

BY KEVIN MACDONALD

Putting the Hurt. Behind

► Producer comes through in supplying concrete for Twin Cities span.





Precast segments rest on top of the bridge piers. The piers have no cooling tubes, so low heat-of-hydration mixes were developed to control thermal cracking.

JOE NASVIK

Before its collapse on Aug. 1, 2007, the I-35W bridge was more than a structure that carried more than 140,000 vehicles per day. The bridge was a vital artery in the life of Minnesota's Twin Cities.

Rebuilding the span became an immediate priority to leaders at all levels of government. In addition to the emotional toll of 13 lost lives and 145 injuries, losing the vital cross-town link cost citizens more than \$440,000 per day in additional user impacts, some economists estimated.

It was into this environment of urgency, community need, and to some extent, healing, that Cemstone Products' leadership team was thrust. Cemstone never faced the unanticipated need for action on such an important project, combined with the fast-track construction nature of this building endeavor. There was very little, if any, project preparation time.

Cemstone was in the desirable position, however, of availing itself of previously developed mixes, as well as existing and well-situated plants, equipment, and dedicated personnel. Cemstone's engineers were able to use proprietary mixture proportioning models to reliably and accurately predict later age properties of concrete mixtures.

Aggregate selection

The first hurdle was choosing aggregates. Minnesota Department of Transportation (Mn/Dot) engineers specified crushed granite for the coarse aggregate. Supplied from quarries in St. Cloud, Minn., the Cemstone production team had to plan

Breathe Easy: Sculptures in Place



Cemstone provided the photocatalytic concrete for a pair of 30-foot-tall sculptures that were installed in the median of the new I-35W bridge in Minneapolis.

The two sculptures, which mark the crossing of the Mississippi River, are constructed from a unique concrete that uses ultraviolet sunlight to promote and accelerate oxidation at the surface of the structures.

In addition to keeping the sculptures a bright white color, the concrete converts smog-causing gases such as carbon monoxide, nitrous oxides, and sulfur dioxide to higher oxidized states. A catalytic converter in automobiles use this same process.

The monuments, which are designed using the international cartographic symbol for water, were developed in partnership with FIGG, designers of the bridge, architect Oslund and Associates, and concrete forming contractor Stonewerks.

The concrete used for these 30-foot-tall sculptures is North America's first use of a concrete that removes pollutants from the atmosphere.

COURTESY OF FIGG; PHOTO BY TIM DAVIS

The Best New Bridge

The concept of Best Value Design/Build is at the heart of the I-35W bridge project's success. Along with providing a durable structure, designed and built to serve the public for more than 100 years, the new bridge has a graceful, elegant modern design. It is positioned for growth, as the new bridge is 76 feet wider than the old one and will accommodate significantly more traffic and possibly light-rail transportation in the future.

Best Value contracting encourages everyone involved in the construction, including the owner, to focus on building the best quality possible. Jon Chiglo, the project manager for the Minnesota Department of Transportation (Mn/DOT), says, the I-35W bridge was their seventh Best Value project. And for producers, it showcases a performance approach to specification writing.

Shortly after the collapse last summer, Mn/DOT invited construction companies to submit "Best Value Design/Build" proposals for the reconstruction. For the contractor, deciding to bid a Best Value Design/Build project imposes additional responsibilities. Each bidder was required

to provide its own design for the bridge, so they approached bridge design/engineering firms to work with them. Because the contractor is responsible for the design, they are not entitled to change orders based on material or labor quantity overages or design conflicts.

Best Value bidding

There were three bid sections for this project: price, time, and Best Value, said Terry Ward, Mn/DOT's deputy project manager. In the Best Value section, the important areas included safety, quality, public relations (including public involvement in the design process), aesthetics, and enhancements. The upfront costs of Best Value contracts are often a little higher than traditionally bid projects. But over the life of a contract there is minimal cost growth due to change orders, and the final numbers turn out to be close to other forms of bidding.

Four bidders submitted bids after one month, during which they conducted research, completed designs, and presented their proposals to the review panel. There were three proposals for structural steel bridges and one for structural concrete.

A panel of experts convened by Mn/DOT evaluated each proposal on the basis of price, time to construct, design, quality, safety, and the proposal's technical content.

In October, Mn/DOT awarded the contract to the joint venture of Flatiron Constructors, Longmont, Colo., and Manson Construction, Seattle—with FIGG Engineering Group (FIGG), Tallahassee, doing the design work and being the engineer of record. The winning proposal was the only one submitted for a structural concrete bridge.

Flatiron was the 70% partner and provided leadership, scheduling, and organization. The contractor self-performed many aspects of the construction, including concrete work. Manson was the 30% partner with expertise working on water and with large cranes. Its responsibilities involved transporting the precast segments by barge and lifting them into position using a 600-ton "ringer" crane mounted on two barges in the river.

