



Canadian Consulting
Engineering Awards

2012

The Bow - An Iconic Skyscraper for Calgary

Submitted by Yolles, A CH2M HILL Company

Category: A. Buildings

Yolles

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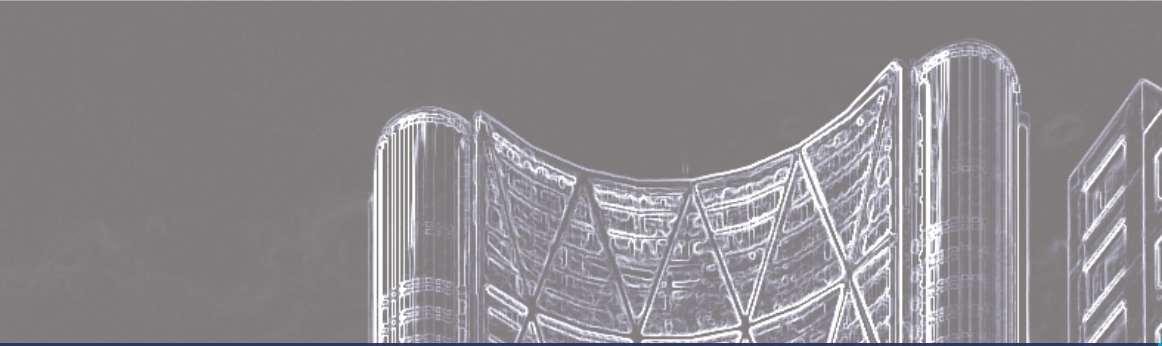
The Bow on the Calgary Skyline

The image is a full-page architectural rendering of a modern building. The building features a prominent, curved facade with a complex, faceted structure composed of numerous triangular and quadrilateral panels. The rendering is presented in a white line-art style against a dark background. The building is situated in an urban environment, with other buildings and street-level details like cars and pedestrians visible in the foreground and background. A dark blue horizontal band is positioned across the upper middle of the page, containing the text 'Award Submission Forms'.

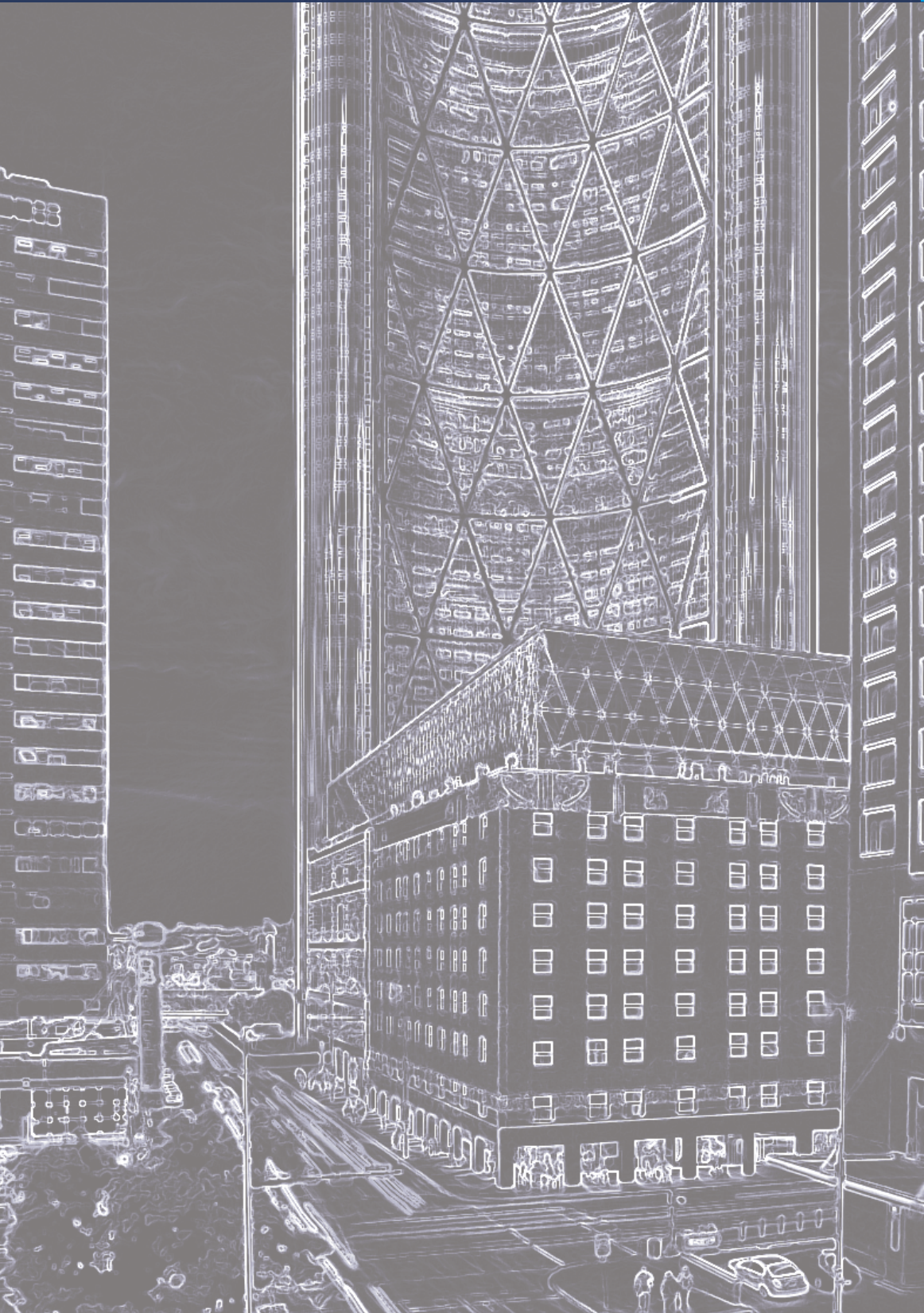
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Project Highlights



