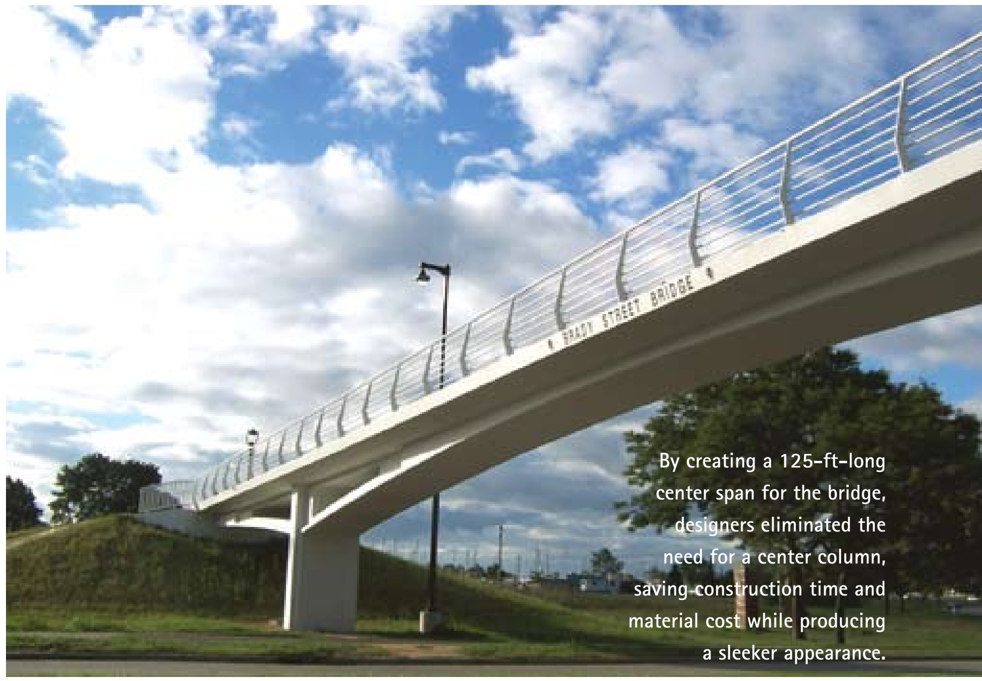
Post-Tensioned Design Creates Pedestrian Landmark

by Craig A. Shutt



By creating a 125-ft-long center span for the bridge, designers eliminated the need for a center column, saving construction time and material cost while producing a sleeker appearance.

Concrete meets a variety of functional challenges while providing strong eye appeal for pedestrian bridge in highly visible neighborhood

Milwaukee County officials knew they faced a number of key challenges when they decided to replace the existing Brady Street pedestrian pathway along the lakefront. To accomplish the range of goals on a difficult site while providing strong aesthetic appeal, the designers created a unique post-tensioned, three-span concrete bridge that will have minimum maintenance needs throughout its lifetime.

The original structure provided access to neighborhoods on top of a bluff along a bike trail and continued to a nearby park on Lake Michigan. It included a series of stairways to accommodate steep slopes coming down from the bluff and a reinforced concrete bridge that led pedestrian traffic via another stairway to the lakefront. Aesthetics for the new bridge were of paramount concern, as the neighborhood has a high profile, hosting the Milwaukee Art Museum and the Milwaukee County War Memorial as well as a number of architecturally interesting bridges.

Vertical Slope— A Key Challenge

"The project's main goal was to address the steep vertical slope across the pathway and make it accessible to pedestrians and bicycles, and comply with the Americans with Disabilities Act (ADA)." explains Yan Nenaydykh, vice president of Bloom Consultants LLC in Milwaukee. He and his colleagues Darrell Berry, project manager; Boris Sloutsky, senior structural engineer; and Yakov Braverman and Anil Kurian, project engineers worked with Edwards & Kelcey (E&K), to create a plan to meet the various site requirements. E&K developed the overall bike trail project, while Bloom Consultants designed and engineered the bridge itself.

A key challenge was to improve the vertical alignment, which E&K proposed accomplishing with a single switchback to address the steep slope. The design offered a constant 5% vertical slope from end to end. The existing stairway at the eastern end, connecting to the lakefront, was replaced with a circular ramp that met ADA and AASHTO requirements. The goal then became finding an approach and materials that

profile

BRADY STREET BRIDGE / CITY OF MILWAUKEE

PROJECT CONSULTANT Edwards & Kelcey, Morristown, New Jersey

BRIDGE ENGINEER AND ARCHITECT Bloom Consultants LLC, Milwaukee, Wisc.

PRIME CONTRACTOR Lunda Construction Co., Black River Falls, Wisc.

CONCRETE SUPPLIER Zignego Ready Mix, Waukesha, Wisc.

POST-TENSIONING CONTRACTOR Dywidag-Systems International USA Inc., Bolingbrook, Ill.

AWARDS *Award of Excellence, 2006 PCA Tenth Biennial Bridge Awards Competition*

'The best aesthetic results for modern-day pedestrian bridges are achieved utilizing thin and continuous superstructures.'

could meet the design requirements and offer the appearance the county desired.

