FEATURE

FLYOVER BRIDGES

NE Anthony Henday Drive and Yellowhead Trail Interchange

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THE NORTHEAST SEGMENT of Anthony Henday Drive (NEAHD) opened on October 1, 2016 and brought to completion a $4 billion investment in Edmonton's Ring Road, the first in Alberta. The NEAHD consists of nine interchanges, 47 bridge structures and 27 kilometres of six to eight lanes of divided highway. The Edmonton Ring Road, the largest highway construction project undertaken in Alberta's history, forms an 80-kilometre free-flowing route around the City of Edmonton and connects 24 municipalities in the Capital Region.

The project included a three-level system interchange connecting NE Anthony Henday Drive to Yellowhead Trail. The combination of high traffic volumes, the free-flowing traffic design, a very small land footprint and tight project schedules under the P3 model made the design of this interchange highly complex. This interchange required the modification of five bridges and the construction of 17 new bridges, including two flyover ramps. This required a great deal of collaboration within the project team in bridge design, fabrication, transportation logistics and site erection.

FIGURE 1: Anthony Henday Drive / Yellowhead Trail Interchange near completion

Courtesy of FDAL JV

The two bridge structures we are profiling are interchange flyover bridges 23.3 and 23.5. These bridges were constructed with straight plate I-girder segments arranged with a series of kinks forming continuous segmentally curved girder lines. Bearings on conventional abutments and intermediate substructures support the steel girders. Figure 1 shows the two flyover bridges within the systems interchange. Structure 23.3 is a 415m long six span (approx. 48-67-92-79-67-64m spans) with a radius of 347m. The bridge forms a S-E ramp connecting southbound Anthony Henday Drive to eastbound Yellowhead Trail with two traffic lanes on a 14.85m wide deck. Structure 23.5 is a 315m long five span (approx. 48-62-86-57-62m spans) with a radius of 340m. A 11.75m wide deck supports one traffic lane that connects northbound Anthony Henday Drive to westbound Yellowhead Trail forming a N-W ramp.

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DESIGN

Span Geometry:

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FIGURE 2: Bridge 23.5 Girder Fabrication

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arteries, provisions for future lanes on Anthony Henday Drive, 9 – 11m horizontal clear zones, and small medians greatly restricted the physical space available for pier placement. Thus, the site constraints dictated long interior span lengths. The versatility of steel girders permitted an economic design by utilizing continuous girders that varied in girder depth, with deeper girders at the longer span(s) and shallow girders at the shorter spans. Varying the girder depth optimized the girders as well as reduced the earthworks required at the bridge approaches.

Girder Geometry:

Before design work on the project commenced, the consultants, contractors, and steel fabricators met to review the fabrication approach for all bridges. It was concluded that the curved bridges should be constructed with straight steel plate I-girders arranged with a series of kinks forming continuous segmentally curved girder lines. Fabricating the girders in straight segments made for easier fabrication and transportation of girder segments. Using straight girder segments also had the benefit of reducing the number of primary tension member cross frames to only those cross frames located adjacent to the kink locations. The fabricator joint venture on this project (Rapid Span/Structal) worked collaboratively to determine the most efficient utilization of their fabrication facilities to complete this project. This involved complex logistics that included deliveries by train and truck requiring transloading from three plants.

Flange widths were limited to multiples of 300mm to ensure efficient material use, ripping multiple flanges from a single rolled plate. Flange thickness increments were generally limited to 5mm to standardize the plate used for all plate girders on the project. The resulting flange sizes varied from 600mm x 30mm to 900mm x 75mm over high demand regions near the piers.

The fabricators' capacity limited the maximum feasible web depth to 3.7m. Deeper webs would have required a longitudinal web splice that was cost prohibitive. For simplicity and ease of fabrication, girder depth variation was accommodated with linear transitions. The resulting web depth of bridge 23.3 varies from 2.22 to 3.52m, which permitted the camber to be cut from the limiting 3.7m plate. To reduce the number of transverse stiffeners required on bridge 23.3, the web thickness varies utilizing 20, 22, and 25 mm thick webs. The web depth variance on bridge 23.5 is less pronounced at 2.4 to 3.0m. With less incentive to vary the web thickness, bridge 23.5 utilized a constant 18mm thick web.

The total girder tonnage, including cross frames and lateral bracing, is approximately 1,900 & 1,200 metric tonnes for bridge 23.3 and 23.5 respectively.