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An Iconic Skyscraper for Calgary

One of the largest steel-framed buildings recently constructed in the Americas, The Bow is a striking presence on Calgary's skyline, with its iconic crescent-shaped, inversely curved form. This innovative 58-storey mixed use development is a groundbreaking structure, representing many "firsts" as well as providing an environmentally sustainable headquarters for a leading Canadian energy company, and a generous social space for Calgary.

The Bow is Calgary's tallest building and first steel skyscraper. It also incorporates the first use of a triangular diagonal grid (diagrid) system in a curved building design in North America. Visually, the diagrid pattern is repeated on the building's exterior every six storeys, and provides superior structural efficiency while significantly reducing the overall steel weight, as well as the number and size of interior columns.

The innovative skyscraper derives its name from the nearby Bow River, and from the tower's heavily-windowed, bow-like shape, which was used to maximize perimeter office space, greatly reduce wind loads, maximize natural light, harness the sun's heat energy, and provide unobstructed views to the majestic Rocky Mountains to the west.

One of the first examples of a truly modern and sustainable high-rise tower for Calgary, The Bow successfully fulfills the owners' goals of a distinctive tower that is both a progressive and sustainable office space and a vibrant cultural, civic, and shopping destination for Calgary residents and visitors. Three sky gardens divide the building into distinct zones, forming a series of destination floors with lobby areas, meeting rooms and communal spaces linked by high-speed lift service running between the lobbies.

The Bow's Structural System - Carefully Considered

Many different structural framing strategies were considered for The Bow, including framed tube structural systems composed of large, closely-spaced columns and deep spandrel beams located around the perimeter of the building; tube-in-tube systems consisting of an internal core, outriggers and a perimeter framed tube with wider column spacing, and a variety of diagrid or braced tube configurations.

Designers opted for the all-steel structure with the diagrid, secondary vertical steel bracing systems, and long-span steel floor framing based on the following benefits:

- More economical foundations as a result of the lighter steel structure
- High strength structural steel allowed for smaller vertical and diagonal columns and braces, and large column-free floor spaces
- Effective use of steel framing resulted in reduced floor-to-floor height for long-span floor areas
- Greater flexibility in accommodating changes to building occupancies, additional loads, and tenant improvements
- Faster top-down construction technique achieved by use of composite structural steel columns and framing below grade

Structural Steel Challenges

A highly complex structural steel system provides the backbone for the Bow and consists of a composite of exterior diagrid framing, vertical vierendeel moment frames, and braced frames, all merging in a crescent shaped footprint to provide resistance to lateral and gravity loads.

