Urban Design Challenge Met With Speed

The Bow Tower, Calgary, Alberta

By David Stevenson, P.Eng

Figure 1: North West Building Elevation. Courtesy of Foster + Partners, London.

In the major urban center of Calgary, Alberta, Canada's third largest city with a population of over one million people, the Bow Tower has started to take form. The Bow is a 59-story structural steel office tower with a perimeter diagonal grid structure and other unusual design characteristics. Implementing these design challenges with little disruption, in a dense urban center known for annual inner city festivals, is a challenge that a construction team would not face alone. The entire design team had a role to play in addressing the unique construction challenges: the crescent shaped building footprint and lateral system, and the fast track project delivery method employed on the project for nearly every aspect of the building.

Background

When completed in 2011, the 59-story Bow Tower will become the headquarters of EnCana Corporation, the largest energy corporation based in Canada. The iconic structural steel tower, designed by Foster + Partners of London, is situated on a two city block development in downtown Calgary. When completed, it will be the tallest building in western Canada, and the second tallest commercial building in Canada at 780 feet (238 meters) in height. The tower, whose footprint measures approximately 320 feet (97.5 meters) from 'finger tip to finger tip' by 190 feet (57.5 meters), utilizes three unique perimeter diagonal grid (diagrid) structural elements, coupled with interconnecting frames, to resist lateral loads. The tower will include a total gross constructed area of over 2,100,000 square feet (195,000 square meters) above grade and 1,000,000 square feet (97,000 square meters), including 1,375 parking spaces along with the loading dock and services areas, on six levels below grade.

The owner, H&R REIT, along with Matthews Development Alberta, who acted as development managers, have driven the project since the start of the concept development phase in late 2005. With Zeidler Partnership Architects filling the role of executive architects, and Halcrow Yolles as structural engineers, this large, fast tracked project was developed through to design development stage in the Fall of 2006, at which time all major subcontractors, including curtain wall, concrete supply, formwork, reinforcement and the structural steel contractor Supreme-Walters Joint Venture, were brought on board to assist the design team in completing the contract documents in a 'Design Assist' capacity.

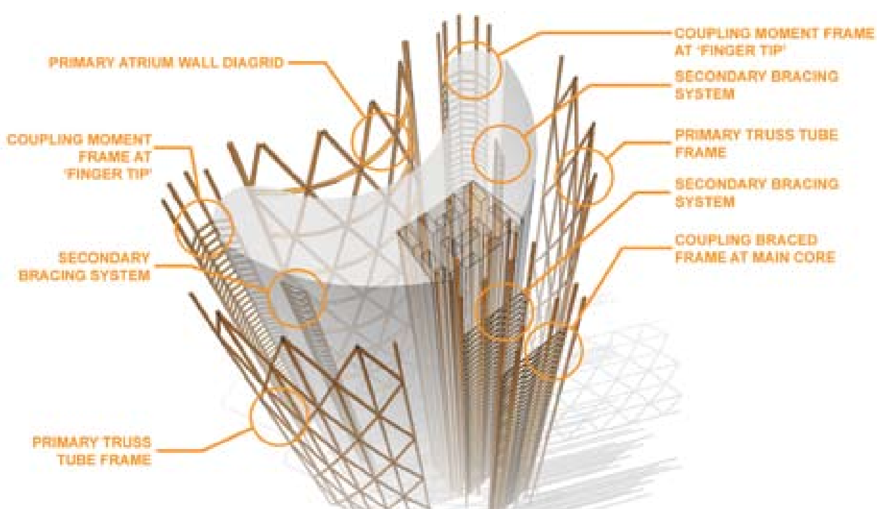

Figure 2: Exploded BIM Image of Tower.

Design and Construction Challenges

6th Avenue Construction

The Calgary Stampede markets itself as the 'Greatest Outdoor Show on Earth'. The event is a 10 day exhibition which features festival activities, a rodeo and the famous Calgary Stampede parade. Immediately following the Stampede parade in July 2007, a 330-foot (100-meter) long section of 6th Avenue, which crosses through the Bow construction site, was closed in order for the excavation of this area to begin. Motivated by stiff financial penalties imposed by the City of Calgary if 6th Avenue was not reopened by June 2008 for the same parade, Ledcor Construction, the construction managers for the project, implemented a plan to construct the five parking levels below grade as well as the deck, which replaces this portion of 6th Avenue, in just under 11 months. Although the 'bridge deck' was initially conceived as a cast-in-place reinforced concrete one way slab and beam system, the design was revised to a post-tensioned/pre-cast hybrid system to expedite construction. Post-tensioned beams spanning 60 feet (18 meters) across the roadway and over the loading dock below, and pre-cast planks spanning 28 feet (8.5 meters) along the roadway, formed the new deck. To minimize reinforcement placement time on site, reinforcement cages were preassembled off site, with the post-tension ducts in place, and lifted into the formwork. The post-tensioned cables were then installed, concrete cast, pre-cast planks erected, and the road bed completed in time for the Stampede parade in July 2008.

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Figure 3: Photo of Calgary Stampede Parade.

Tower Mat Foundation

The foundation below the Bow Tower consists of a 10-foot (3-meter) thick reinforced concrete mat containing over 2,750 tons of reinforcement. To expedite construction, the construction manager, with the concurrence of Halcrow Yolles and the rest of the project team, proposed casting the entire 18,300 cubic yard (14,000 cubic meter) 7,250 psi (50 MPa) concrete mat in a single pour.

