Steel Bridge NEWS
NATIONAL STEEL BRIDGE ALLIANCE
JUNE 2007

Form Meets Function in Hybrid Steel Design

BY CRAIG HETUE

With a design heavily influenced by history and context, Chicago's signature North Avenue Bridge employs intricate steel work.

WHEN IT COMES TO INFRASTRUCTURE PROJECTS IN CHICAGO, "THE CITY THAT WORKS" IS MORE THAN JUST A CATCHY CIVIC SLOGAN. Community leaders, from Mayor Richard Daley on down, expect innovative engineering solutions that also respect the city's rich architectural heritage.

Those expectations, combined with the challenges of an urban location, set the bar high for the new North Avenue bridge that's currently being built over the Chicago River.

"In Chicago, the mayor takes a very direct interest in everything about the city, from bridges to parks," said Brian Steele, spokesman for the Chicago Department of Transportation (CDOT). "Mayor Daley was very much involved in the selection of bridge type and the aesthetics, and the city sold the public on the concept."

The new four-lane structure, designed by HNTB Corporation, is a hybrid suspension and cable-stayed bridge, the first of its kind in Chicago and only the second of its type in the nation. The design incorporates several creative uses of structural steel.

Because Chicago has a history of innovative bridge designs dating back to the turn of the 20th century, history and context significantly influenced the design selection process, said Dan Burke, P.E., S.E., CDOT chief bridge engineer. The original North Avenue bridge was

NUTS AND BOLTS

- ✔ The project is budgeted at $21.4 million.
- ✔ The North Avenue Bridge replaces a structure that would have been 100 years old this year.
- ✔ The bridge will be 420 ft long.
- ✔ The main span is 252 ft long, with two 84-ft-long secondary spans.
- ✔ Four prefabricated steel pylons support the deck.
- ✔ Support piles reach down 100 ft to bedrock.

constructed in 1907 as a double-leaf, three-truss bascule structure. The two lanes narrowed to one, creating a major bottleneck as traffic volume increased to more than 35,000 vehicles a day. In addition, river traffic has shifted from commercial to recreational over the past century, diminishing the need for a bridge of this type.

"It's still a navigable waterway, but not to the extent that it requires a moveable bridge anymore," said Ken Price, P.E., vice president for bridge and tunnel services for HNTB's Great Lakes division. "Most of the commercial traffic has moved farther south."

Rapid development has given the area a high profile on both ends of the bridge.

"North Avenue is one of the most important east-west arterials in the River North part of the city," Price said. "It is located on the north side of the turning basin on the north branch of the Chicago River, where there is a tremendous amount of new residential and retail development. Looking south from the bridge toward the city, there is a spectacular view of the skyline. It's a highly visible location."

Meeting the challenges

The importance of the new bridge to the city's future, both in relieving congestion and in complementing area development, made the design challenging as well as exciting. Price and colleague Eddie He had designed a similarly high-profile span, the nearby Damen Avenue bridge. This bridge, much like the North Avenue span, required a creative design that also was efficient and cost-effective.

The initial design phase included reviewing the project's challenges and goals, and eliminating bridge designs that wouldn't meet the requirements.

For example, Price said, "One of the key considerations was structure depth. North Avenue at this location is tightly constrained vertically. We had to keep the profile to an absolute minimum. At the same time, the superstructure above the bridge needed to be as transparent as possible so it wouldn't overwhelm the neighborhood and at the same time would complement the skyline."

The design team eliminated various arch- and truss-type bridges for aesthetic reasons. Likewise, they ruled out a cable-stayed bridge because it would have required much higher pylons that would have been visually intrusive, and which would have obstructed the skyline.

Finally, geotechnical conditions precluded a suspension bridge, which would have required large gravity foundations. The bedrock lies 70 ft beneath the surface and is fractured for another 30 ft down, and two tunnels carry natural gas beneath the river. Even if gravity foundations had been feasible, these conditions would have made them too expensive. The self-anchored bridge requires much smaller foundations than would be needed for a conventional suspension bridge.

Instead of impractical rock anchors, the pylons are founded on concrete-filled piles about 10 in. in diameter. These piles reach the bedrock 100 ft below, while straddling the natural gas tunnels. Piles also are used to support the bridge abutments.

Designers addressed the superstructure challenges with a hybrid solution that borrowed the best from two classical bridge types. The self-anchored suspension bridge eliminated the need for a large gravity anchor, and the superstructure was stiffened using a classical layout of cable stays.