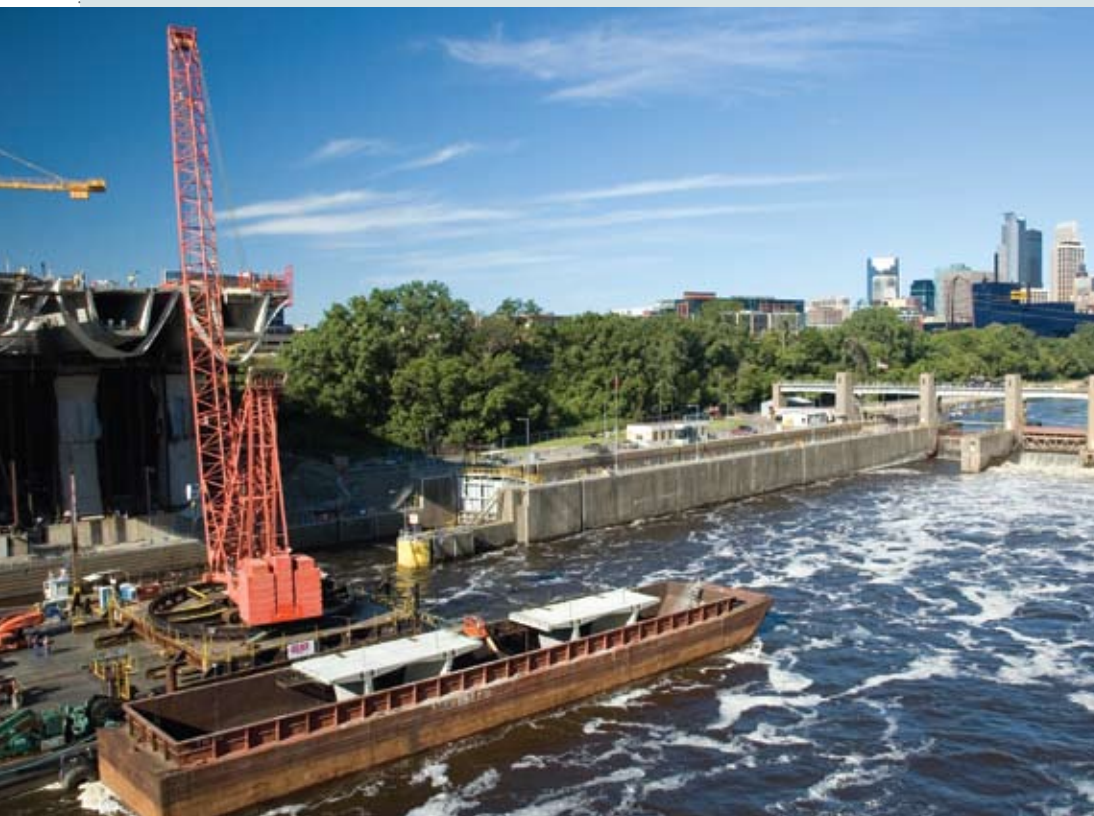
The bridge is actually two bridges—one for each direction of travel. To further speed construction, the venture decided to cast the back-span sections of the

bridge in-place and use precast segmental construction for the main spans, making it possible to work on all portions of the deck at the same time.

With this approach, the contractor could double up its efforts. For example, contractors typically buy one set of bridge pier forms, constructing one pier at a time, says Ward. But on this project, the contractor bought enough forms to construct all substructure elements at the same time. Also, contractors typically set up one or two casting beds onsite to produce precast segments. But here, eight casting beds were set up.

Flatiron's managers decided to use structural concrete because they would stand a better chance of completing the bridge on time and have better control of their very tight schedule.

A barge on the Mississippi River transports precast segments to the jobsite.



JOE NASVIK

—By Joe Nasvik, senior editor with CONCRETE CONSTRUCTION, TCP's sister publication.



Project Facts

Overall length: 1223 feet

Main span: 504 feet

Back spans: 330 feet and 242 feet

Height above the river:
110 feet from the bridge deck

Width of each bridge: 90 feet, 4 inches

Cubic yards of concrete: 50,000

Steel reinforcement: 15.8 million pounds

Post-tension reinforcement:
4.15 million pounds (1000 miles)

and manage its production scheme to ensure adequate and consistent supply. Cemstone counted on an eight-week window during which they had to meet much of the project's needs before shutting washing operations.

Mixtures also had to be selected without opportunity for development or qualification testing. Cemstone scruti-

An aerial view of concrete being placed at the I-35W jobsite.

nized and pulled from its vast collection of performance-based concrete mixtures, choosing those that met the varying project requirements. These included low heats of hydration, high early strength, high resistance to chloride ion penetration, freeze/thaw durability, low shrinkage, dimensional stability, and high abrasion wear. Cemstone also was first to develop mixtures for photocatalytic self-cleaning concrete in North America and the worldwide first use of this cement in self-consolidating concrete.

Providing the appropriate mixtures was only one component of meeting the rigorous project requirements. Efficient and consistent concrete production for this project, while minimizing interruption of other scheduled projects, was essential.

