conference preview

STEEL BRIDGES LINK TEXAS HIGHWAYS

BY GREG KOCHERSPERGER, P.E.

Tub girders easily handle the long spans on a prominent Dallas-area interchange.

Austin Bridge & Road

Dual, curved trapezoidal steel box girders connect I-30 and the Eastern Extension of the President George Bush Turnpike near Dallas.

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DRIVING LONG DISTANCES is a reality for many in the Metroplex (also known as the Dallas-Ft. Worth area). And as the area continues to expand, so does the need for an additional high-volume, high-speed roadway to ease the burden of getting there from here.

With the recent completion of the Eastern Extension of the President George Bush Turnpike (PGBT), the North Texas Tollway Authority (NTTA) has completed a vital link and increased mobility between outlying cities to the west and north of Dallas.

Critical to accessing this new extension is the interchange at Interstate 30, constructed by the Texas Department of Transportation (TxDOT). The interchange consists of four direct connector ramps linking the PGBT main lanes to the reconstructed I-30 main lanes. The direct connectors consist of a single-lane ramp supported primarily on pre-stressed concrete U-beams with spans varying from 80 ft to 100 ft. As the bridges cross the I-30 frontage roads and main lanes, however, steel superstructures are required to accommodate the longer spans and the tighter horizontal curvature they involve.

Trapezoidal steel box girders, with spans up to 255 ft, were chosen to match the appearance of the concrete U-beams and for their desirable aesthetics. Where column placement could not be accommodated within the interstate main lanes, steel box straddle bents were used to support the tub girders and reduce the required spans. All structural steel on the project is ASTM A709 Grade 50W weathering steel, providing a uniform aesthetic with other projects in the Dallas area and reducing maintenance costs for both TxDOT and the NTTA.

Steel Trapezoids

The project has eight trapezoidal steel box girders (or tub girder) units. Each unit has a unique span arrangement and horizontal curvature with a minimum radius of 890 ft. The concrete deck is 8 in. thick and

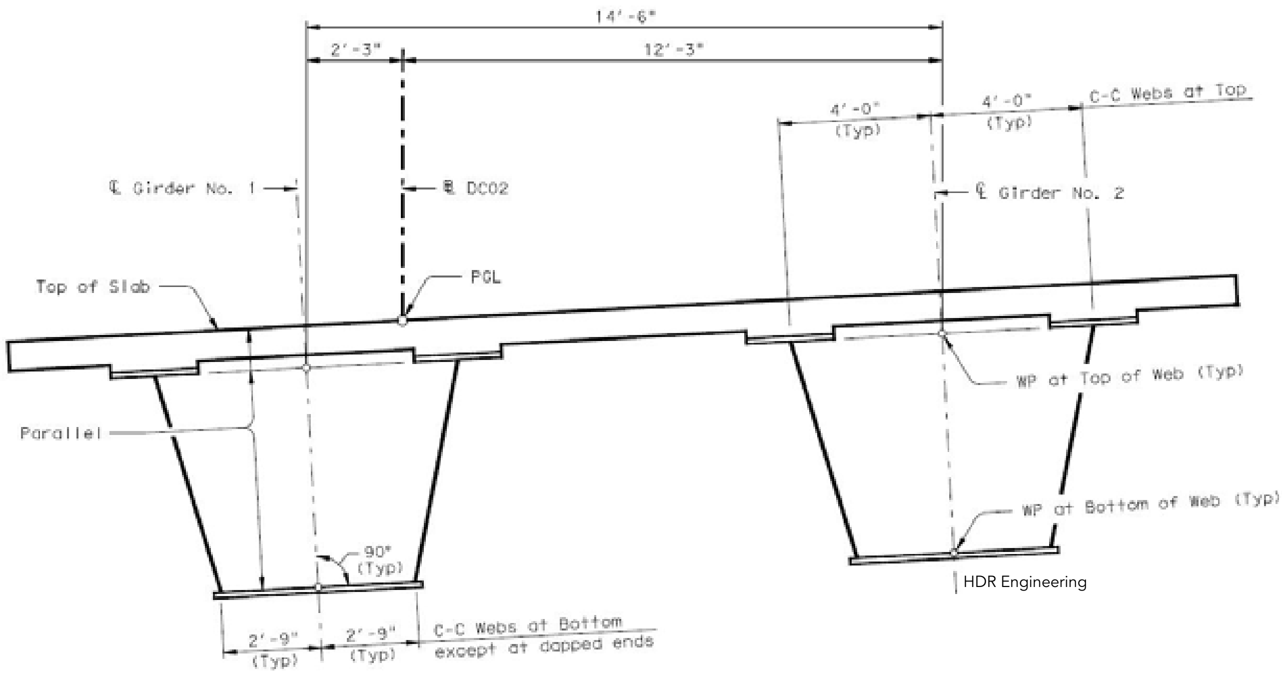

Fig. 1: A typical section showing the 5-ft-deep tub girder webs; the depth of the webs helped facilitate inspection.