Speaking to the choice of steel for these bridges, Paul King of Rapid Span and Albert Chiza of Structal stated, "It's no secret to those in the business that steel bridge girders offer many advantages in terms of versatility, constructability and economy. While only 15 of the 47 bridges on this project were steel, they constituted the longest and the most complex structures. Steel's versatility easily accommodated the many horizontally curved alignments and highly skewed crossings. This is why steel ended up being used in over half of the bridges, in terms of total length, for this challenging project."

Field Segment Geometry:

The kink locations were chosen to produce kinked field splices, as shown in figure 2, which eliminates competing efficiencies of placement in low demand regions. Detailing two kinks within each intermediate span and one kink at each end span produced a maximum field segment of 41m for both structures. The heaviest girder segment weighed over 62 metric tonnes. The average field segment length was 37 and 35m for bridges 23.3 and 23.5 respectively.

Cross frames:

One distinct advantage of having the flange noncollinearity concentrated at the kinks is the ability to locally strengthen the flanges for these effects. To increase flange capacity,

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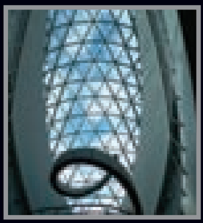

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FIGURE 3: Bridge 23.3 Girder Cross Frames

while simultaneously reducing the flange lateral bending demand, cross frames are located on both sides of each girder kink. This arrangement greatly reduced the flange unbraced length at the kink locations. Furthermore, the resultant lateral thrust from the misaligned flange forces has a decreased eccentricity to the supporting cross frames.

ARTICULATION:

Both structures are tangentially restrained at the centermost pier support with fixed pot bearings at the interior girders and radially guided pot bearings at the exterior girders. The remaining exterior girder bearings are free in both directions, eliminating radial thermal induced forces. Guided pot bearings at interior girders provide articulation, allowing translation parallel to the flanges.

CONSTRUCTION:

To minimize a lateral bending component from an out-of-plumb girder, cross frames were detailed to fit under total dead load conditions (TDLF). This was facilitated by straight girder segments that are torsionally flexible, allowing the girders to be readily twisted to achieve fit.

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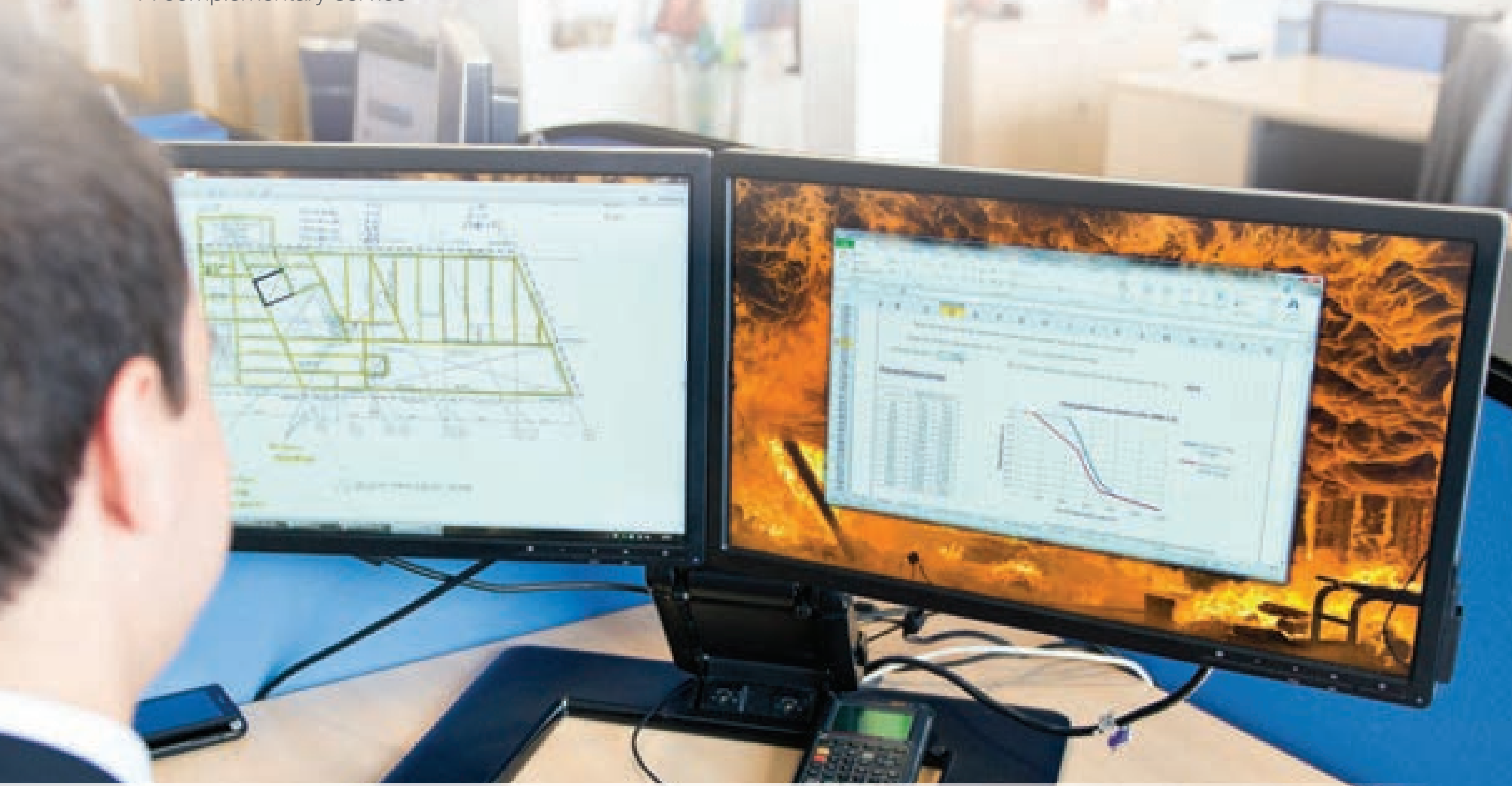