"We basically started from square one looking at different bridge types and evaluating what sort of structure would fit the location," Price said. "We developed this concept and turned it into what it is today. It borrows from the Brooklyn Bridge, only on a smaller scale. It makes a statement."

CDOT took the lead in selling the design to a diverse group of stakeholders that included city and state agencies, property owners, residents, the U.S. Coast Guard, and the U.S. Army Corps of Engineers. One of these groups' main concerns was maintaining residential and retail access during construction. This was addressed by building a temporary bridge that will keep traffic moving until the new bridge is completed.

"We weighed our ideas against what the impact would be during construction," Burke said. "The temporary bridge concept was very well received."

Structural Steel Supports Complex Design

The 420-ft-long bridge consists of a 252-ft-long main span and two 84-ft-long secondary spans. The main span is supported by suspension cables only in the middle portion of the main span, and is stiffened by cable stays on the remainder of the main span. The two shorter spans also are supported by cable stays. The top of each pylon houses a prefabricated suspension cable saddle and an anchor box assembly for the stay cables.

"The pylon structures are all steel, in part because of the scale of the job," Price said. "Steel gives us flexibility and allows the pylons to be completely prefabricated and assembled off-site, and delivered and erected as a complete unit. The size and weight of each pylon is manageable for delivery and erection as a single unit."

The pylon cross section is formed of two ellipsoidal shapes that are connected by some rather intricate steel work. After fabrication in Duluth, Minn., they will be shipped by lake and river directly to the project location, and then erected on-site.

The pylons support a 10-in.-thick concrete deck, which is in turn supported by concrete edge beams and transverse steel box beams. Steel also is an important component of the deck structure Price said. "The deck framing system consists of fabricated steel box beams in the transverse direction and in the longitudinal direction. The deck framing system was designed to enable the contractor to assemble the deck and engage the superstructure as a self-anchored structure during construction, eliminating the need for extensive falsework."

Also, the deck is longitudinally post-tensioned, and there are relatively large moment reversals in the deck due to live load. In addition, given the variable stiffness in the superstructure, the post-tensioning enables the deck to handle stresses where the bridge transitions between the suspended and cable-stayed sections.

The open superstructure design adds a signature span to the neighborhood without detracting from the dramatic views.

"Because this is a highly visible location in an important corridor, we wanted a bridge like this to make a strong aesthetic statement," Burke said.

Staying on Course

Construction began with the temporary span in June 2006. A generally mild winter has the project on target for completion this fall.

"We are very pleased with the way it is progressing," Steele said.

URS Corp. of San Francisco is performing construction engineering services for the $21.4 million project, with Chicago-based James McHugh Construction Co. building the bridge. McHugh will begin by erecting the cable-supported

portion of the bridge using the cantilever method. Next, crews will place the suspension cable and erect the suspended portion of the center span. Architectural lighting will be used to showcase the stainless steel cladding.

Because of the design complexity, HNTB will perform consultation services during critical construction operations, including the erection sequence, and stressing of the cable stays and suspension cable.

The hybrid design, although ideal for this project, is not a concept that will likely be used very often in other contexts, Price said.

"I doubt that there are many other sites where this design, with the self-anchored concept and the low-profile bridge will be right answer," he said, "but here it gave us an effective solution that was relatively low-cost."

The lesson of the North Avenue bridge project is that it still is possible to design a span that is functional and makes a statement, without breaking the bank in the process.

"The key message from Chicago is that a creative structure can be functional and cost effective at the same time," Price said. "A number of signature bridges have encountered challenges because of funding constraints, scale, and magnitude. The city of Chicago, on the other hand, has been very successful at getting signature bridges built." MSC

Craig Hetue is the structural department manager in the Chicago office of HNTB Corporation. You can contact him at 312. 930.9119 or chetue@hntb.com.

The center section of the temporary North Avenue bridge is lifted into place. Photo by Chicago Department of Transportation.

Contractor
James McHugh Construction Co., Chicago

Engineers
URS Corp., San Francisco
H.W. Lochner Inc., Chicago
Bridge Concepts, Tampa, Fla.

Design
HNTB Corporation, Chicago

Fabricator
BendTec, Inc., Duluth, Minn. (AISC member)

Project Architect
Muller & Muller Architects, Chicago