Many challenges were involved in designing and erecting this complex geometric form. Steel connections required to be fabricated to extremely tight tolerances so that the overall structure could

be built to tighter erection tolerances. The atrium diagrid structure comprised of triangular diagrid sections and nodes weighing up to 85 metric tonnes each had to be erected to within 25 mm tolerances for a ratio of building height to out-of-position of H/9500. Surveying and maintaining tight erection tolerances in the field were tremendously challenging in Calgary's extreme climatic conditions.

Another challenge involved the differential settlement of foundations that occurred as this massive structure was erected. Because interior steel columns settled more than exterior elements, a complex system of adjustments were made and monitored as construction progressed to ensure the structure remained plumb and did not twist. In a North American first, the project team used surveying techniques pioneered on the world's tallest structure, the Burj Khalifa in Dubai.

Because conventional tower cranes did not have the lifting capacity to hoist the heavier sections, self-climbing tower cranes were used to erect the structure. Self-climbing machinery was custom designed and fabricated to support the tower-gantry cranes.

In order to accelerate the schedule, Yolles used top-down construction design: below-grade columns were installed as concrete-filled hollow steel sections that were six storeys high with collars to permit the floors to connect later. This allowed the tower construction to proceed before the parking garage levels were built.

A late-breaking client request prompted a significant challenge. After the structural steel had been issued for construction, a major design change was requested to infill the atrium areas on most floors up to Level 42 to increase usable floor space. Yolles achieved this re-design while continuing to maintain schedule.

Other key innovative structural design features include the transfer of diaphragm forces from the perimeter diagrid through the thin concrete-on-steel deck floor framing system and the design of large triangular sections comprising the south atrium wall where combined steel plate thicknesses were in excess of 100 mm.

Designing for Sustainability

Yolles chose the diagrid structural steel system not only for its striking aesthetics, but for the space and material efficiencies it allows, and its contribution to sustainability goals. The external structural system creates significantly more usable floor space, providing most building occupants with an office space adjacent to the building perimeter and access to natural light. Building geometry allowed architects to minimize the size of the elevator core and employ state-of-the-art technology to stack two elevator cars inside one shaft, reducing space needed for both building infrastructure and reducing elevator wait times.

The combination hybrid structure and curved bow shape required 20 percent less steel than normally required for a steel structure of this form. Because the curved floor plate also helps reduce wind loads associated with similarly sized rectangular buildings, the amount of steel required was further reduced. The building's form and massing closely follow Calgary's climatic characteristics, and site-specific seasonal sun paths, rainfall, prevailing winds, humidity levels and temperatures - a scenario that allows the building to harness climatic conditions to enhance building performance and longevity as well as occupant comfort. Architects respected Calgary's building height limitations to ensure that the building's namesake, the Bow River, was never compromised by the shadow of the new tower.

With fewer interior columns and thinner elevator shaft walls, a more unobstructed floor plan fosters the collaborative work environment desired by the client. This, combined with the installation of a raised floor and modular furniture, gives maximum flexibility for future growth and reconfiguration.

The image is a detailed architectural rendering of a modern building. The central focus is a tall, curved structure with a complex, faceted facade made of triangular and quadrilateral panels. To its right is a more traditional rectangular building with a grid of windows. In the foreground, a street scene is depicted with a car, pedestrians, and streetlights. The entire scene is rendered in a light, sketch-like style against a dark background.

Detailed Project Description

Yolles

A CH2M HILL Company

The Team

Owner:	H+R Real Estate Investment Trust
Development Manager:	Matthews Development (Alberta) Inc.
Construction Manager:	Ledcor Construction Limited
Design Architect:	Foster + Partners, London, UK
Executive Architect:	Zeidler Partnership
Interior Design:	Zeidler Partnership / Gensler
MEP Engineers:	Cosentini, New York
Structural Engineer:	Yolles, A CH2M HILL Company