"The best aesthetic results for modern-day pedestrian bridges are achieved utilizing thin and continuous superstructures, with structural member shapes that reflect the forces acting on them," explains Nenaydykh. "Special attention had to be paid to the structures in close proximity to the project as well as to the relationship between the bridge and the surrounding landscape."

Sloutsky developed the original bridge concept and together with his structural colleagues prepared design and finite-element analyses of the structure. The bridge design features high performance concrete (HPC), allowing the engineers to take advantage of post-tensioning techniques to eliminate the center pier and create a long center span. This approach not only provided better access and aesthetics, but it reduced construction time and material. "Overall, the community received a graceful, economical structure with a service life of 100 years," says Nenaydykh.

Cost savings on the bridge will grow, as its design minimizes long-term maintenance costs, notes Nenaydykh. "There are no bearings or joints on the bridge that will deteriorate with seasonal changes," he points out. "With the combined effect of HPC, post-tensioning, and conventional reinforcement, there is an increased reserve load capacity and load distribution, which will also result in better resistance to damaging loads."

Span-To-Depth Ratio: 71

The bridge design features two end spans of 40 ft each and a 125-ft-center span. The bridge has a 10-ft-wide travelway with $9\frac{1}{2}$-in. curbs, and 4-ft 6-in.-tall railings on each side. The superstructure has a shallow arch bottom, with a minimum thickness of 1 ft 9 in. at the middle of the center span, creating a span-to-depth ratio of 71. The superstructure features a 6000 psi compressive strength HPC concrete slab section varying in thickness with the span. Triangular openings were provided in the superstructure on either side of the piers to reduce the volume of concrete used and enhance the structural beauty. The minimum vertical clearance under the bridge is 14 ft 7 in., less than the state minimum (16 ft 3 in.), which was waived because no truck traffic is allowed on the Milwaukee's Lincoln Memorial Parkway below.

At the middle of the center span, auxiliary non-prestressed reinforcement was used, along with the post-tensioning to resist flexural tension at ultimate design loads. The non-prestressed reinforcement also provides structural redundancy during cases of overload. Five tendons were used to post-tension the superstructure. Each tendon consisted of nine 0.6-in.-diameter low-relaxation strands with an ultimate strength of 270 ksi. They were bonded

A berm was created up to the edge of the bridge along the end facing the lake to avoid the need for a long stairway and to lower budget needs.

POST-TENSIONED, CAST-IN-PLACE, HIGH PERFORMANCE CONCRETE / MILWAUKEE COUNTY, OWNER

BRIDGE DESCRIPTION: A three-span, post-tensioned concrete bridge with a 125-ft center span to eliminate the need for an interior column support

STRUCTURAL COMPONENTS Two 40-ft slab end spans and 125-ft shallow arch center span, plus piers, foundations, and abutments

BRIDGE CONSTRUCTION COST: $450,000, including removal of old structure

PTI Celebrates 30th Anniversary… Expands Bridge Efforts

The Post-Tensioning Institute (PTI) is pleased to be a co-sponsor of *ASPIRE™—The Concrete Bridge Magazine* and would like to thank the story contributors and editorial staff for making this inaugural issue possible.

Established in 1976, the PTI is recognized as the worldwide authority on post-tensioning and is dedicated to expanding post-tensioning applications through marketing, education, research, teamwork, and code development while advancing the quality, safety, efficiency, profitability, and use of post-tensioning systems.

PTI members include post-tensioning material fabricators, prestressing steel manufacturers, contractors, and other companies that supply materials, services, and equipment used in post-tensioned construction. In addition, PTI has more than 700 professional members that include engineers, architects, inspectors, government officials, academics, and students.

After years of focusing its attention on other construction markets, PTI has committed to strengthening its support for the bridge engineering and construction community. Several new bridge-related efforts have been launched in recent years including the formation of a new Bridge technical committee.

Key bridge activities include:

- *6th Edition of the Post-Tensioning Manual*—this major update includes two new chapters on bridges and stay cables, authored by Dr. Paul Gauvreau and David Goodyear, respectively.
- *Grouting Specification*—developed by PTI's Grouting Committee, this new specification represents a major advance in post-tensioned construction.
- *PT Bridge Manual*—updated combination of existing PTI publications providing guidance on design and construction aspects unique to post-tensioned bridges (currently under development by the PTI Bridge Committee).
- *Design and Construction of Post-Tensioned Bridge Decks*—a new manual addressing the design and construction of post-tensioned bridge decks (currently under development by the PTI Bridge Committee).
- *Recommendations for Stay Cable Design, Testing and Installation*—the PTI Cable-Stayed Bridge Committee is currently drafting the 5th edition of these recommendations, which serve as the standard for cable-stayed bridge construction around the world.
- Certification – Bonded Tendon Installation—this comprehensive training and certification program is intended for all field personnel involved in the installation of bonded post-tensioning, including installers, inspectors, and construction managers.

In addition to these specific activities, PTI has other areas of interest to bridge designers. The *PT Journal* is published semiannually and often includes papers on durability and bridge design. PTI also sponsors an annual technical conference to showcase the latest in post-tensioning technology. The next conference will held in Miami, Florida, on May 6-8, 2007.