The 39-hour continuous pour, which is reportedly the third largest building foundation pour in the world, began on May 9, 2008 and was finished by noon on May 11. The pour was a complete success due to the continued support of over 500 laborers, 12 concrete pumps, which were in turn supplied by close to 100 ready mix trucks delivering almost 1,500 loads of concrete during the pour.

Ground Floor Umbrella

To facilitate the erection of the steel tower ahead of the completion of the parking slabs below grade, 'top-down' construction techniques were utilized to construct the majority of the steel ground floor 'umbrella'. The top-down construction method enables the superstructure and substructure of a high rise building to be built simultaneously, thus saving valuable construction time. The ground floor umbrella was essential to provide the necessary material handling and staging areas to feed three tower cranes during the tower erection. The use of top-down construction, and the fact that the concrete substructure and perimeter foundation walls would not be completed until the steel erection approached the 30th floor, created several significant challenges including resisting both gravity and lateral loads during construction.

Figure 4: 'Top-Down' Construction Techniques.

The majority of the columns supporting the tower were designed as 60-foot high (18-meter) laterally unsupported large diameter steel pipe columns filled with concrete. The columns varied from 48 inches to 63 inches (1200 to 1600 millimeters) in diameter. The pipe columns were set down over heavy base anchorages onto the mat, and reinforced prior to the placement of the base plates and diagrid nodal connections at the ground floor. Spigots at the base of the pipe columns were provided to allow for base pumping the 12,300 psi (85 MPa) concrete up into the columns. Since the base plates and nodal connections were set before the concrete fill was pumped, the base plates were temporarily supported on the steel pipe columns until such time as the concrete had cured and the high strength non shrink grout was placed between the concrete fill and the underside of the base plates above.

To support the below grade parking slabs, Halcrow Yolles developed stiffened circular steel collar details to support the slabs at the intermediate floor levels. These collars were detailed to accommodate vertical adjustability, and utilized reinforcement couplers to interconnect the concrete parking slabs with the pipe columns.

While the concept of a steel umbrella at ground floor seemed like a simple one initially, it proved to be a significant challenge in the end. The detailing of a ground floor structure is historically difficult due to such things as the various requirements for pits, trenches, incoming building services, distribution of MEP systems at the underside of the large lobby areas, and interface with perimeter excavation support systems. At the Bow site, detailing was complicated even further by the overall geometry of the building footprint, the need to minimize the total depth of the floor structure, the several significant steps in the structure, and the need to design for concentrated loads imposed by construction hoists, mobile cranes and the various construction vehicles accessing the umbrella.

Erection Schedule and Sequencing of Atrium Areas

The design and construction challenges continued above grade in terms of developing a temporary lateral stability strategy for the tower as erection proceeded. As described above, the main lateral load resisting system consisted of the three perimeter trussed tube frames, one of which exists on the south elevation of the building adjacent to the spacious atrium and garden areas. Given the exposed nature of the south atrium wall structure, and the forces acting on these 82-foot (25-meter) long unsupported triangular shaped elements, the fabricator needed to develop field welded details for the diagonal to node connections. To accommodate the complexity of the connection details and the amount of weldment required, the design team needed to divorce the erection of the tower from the erection of the atrium wall structure in order to

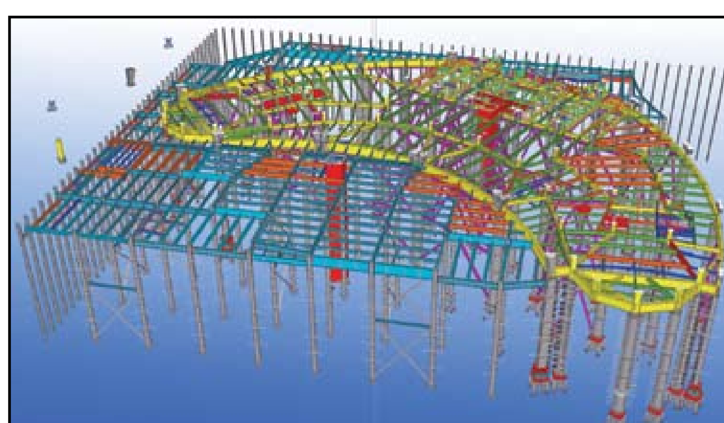

Figure 5: BIM Image of Umbrella Steel. Courtesy of Supreme-Walters Joint Venture.

Figure 6: Photo of Atrium Wall.

meet the overall project schedule. This meant that one of the three main lateral load resisting elements would lag behind the erection of the tower by as much as 6 to 12 floors. As a result, the steel fabricator developed a temporary vertical bracing system to augment the permanent bracing system on the two northern flanking building elevations. This bracing system, coupled with temporary horizontal diaphragm bracing, assisted the permanent structural elements in resisting loads during erection.

To erect the atrium wall after the main tower, and to ensure the tight erection tolerances for the exposed structure were met, the design team provided temporary braces and shoring towers to ensure accurate placement of nodes, which weigh up to 60 tons, and the subsequent erection of the triangular shaped diagrid elements.

Summary

The geometry of this unique crescent shaped Bow Tower, along with the tight construction schedule, posed several design and construction challenges. Through the collaboration of all members of the project team, these challenges have been successfully overcome. The erection of the structural steel tower has reached the 6th floor level at the time of the writing of this article.▪

Figure 7: Ground Floor Nodal Connection. Courtesy of Terri Meyer Boake.

David Stevenson, P.Eng, a Senior Principal with Halcrow Yolles in Toronto, Ontario, has 25 years experience in the design of complex high rise building structures. David can be reached at ***david.stevenson@halcrowyolles.com****.*

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