Design Concept and Rendering of the Bow

Building Statistics

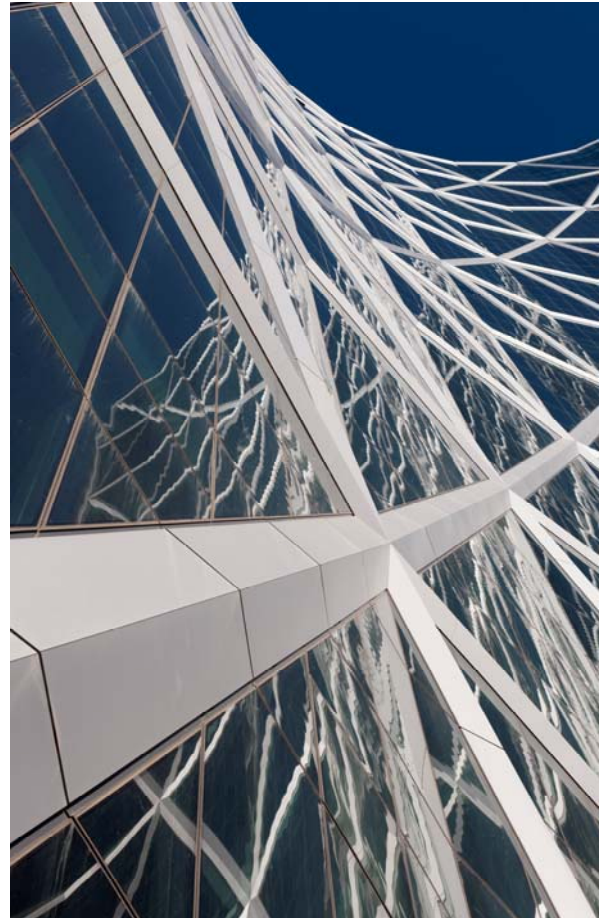
- Downtown Calgary, 2 city blocks
- “AAA” Office
- \$1.1 Billion Capital Costs
- 58 storeys at 774 ft (236 m) tall
- 3 Sky gardens / 2 Retail floors
- Tallest building in Western Canada
- 2.1 million ft², 1.6 million ft² rentable
- Six levels of parking
- Design commenced in late 2005
- Broke ground in 2007
- Occupancy in 2012

Design Objectives

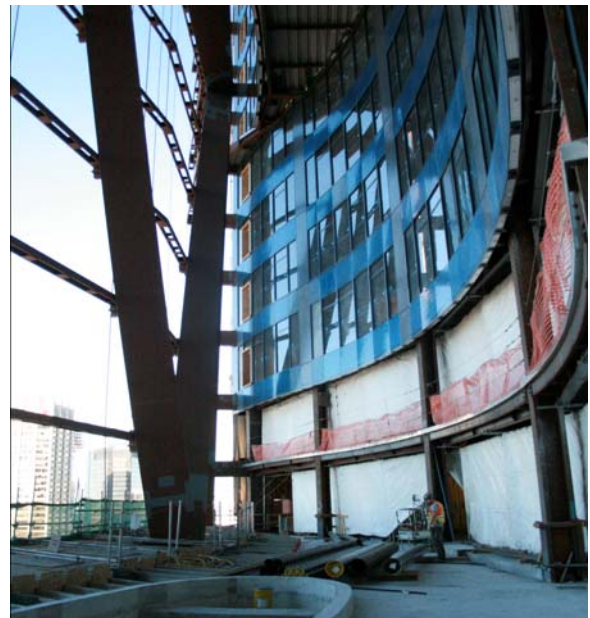
- Iconic design
- Destination place
- Enhanced connections
- Sustainable design
- Campus feeling
- Public amenities
- West Canadian “feel” in materials



