American Segmental Bridge Institute

Concrete Segmental Bridges
Retrofit Ends Michigan Moratorium

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Engineers at the Michigan Department of Transportation (MDOT) put a moratorium on designing concrete segmental bridges after a complex project in the 1980s resulted in a major accident during construction. When recently returning to retrofit this and another bridge they discovered the long-term durability that segmental bridges can offer—and they lifted the moratorium.

"The lessons we learned from working on those bridges made us realize they offer a very durable design," says Matthew J. Chynoweth, Chief Bridge Engineer. Corey Rogers, former engineer of bridge field services, agrees. "We were pleasantly surprised to see how well they held up. We saw no sign of tendon corrosion in any conduits and the wearing surfaces were in good shape."

The moratorium stemmed from work on the Zilwaukee Bridge over the Saginaw River in Zilwaukee, Michigan. The largest single-cell segmental box-girder design bridge in the U.S. at the time, it features twin 8,100-foot bridges with segments varying in depth between 8 feet at midspan and 20 feet at the piers. A major accident occurred during the construction, and although the damage was repaired and the bridge now has been in service for 26 years, the experience left the previous generation of MDOT leadership leery of considering segmental construction.

In addition, segment design details and complex erection sequences due to the bridge's size created long-term challenges, Chynoweth explains. Problems arose due to the amount of creep and shrinkage in the bridges. Shortly after completion in 1988, pot bearings began leaking elastomer and polytetrafluoroethylene (PTFE) discs ground against the steel pot sealing. "We found that in the first 12 years, there was a lot of creep and shrinkage as the post-tensioning relaxed and the original bearings became over-rotated and over-translated," Chynoweth says. "Crews had to keep trimming the plates to allow the bridge to rotate."

Zilwaukee Bridge over the Saginaw River
Zilwaukee, MI

Muskegon River Bridge over US-131, MI

Bridges Lifted Up

To replace the bearings on the two bridges, the superstructure was lifted with hydraulic jacks. Engineers externally post-tensioned the bottom slab at the piers with 2.5 million pounds of force to alteraccommodate the change in load path from the bearings to the jacks on the slab floor. Jacks were placed as close to each pier as possible. Eight-800-ton jacks on each side of the pier segment were used to lift at each point, allowing them to lift 10 to 15 million pounds. Once the superstructure was lifted, the bearings were sawed out, rebar reinforcement was placed, bearings were replaced, the joints were pressure-grouted and cured for three days to achieve 5,000 psi compressive strength, and the bridge was lowered.

The work took about four weeks per pier and was phased over two years, with the southbound bridge done in 2013 and the northbound bridge completed in 2014. In all, more than 1,400 core holes were cut in the segmental superstructure to allow for external post-tensioning rod installation and stressing.

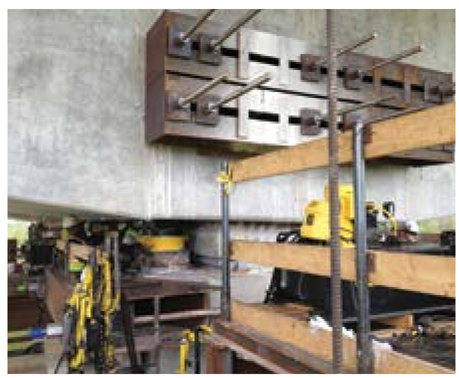
The same process was also used in the fall of 2015 on the Muskegon River Bridge over US-131, another concrete segmental bridge completed in the same time period as the Zilwaukee Bridge. Engineers again drilled holes in the bridge to locate reinforcement, then post-tensioned concrete retrofits to support longitudinal harped external post-tensioning cables. Deviator diaphragms were cast at end spans, and piers diaphragms were modified to adjust for the work, Rogers explains. Concrete corbels were poured on either side of the piers so post-tensioning could be provided across them to redistribute the load with grout-filled flat jacks.

The bridges were retrofitted in 2013 and 2014, and designers were impressed by the concrete's condition. The original moratorium had been placed as those engineers, who had originally worked on the project, took on leadership roles and didn't want to face those design and construction challenges again. As they examined potential designs for a new prominent bridge, they reconsidered the use of a segmental concrete bridge as they began design on a major structure.

New Bridge Planned

The Gordie Howe International Bridge over the Detroit River, to connect Detroit and Windsor, Ontario, will feature sweeping ramps from plaza entries to the bridge. Designers were considering 11-foot-deep steel-plate girders, but after seeing the high durability on the earlier concrete segmental structures, they re-evaluated their options. "We looked at the history of why we'd put a moratorium on segmental design concrete bridges and realized they offered potential today. We gained confidence seeing how well the projects had stood up, so we lifted the moratorium."

Installation and stressing of pier compression collars prior to jacking.



Transverse post tensioning of 2.5 million lbs to distribute jacking forces in the segment bottom slab.

Completed disc bearing.

New Concrete Mix

MDOT also has taken steps to improve the overall durability of its concrete bridges, creating a Grade DM mix of high-performance concrete that includes slag cement and silica fume. "We're using it for bridge decks now," says Rogers. "It's less permeable than other mixes and gains strength quickly." It can achieve a seven-day strength of 6,500 psi.

Initially used on bridges in Livonia, Michigan, in 2014, the mix is now rolling out for use in the majority of bridge decks. "We had so much success with it, we want it to be used on all new bridges."

MDOT currently aims for AASHTO's 75-year service design life as a standard, but it's not stopping there. "We're very much interested in examining new materials and techniques that can get us to a 100-year bridge," says Chynoweth.

Adds Rogers, "Coring can be a critical aspect of retrofitting a bridge to add to its service life. The challenge is really in locating and identifying the steel reinforcement and avoiding those post-tensioning tendons during the rehabilitation work. We've documented the as-built condition of the segmental bridges now to ensure the steel reinforcement and ducts have been located for future maintenance needs. That goes a long way toward helping to make future maintenance work efficient."

The original 1980s segmental bridges may see the ultimate service life the engineers are striving for today, Chynoweth notes. "A lot has changed since those bridges were built. The modern art of material practices has grown. We're paying closer attention to the details to ensure that maintenance in the future will be easy. Now that we've replaced the bearings, I don't see any reason we can't expect another 50 years of life from the bridges."

Silica Fume

White Silica Fume

Slag Cement

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