For more information on PTI, please visit www.post-tensioning.org.

to the surrounding concrete by injecting cementitious grout after tensioning the tendons.

Piers and foundations were constructed of conventional concrete. The pier columns have a 3- by 7-ft rectangular shape and are rigidly connected to the superstructure. The piers rest on a pile foundation consisting of twenty $10\frac{3}{4}$-in.-diameter concrete-filled steel pipe piles driven to a minimum bearing capacity of 40 tons and an average embedment length of 55 ft.

The superstructure rests on jointless fixed-integral abutments. "The long center span, compared to the end spans, produced uplift at the abutment ends, but integral abutments were designed to provide resistance against this uplift," Nenaydykh explained. A 1-ft-thick slab at the base of the abutment and structural backfill on top of the slab provided the necessary resistance to uplift. The abutments were supported on a single row of five 10 3/4-in.-diameter concrete-filled, steel-pipe piles driven to a minimum bearing capacity of 50 tons and an average embedment length of 70 ft. Reinforcing bars were welded to the side of the pipe piles to transfer uplift tension in piles to the abutment.

The slenderness was further enhanced by the bridge's finishes, which included a penetrating, acidic stain for all portions of the concrete surfaces above grade level. "The white color matched the color of the Calatrava Bridge located just south of the project and also gives the Brady Street Bridge a clear definition as an object in the landscape," explains Nenaydykh.

End Spans Built First

The abutments, piers, and end spans were constructed first, with the center span using an additional temporary support at the median. Shear keys were supplied at the superstructure construction joints to transfer vertical shear across the joint. Sequential jacking of the tendons began with the middle tendon being stressed first, followed by the adjacent two and then the outermost two tendons. The

The thin lines of the metal railing help emphasize the shallow profile of the bridge.

The sleek look of the new bridge was created by post-tensioning the three spans; thereby reducing the weight of the superstructure.

'There are no bearings or joints on the bridge that will deteriorate with seasonal changes.'

tendons were jacked from both ends of the superstructure at the same time.

Approximately 125 cu yd of concrete were used for the substructure units, with another 170 cu yd used for the superstructure. The project took approximately 10 months for completion.

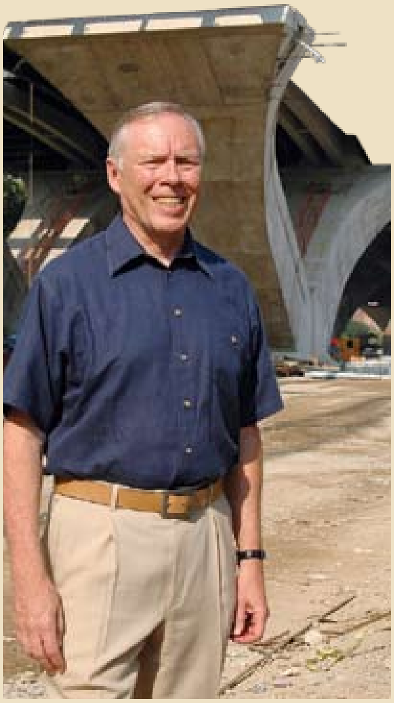
"Reinforced concrete rigid-frame bridges have long been a mainstay in the bridge world," Nenaydykh says. "They offer many advantages in comparison to their materials in terms of durability, economy, and maintenance. With increasing span lengths, conventionally reinforced concrete bridges tend to get bulkier, which can quickly add cost." The post-tensioning provided a continuous design and prevented that from happening in this case. "On the Brady Street Bridge, we used an innovative hybrid scheme, consisting of a concrete rigid-frame structure with a sleek shallow arch in the main central span," he notes.

"The Brady Street Bridge serves the twin purpose of functionality and architectural expression while also enhancing the beauty of the natural surroundings," he says. "The success of this project can encourage bridge designers to make use of the best technology available to design beautiful bridges that challenge the imagination."

For more information on this or other projects, visit www.aspirebridge.org.

AESTHETICS **COMMENTARY**

by Frederick Gottemoeller



Replacing an attractive and well-loved bridge is always a challenge, particularly when the bridge is in a park and crosses over a well-traveled roadway. The designers of the Brady Street Bridge have taken this challenge and mastered it. The existing bridge was one of a family of similar bridges over Milwaukee's Lincoln Memorial Parkway. These bridges have curved soffits and a very open and transparent appearance.

The new bridge provides both of these features. The curved soffit is created by the haunched girder design, which deepens the girder at the piers to match the forces there, while making it as thin as possible at center of the main span, where the forces are the lowest. The openness is created by removing triangular sections of what otherwise would be the web of the haunched girder. The openings make the bridge lighter visually as well as reducing the self weight. The openness is reinforced by the selection of a railing design with horizontal elements. The railing is transparent from all angles, which would not be the case if it were made up of vertical pickets. The railing posts are thin and are themselves shaped to reflect the forces on them.

The designers are to be congratulated on creating a bridge that is efficient, economical, and elegant, which fits into and reinforces the family of bridges over the Lincoln Memorial Parkway in Milwaukee.