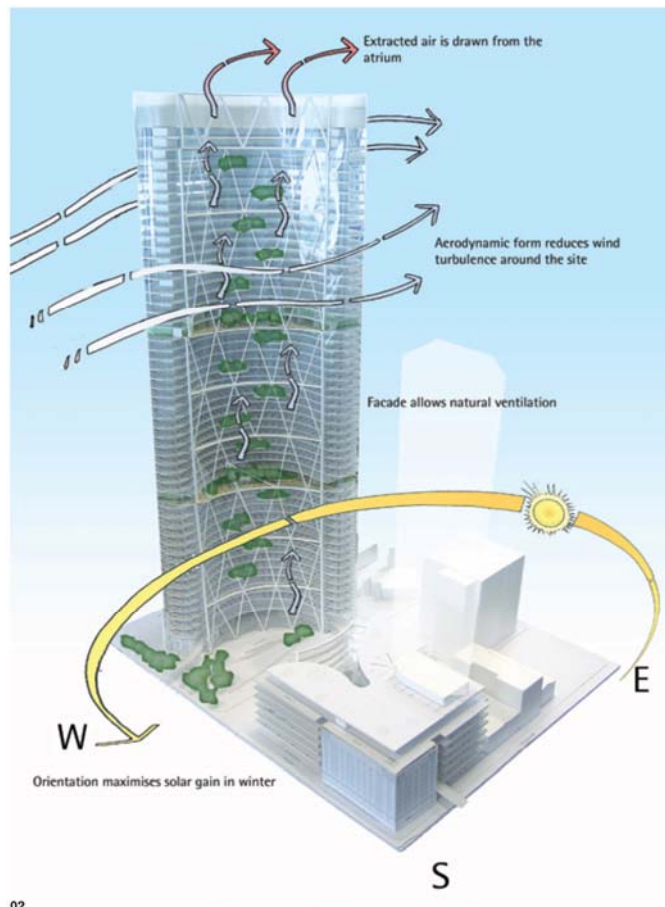
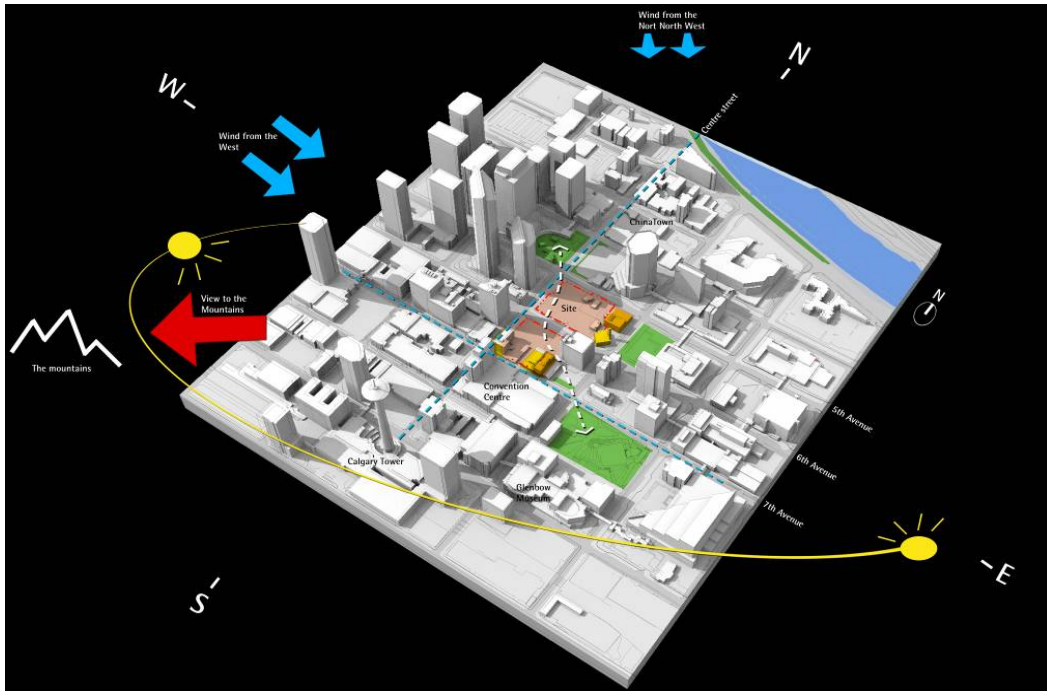
City Views and Urban Landscape of the Bow