Fortuitously, a Cemstone batch plant sits on the Mississippi River five

miles from the I-35W bridge site. This allowed easy access to both banks where the project was being constructed and to the precast yard which had been set up on an unused portion of the highway. A second Cemstone plant, located in the Midway region between St. Paul and Minneapolis, is almost as close and served as a backup.

Both plants were outfitted with central mixers and each had the capability of stockpiling large quantities of aggregate, a necessity for nighttime and weekend placements outside of the normal material delivery schedules.

Pump parameters

Cemstone partnered with Nordic Contracting Inc. for pumping operations. This included a pair of placing towers for the cast-in-place portions of the bridge deck, and pumps with boom lengths

Concrete Mixes

Winning the contract to supply concrete with a 100-plus-year service life was a big challenge, says David Pace, vice president of strategic accounts for Cemstone Products. The producer delivered to the project's drilled shafts two weeks after receiving the contract.

Normally, concrete mixes with demanding performance specifications are developed by creating trial mixes and testing them over time. However, there wasn't time for that on the I-35W project. Cemstone engineers used mathematical modeling techniques to adjust current mix recipes to meet the bridge's design requirements. The team developed a special mix for each bridge element.

Drilled shafts: At a maximum of 8 feet in diameter, mass concrete for the shafts had to resist thermal cracking. Because steel reinforcement was congested and there was no way to consolidate it with vibration, Mn/DOT permitted using self-consolidating concrete (SCC) with a spread of 28 inches, requiring test placements to ensure the concrete consolidated around the steel reinforcement properly. The requirement for strength was 5000 psi within 56 days; Cemstone designed it for 9000 psi. The amount of cement and pozzolans in the mixes was less than 600 pounds, 60% of which was pozzolans.

Footings: The footings, which rest on the drilled shafts, are exposed partially and are 13 to 16 feet thick. Workers installed cooling tubes to help control thermal cracking. Electronic sensors monitored the temperatures and water was pumped through the tubes when needed to maintain proper temperature. To avoid problems, the concrete was air-entrained. The compressive strength requirement was 5500 psi.

Piers: There were no cooling tubes installed in the piers, so low heat-of-hydration mixes were developed to control thermal cracking. Only 15% of the cementitious material in the concrete was portland cement. After workers placed the concrete, temperatures didn't exceed 100° F. After three days, the average compressive strength development was 2500 psi—the ultimate strength being 4000 psi.

Superstructure and deck: Kevin MacDonald, vice president, engineering services at Cemstone, says they used one mix design for box girders. It was designed for low shrinkage and impermeability. Concrete for the deck was air-entrained, containing 750 pounds of cementitious material: 25% being fly ash and 4% being silica fume. They didn't use slag because of the increased risk of scaling, says MacDonald. He also used a rheology admixture to reduce the stickiness of the mix so that finishers could finish it more easily. It was placed with a striking slump of 7 inches. The concrete typically achieved 6500 psi compressive strength within the first seven days.

Precast segments: The segments were "match cast" in long lines to ensure perfect alignment when placed. There was an added complexity during pouring. Workers cast each element with three different concrete mix recipes. The box girder's bottom was first cast with SCC. Then the wall forms were filled with a stiffer mix. And on top, they placed an additional 2½ inches of concrete, cast integrally as a traffic wearing course.

This internal wearing surface approach is a first for Mn/DOT and provides a high-quality deck and riding surface. When chloride eventually penetrates this wearing course, Mn/DOT crews can mill off up to 2 inches and replace the contaminated concrete with a polymer concrete topping.

—Joe Nasvik



A close-up look of workers near the bridge segments.

ranging from 17 to 61 meters for all aspects of bridge construction (foundation through precast elements).

In addition to having the right mixtures, equipment, and plants, Cemstone's senior management and quality control personnel were at the site continuously, so the could respond to delays in scheduled placements due to inspections, a necessity for avoiding the inherent risks of fast-track construction.

Multiple levels of inspection occasionally resulted in rescheduling of placement deadlines. Cemstone plant staff also frequently determined moisture content of incoming aggregates and checked air content and other properties.

Cemstone's dispatch center normally controls movement of trucks and materials, but during off hours, local dispatch operated from the batch plant. Consequently, the producer had a very responsive control system for delivering the materials.

Cemstone's engineering department was heavily involved in modeling life-cycle costs, including time-to-corrosion and cracking. It performed thermal modeling with assistance from CTLGroup of Skokie, Ill. Mass pours were performed in extremes temperatures, ranging from 100° F to -40° F. The concrete contained more pozzolan than portland cement, and no cracking or other issues arose because of temperatures.

Cemstone's preparedness allowed it to meet the concrete needs of the new I-35W bridge construction. The expansive bridge opened Sept. 18, 2008, well ahead of the original fast-track Dec. 24 deadline. **TCP**

Kevin MacDonald is Cemstone Products' vice president, engineering services. He is a licensed professional engineer in Minnesota and Ontario, Canada, and is a fellow of ACI. For more on the producer, visit www.cemstone.com.