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Proper frame work

Waco, TxDOT come up with right solution for IH-35

Bruce Jackson, a noted professor of American culture, said, "Bridges are perhaps the most invisible form of public architecture; they become frames for looking at the world around us."

Taking that philosophy out of academia and putting it into practice, the Waco District of the Texas Department of Transportation (TxDOT) has initiated a unique bridge project spanning the Brazos River. Though only two frontage road bridges are involved, the $17.3 million IH-35 Extradosed Bridge Project will pioneer a bridge technique in the U.S.

As part of the American infrastructure, bridges often become treasured landmarks in their communities. Majestic, grand and inspirational, in many ways bridges define their surroundings. Needing to expand I-35 (IH-35), representatives from the city of Waco wanted signature bridges with an "art deco" look to complement other recent downtown economic revitalization projects. Because the frontage road bridges were going to be constructed first—the mainline bridges will be replaced later—TxDOT and Waco representatives decided to create signature twin frontage road bridges on each side of the mainline bridges. Though aesthetics was certainly a driving force behind the new bridge design, the initial defining characteristic of the project was functional need.

Brazos bravado

IH-35 runs north-south through the heart of Texas. A major transportation artery for the

state, the highway carries thousands of business travelers and local commuters on a daily basis. That demand has caused significant congestion along some areas of the route. Given Texas' ever-increasing population, this congestion is only expected to worsen. To remedy this, the Waco District of TxDOT has committed to expanding a 94-mile stretch of IH-35 from the Williamson County line (north of Austin) to the city of Hillsboro (south of Dallas). With its ongoing $1.9 billion expansion program, TxDOT looks to create continuous frontage roads along the mainline interstate in areas where it is needed most. In Waco, the mainline bridges over the Brazos River provided the perfect profile. After discerning the need, though, project designers turned their thoughts once again to aesthetics. Fielding input from the design team of TxDOT staff, AECOM staff, Waco city officials and the Waco-area public, TxDOT selected an extradosed style for the set of two 620-ft-long bridges.

Debate rages over the boundary between extradosed and traditional cable-stayed bridges, but extradosed bridges have a distinguishing feature—lower tower height (than traditional cable-stayed bridges) in proportion to the main span. Typically, cable-stayed bridges have tower heights around one-fourth to one-fifth of the main-span length. Extradosed bridges, however, have shorter tower heights equal to approximately one-10th of the main-span length. The shorter tower height results in shallower cable angles that in turn lead to an increase in the axial compression in the superstructure and a decrease in the vertical stay forces that act as supports in a conventional cable-stayed bridge. So, cables on an extradosed bridge serve a prestressing function. But that is not the only notable feature of an extradosed bridge.

Due to the additional support of the cables, an extradosed bridge may have a shallower superstructure depth relative to a traditional girder bridge. The span-to-depth ratio of extradosed bridges is typically on the order of 35-to-1, versus approximately 20-to-1 to 25-to-1 for girder bridges. However, an extradosed bridge still acts as a girder bridge, so the superstructure depth is greater than a conventional cable-stayed bridge, with a typical span-to-depth ratio of approximately 100-to-1. In addition, due to an extradosed bridge's relatively stiff superstructure, which resists a majority of live-load forces (rather than having the stays carry the load), these bridges also are often characterized by low live-load stress ranges in the stay cables. Taking this all into account, what does this mean for the IH-35 bridges?

Spanning the Brazos River and parallel to the existing mainline interstate bridges, the new IH-35 frontage road extradosed bridges will each be 620 ft long. Traffic on each bridge will be one way, with the new bridges placed to the outside of the mainline bridges. Though the existing mainline bridges are steel-plate I-girders, they will be replaced with new steel box-girder bridges as part of the IH-35 corridor improvements. In the final configuration, both the northbound and southbound frontage road bridges will be separated horizontally some 60 ft from the corresponding mainline bridges. The roadway for each frontage road bridge will carry three traffic lanes with shoulders, as well as a 10-ft 6-in.-wide sidewalk for pedestrians and cyclists. In addition, scenic overlooks providing unobstructed river views were incorporated into the pylons to enhance the bridge experience for pedestrians.

Each of the new twin structures will be a three-span bridge with a 250-ft center span and 185-ft side spans. Matching the span configuration of the proposed new mainline bridges, this configuration will align the piers within the river for all the bridges in their final condition. The resulting side span–to–main-span ratio is 0.74, common for ordinary girder bridges with the side-span length generally varying from 0.6 to 0.8 of the main span. For cable-stayed bridges, this ratio is typically between 0.35 and 0.50. For extradosed bridges, the recommended side span–to–main-span ratio is essentially the same as for ordinary girder bridges, but tends to average on the lower end—around 0.6—for many existing extradosed bridges. However, this ratio often varies for extradosed bridges, depending on site conditions rather than structural optimization. This is exactly the case for the IH-35 bridges, where the span layout has been set to match the proposed mainline bridges.

Each new bridge's superstructure will consist of a 10.5-in. cast-in-place concrete deck with 6-ft 6-in.-deep steel trapezoidal box edge girders and 3-ft 6-in.-deep steel-plate I-girder floor beams. Transverse floor-beam spacing will vary from 13 ft 3 in. in the end region of the side spans to 15 ft in the regions near the pylons. The trapezoidal box edge girders are composed of ¾-in. web plates, with 2-ft-wide top flange plates and a 5-ft-wide bottom flange plate. Top flange plate thickness varies from a typical 1 in. up to 3 in. for the regions over the bearings at the pylons, and the bottom flange plate varies from a typical 1¼ in. to 3 in. over the pylons. The box edge girders are continuous for the entire length of the bridge, supported on single disc bearings at the abutments and pylons. The transverse I-girder floor beams consist of ½-in. web plates with 1-ft 6-in.-wide by 1-in.-thick top and bottom flange plates.