South Façade and External `Diagrid` Views

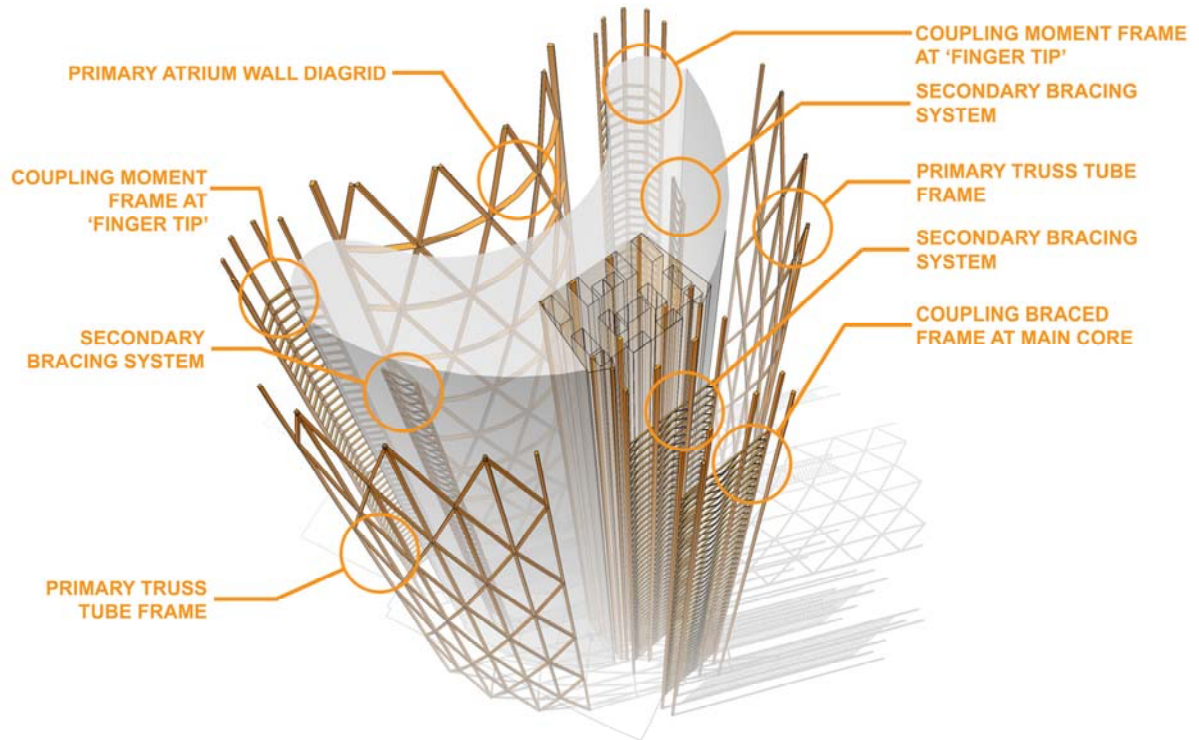


South Façade Internal `Sky Garden` Views

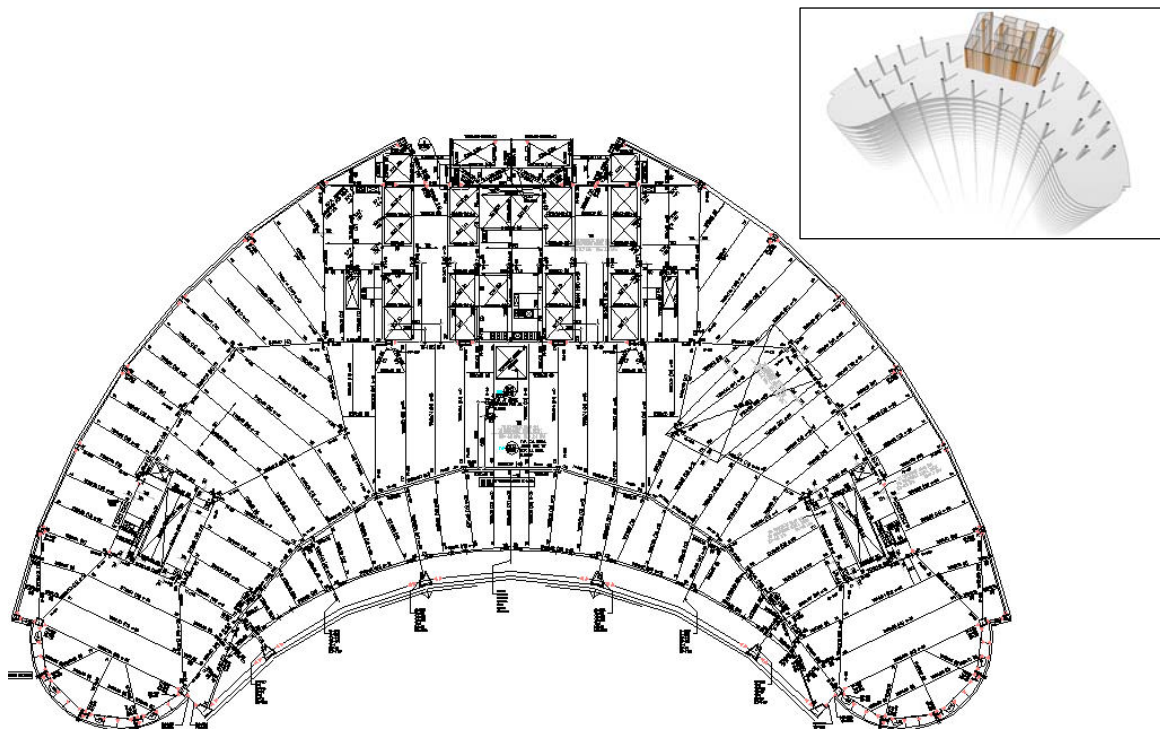


02

Arriving to the Tower Form – Site Planning and Environment



Structural Lateral System and Composite "Diagrid" (Hybrid LRFS)