Fig. 2: Completed tub girder sections were assembled in the fabrication shop, with internal diaphragms and top lateral bracing installed.

28 ft wide and is supported by two tub girders spaced on 14-ft, 6-in. centers. The girder webs are 5 ft deep to facilitate inspection and the webs are 8 ft apart at the top flanges. Webs slope at 4:1 to match precast concrete U-beams, resulting in a 70-in.-wide bottom flange (see Figure 1).

Tub girders on horizontal curves behave fundamentally differently than curved I-girders. I-girders have very little torsional stiffness and require cross frames between the girders to redistribute torsion in the system into shears between the girders in the cross section. Tub girders, on the other hand, have significant torsional stiffness and typically are stable without the need for additional cross frames or diaphragms between the girders. In the completed structure, the torsional stiffness results from the closed section created by the three-sided box and the concrete slab. Prior to the slab hardening, tub girders rely on top flange lateral bracing to form a pseudo-closed section and provide adequate torsional stiffness during erection and slab placement. Intermediate diaphragms are typically provided between multiple tub girders, but only to minimize rotation of the girders during slab placement, not for overall stability. The intermediate diaphragms often are removed after slab placement, although many agencies now prefer to leave them in place. (The intermediate diaphragms on this project were detailed to be left in place.)

Prior to designing the eight separate units, the designers performed an in-depth study of one of the units and developed a consistent design methodology. Items investigated included torsion during slab placement sequence, top flange lateral bracing orientation, the effect of access holes in pier diaphragms and the use of elastomeric bearings. After the initial investigation, the tub girders were designed using MDX, a commercially available 2D grid analysis software package that sizes girder webs and flanges. Miscellaneous girder members, such as top flange lateral bracing and internal and external diaphragms, were designed using hand calculations and in-house design spreadsheets. Although the final calculations were based on the MDX model, extensive 3D finite element analysis was performed to verify the analysis as well as the methodology used for designing the miscellaneous members. By fully vetting the design methodology and detailing on the first unit, the following seven units were designed very efficiently.

The girder sections were assembled in the fabrication shop with internal diaphragms and top lateral bracing installed as shown in Figure 2. Installing these members in the shop created a very stable section that was much easier to handle than a traditional I-girder. In the field, the additional torsional stiffness of the tub girders allows them to be erected without the need for external diaphragms, which greatly reduced the

Fig. 3: The contractor was able to bolt an entire span on the ground and lift it as one girder, eliminating the need for shoring towers.

Fig. 4: Steel box straddle bents were introduced to reduce the required spans of the superstructure over I-30.

time needed for erection. Figure 3 shows how the contractor was able to bolt an entire span on the ground and lift it as one girder, eliminating the need for shoring towers.

The steel tub girders were supported on large, laminated elastomeric bearings. (The design of these bearings was based on previous research and methodology developed by TxDOT and had proved successful on many other projects around the state.) Although the bearings were rather large—up to 24 in. by 40 in.—they provided significant cost savings compared to conventional high-load, multi-rotational bearings.

Steel Box Straddle Bents

At locations where the direct connectors cross over I-30, the required spans were beyond what could be accommodated economically with steel tub girders alone. At those locations, steel box straddle bents were introduced to reduce the required spans of the superstructure, as shown in Figure 4. Although post-tensioned concrete straddle bents were used elsewhere on the project, the use of steel straddle bents over the main lanes eliminated the need for extended closures of the Interstate. The contractor was able to erect a straddle bent cap, as well as the tub girders on top of it, in a single nighttime closure.

These steel box straddle bents are considered fracture-critical and will require regular inspection. (TxDOT discourages the introduction of new fracture-critical elements on its projects.) The tub girder units on this project are also fracture-critical, but the additional effort to inspect additional elements on the project was deemed acceptable when weighed against the impact of Interstate closures during construction.

Picking Up the Slack

In a state dominated by pre-stressed concrete bridges, the use of structural steel is still an essential part of the bridge engineer's tool box—especially in the case of the PGBT/IH 30 interchange, where it proved the best solution for the long-span connector ramps and minimized construction impact on the traveling public. MSC

Owners

Texas Department of Transportation and North Texas Turnpike Authority

Steel Team

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This article provides a preview of some of what the author will present in Session B13 at the World Steel Bridge Symposium, April 18-20 in Dallas. Learn more about the World Steel Bridge Symposium and NASCC: The Steel Conference at www.aisc.org/nascc.