The superstructure of the I-35 frontage road bridges will have a steel-girder composite cross section.

As for the edge girders themselves, once again this is where extradosed features helped the project depart from the norm. The superstructure for almost all extradosed bridges to date has been either precast or cast-in-place concrete box girders or cast-in-place concrete slab cross sections. However, with the IH-35 frontage road bridges, the project team chose a steel-girder composite cross section. Though a concrete cross section is more the norm for extradosed bridges, steel girders with concrete decks have been considered. But so far, the only known bridge to be constructed with extradosed features and boasting a steel-girder composite cross section is the Golden Ears Bridge in Vancouver, Canada. So, the IH-35 bridges will be the first use of this combination in the U.S. But this decision was not made by fiat.

Having considered the use of a cast-in-place concrete box girder, the project team rejected this type of superstructure, as they determined it to be economically untenable in this case. Because the overall length of the bridge is only 620 ft, the span length does not justify the cost of purchasing form travelers necessary to construct a cast-in-place concrete bridge. In addition, the project team used a steel trapezoidal box section for the edge girders, rather than a steel-plate I-girder section more commonly used on composite cable-stayed bridges. This was done to provide greater superstructure stiffness and less reliance on the cable stays, common on extradosed bridges. The project team also wanted to visually match the new mainline bridges (the current bridges are scheduled to be replaced with steel box-girder bridges).

For aesthetic reasons, the design team chose to use five cable stays. The cable system consists of a single plane of five cable stays at each pylon supporting the edge girders (a total of 20 stays for each bridge). The cable stays will be anchored at the deck level to the web of the steel box girder and pass through cable saddles in the pylons. With 12 strands per cable, the stays will be composed of 0.62-in.-diam., seven-wire, low-relaxation strands. For improved corrosion resistance, each strand will be coated with wax and encapsulated inside high-density polyethylene (HDPE) sheathing. And the strand-bundled stays will be protected by an outside HDPE pipe.

Since an extradosed bridge has two load-carrying systems, cable support can be provided for only a portion of the span. Consistent with the geometry of many extradosed bridges, the first stay for the IH-35 frontage road bridges will be offset from the pylon by approximately 20% of the main span. From this first stay, the cable support points are spaced 14 ft 9 in. along the edge girder, for a total of 59 ft. This results in approximately 50% of the main span being cable supported, which is consistent with most existing extradosed bridges that have cables distributed across approximately 60% of the span. But the extradosed features created yet another unusual circumstance.

Due to the use of the relatively more flexible steel superstructure (supported at the pylons by bearings), the resulting live-load stress range in the stays was greater than the Post-Tensioning Institute's (PTI) limit that would allow the stays to be designated as low-fatigue. The stress variation caused by live loads (AASHTO HL-93 live load with no pedestrians) varied up to approximately 15 ksi versus the 6.75-ksi limit for the stays to be considered extradosed. So the stays were designed accordingly, using

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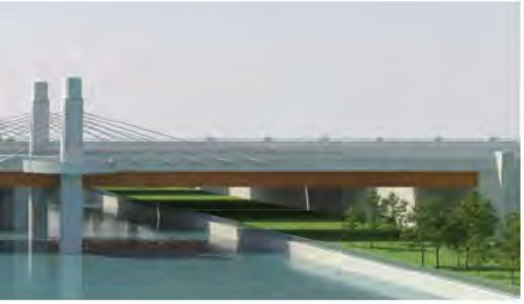

the same provisions in the PTI manual as for conventional cable-stay bridges.

Also, the cable-stay and saddle system chosen was specified to allow for the installation and replacement of stay strands on an individual strand-by-strand basis. This is no small consideration. The ability to replace strands on an individual basis will allow future bridge maintenance workers to pull and inspect strands without needing to replace the entire stay. Stay strands will be placed within individual holes in the cable saddle, significantly reducing the risk of fretting corrosion and facilitating strand-by-strand replacement. Although a common practice elsewhere in the world, this, too, is relatively new in the U.S.

Finally, each H-shaped pylon will consist of two 9-ft 3-in. by 9-ft 3-in. rectangular towers with a haunched 5-ft 3-in.-wide crossbeam that supports the superstructure. The pylons will be solid, cast-in-place reinforced concrete, founded on a single 10-ft-diam. drilled shaft at each tower (two shafts total for each pylon). The pylon towers will rise approximately 68 ft above the water level and approximately 35 ft above the deck level. Pylon tower height above the deck level equates to a main span–to-tower ratio of approximately 7-to-1, a little less than most existing extradosed bridges (typically 8-to-1 to 10-to-1). To produce a greater visual impact, the pylon tower height will be extended slightly more than the average extradosed bridge.

To further enhance the aesthetic impact of the bridge, several art deco-type architectural features will be incorporated into the pylons to complement other surrounding structures in the city of Waco. Simulated grout lines with a heavy sandblast finish will create the appearance of limestone block on the tower faces. Four-inch-deep flutes on the upper portion of the towers will match the piers on the proposed mainline bridges. And an 11-ft-tall architectural cap will be added to the top of each tower.

In America, bridges are often viewed as iconic structures. Majestic, grand and inspirational, bridges define their surroundings. So, when the city of Waco and TxDOT needed to expand I-35, they wanted to do more than just add capacity. They wanted to make a statement. By pioneering the application of extradosed bridges in the U.S., the city of Waco and TxDOT will do just that with the IH-35 frontage road bridge project. If Bruce Jackson is right and bridges become frames for looking at the world around us, the city of Waco and TxDOT will soon give bridge users a unique new viewing platform. **R&B**

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