distribution of reaction forces at the girder stems. The flexural capacity of the proposed specimens was more than 1.5 times that of the conventional specimen."

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REUSABLE PRECAST PAVEMENT PANELS PAIR WITH SCC FOR REHAB

At TRB an innovative process was described that accelerates slab replacement in concrete pavement rehab projects, increasing productivity while reducing construction time. The process involves the use a system of temporary and reusable precast panels, and self-consolidating concrete (SCC) mix, write Jamshid Armaghani, Ph. D., P.E., Global Sustainable Solutions, LLC; Kamal Tawfiq, Ph. D., P.E. and Steven Squillacote, FAMU-FSU College of Engineering, Tallahassee; and Michael Bergin, P.E., Florida Department of Transportation, Gainesville, in Temporary Precast Panels and Self-Consolidating Concrete for Accelerated Slab Replacement.

"Slab replacement is the main activity in most concrete pavement rehabilitation projects," they write. "Cracked slabs are replaced partially or fully with new concrete as part of the pavement rehabilitation project to extend service life of the pavement." Due to the short construction window, high early strength is specified for the concrete for the replacement slabs, they add. That's because the construction window is limited to only a few hours, during which the lanes are closed to accomplish this and other tasks.

"In urban streets and/or highly congested roads and highways, the lane closure time for slab replacement may range from eight to 10 hours, and mostly, during nighttime," Armaghani, Tawfiq, Squillacote and Bergin say. "The short construction window limits the contractor's production rate for slab replacements."

In response, precast concrete pavements have been used in rehabilitation projects as permanent replacements or overlays for long continuous sections of concrete pavements, or in isolated individual or group slabs, they write. The technology includes precast post-tensioned slabs for continuous sections, or precast reinforced panels for applications in isolated individual or consecutive slabs. But there is much room to expand usage of precast slabs for highway construction.

Likewise, self-consolidating concrete (SCC) has not seen wide use in pavement construction, although it's used in structural work like bridge foundations. To facilitate use of precast panel technology in pavements, the researchers simulated how panels could be combined with SCC to build pavements under traffic. "The research objective was to speed up construction of replacement slabs, increase contractor productivity during lane closure periods, and shorten the time for maintenance of traffic and overall construction," the authors observe. "Other potential benefits from the research include mitigation of premature cracking and cost savings."

An SCC mix was developed to satisfy high workability for rapid discharge and casting, and meet high early strength of 2,200 psi required by the Florida DOT for lane opening. Several trial mixes were prepared and tested for workability and strength to arrive at the final SCC mix design.

Field demonstration of the system of temporary precast panels and SCC mix for slab replacement was conducted in a test pit at a dedicated test track in Green Cove Springs, south of Jacksonville. A 4,000 psi concrete mix was prepared in a commercial batch plant and cast around the test pit to simulate an existing concrete pavement around a removed distressed area—the replacement slab pit—of a pavement. Two precast panels were used in the evaluations. The panel dimensions were 6- x 12-ft. x 8-in. Each panel had two reinforcing layers; in the first, #4 bars were used for reinforcement, and #5 bars in the second. The reinforcing bars were spaced at 12 in. on centers in both directions. Also, four lift anchors were embedded in each slab and were fastened to the reinforcement.

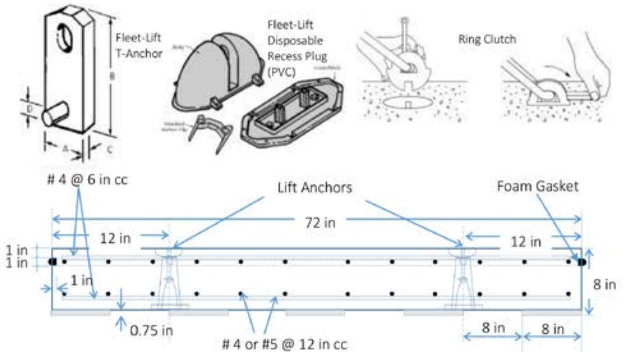
The planar dimensions of the two panels were approximately 3 in, shorter than the pit dimensions, which would create a 1.5-in. gap between each panel and the surrounding concrete. The perimeter of each panel was grooved and fitted with 1.5-in. backer rod foam to fill the gap between the adjoining sides of the panels as well as the gaps with surrounding concrete.

A 60,000-lb. concrete pump truck was used to load the precast panels. After completing the load testing, the precast panels were left in place at the test pit in test track for a period of four weeks. A day prior to casting the replacement slab, the two panels were removed by the same excavator used in the original installation. The removal of both panels took less than 10 minutes. The SCC mix then was placed in the test pit.

"It was not possible to achieve a smooth surface finish because of the lack of proper tools and professional finishers at the site as the mix started to settle and set rapidly," the authors say. "However, at the job site, with the availability of skilled labor and proper finishing equipment, the slab would have been cast and finished in less than 10 minutes. This rate will contribute to a much higher productivity compared to conventional concrete mixes."

The authors conclude:

- Due to robust design, the temporary re-usable precast concrete panels were highly durable during installation, and very stable in the slab replacement pit under heavy loading and breaking force;
- The SCC mix, of Type I/II cement, 57 grade aggregate, silica sand, low w/c as well as a combination of HRWR, workability retainer and accelerator met the high workability requirements for rapid discharge and shorter casting time, and exceeded the 2,200 psi strength required by the Florida DOT for lane opening; and,
- The SCC mix retained its high slump flow for almost 60 minutes without significant loss of workability. This makes it very adaptable to batch plant mixing, and to truck mixer transport and discharge without segregation.



GRAPHIC, PHOTO: Armaghani, Tawfiq, Squillacote and Bergin

Typical pavement precast panel design for Florida experiment. SCC mix delivery for test track replacement slab pit.