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FIGURE 4: Bridge 23.3 Girder Erection (Pier 5 to Abutment 1)

FIGURE 5: Bridge 23.5 Girder Erection (Pier 1 to Pier 2)

FIGURE 6: Bridge 23.5 Girder Erection Completed (Pier 4 – Abutment 1)

FIGURE 7: Bridge 23.5 Completed

Girder segments were erected using crawler cranes and temporarily supported on steel bents during construction. Girder erection started at the centermost pier support with the first girder line segments supported by shimmed bearings and a temporary shoring tower. Temporary restrainers prevented bearing movement prior to grouting the shimmed bearings in place. Girder segments were placed individually, progressing radially. Cross frames were installed incrementally between girder lines as girder erection progressed. Once the four girder line segments were complete with cross frames and lateral bracing, girder erection progressed tangentially down chainage with placing the next four girder line segments. This erection pattern was repeated until completing girder erection to the down chainage end of the bridge. Afterwards, girder erection progressed similarly up chainage from the centermost pier to the other end of the bridge. Temporary shoring towers supported the girder segments as needed and were removed prior to precast deck panel installation. As seen in figure 6 the shoring towers under the longest span remained in place to completion of girder erection to control girder deflections. Temporary shoring towers under shorter spans were removed once all field splices, cross frames, and lateral bracing were completed within the span. Bridge 23.3 and 23.5 girder erection was completed over approximately 10 weeks and six weeks respectively.

CONCLUSION:

The two fly-over bridges at the Yellowhead Trail and NE Anthony Henday Drive interchange are eye-catching and elegant as they carry all manner of vehicles across their long curved spans. They are an excellent representation of the strengths of designing bridges in steel to meet complex project demands. Design challenges were overcome by working with the entire P3 team to develop innovative solutions to deal with space limitations, height constraints and project deadlines that kept the project on track and allowed the final section of the ring road to be opened to traffic ahead of schedule. The project team, the Province of Alberta and the steel construction industry can be very proud of these elegantly beautiful fly-over bridges. AS

PROJECT TEAM FOR BRIDGES 23.3 & 23.5:

OWNER: ALBERTA MINISTRY OF TRANSPORTATION **CONTRACTOR:** FLATIRON-DRAGADOS-AECON-LAFARGE (FDAL) JOINT VENTURE

PROJECT PRIME CONSULTANT: AECOM **DESIGN ENGINEER:** STANTEC CONSULTING LTD. **FABRICATOR:** RAPID-SPAN/STRUCTAL JOINT VENTURE

(CANAM-BRIDGES, FORMERLY KNOWN AS STRUCTAL-BRIDGES, FABRICATED 23.3; RAPID-SPAN STRUCTURES LTD. FABRICATED 23.5)