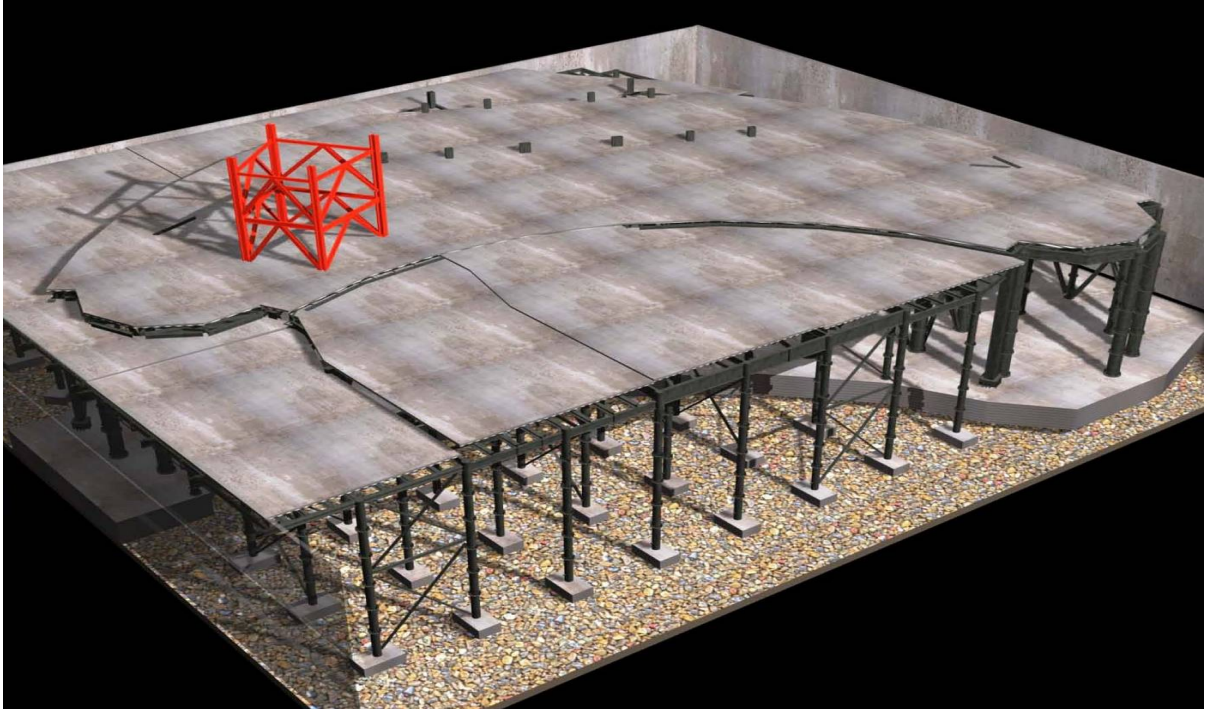
Structural Gravity System (Composite Steel Framing)



The Great Dig (400,000m³ and 20m deep)



The Raft (a single pour, 40hrs, 14,000m³)



Top Down Construction (6 storey tall composite steel columns)



Structural Steel Construction Progress



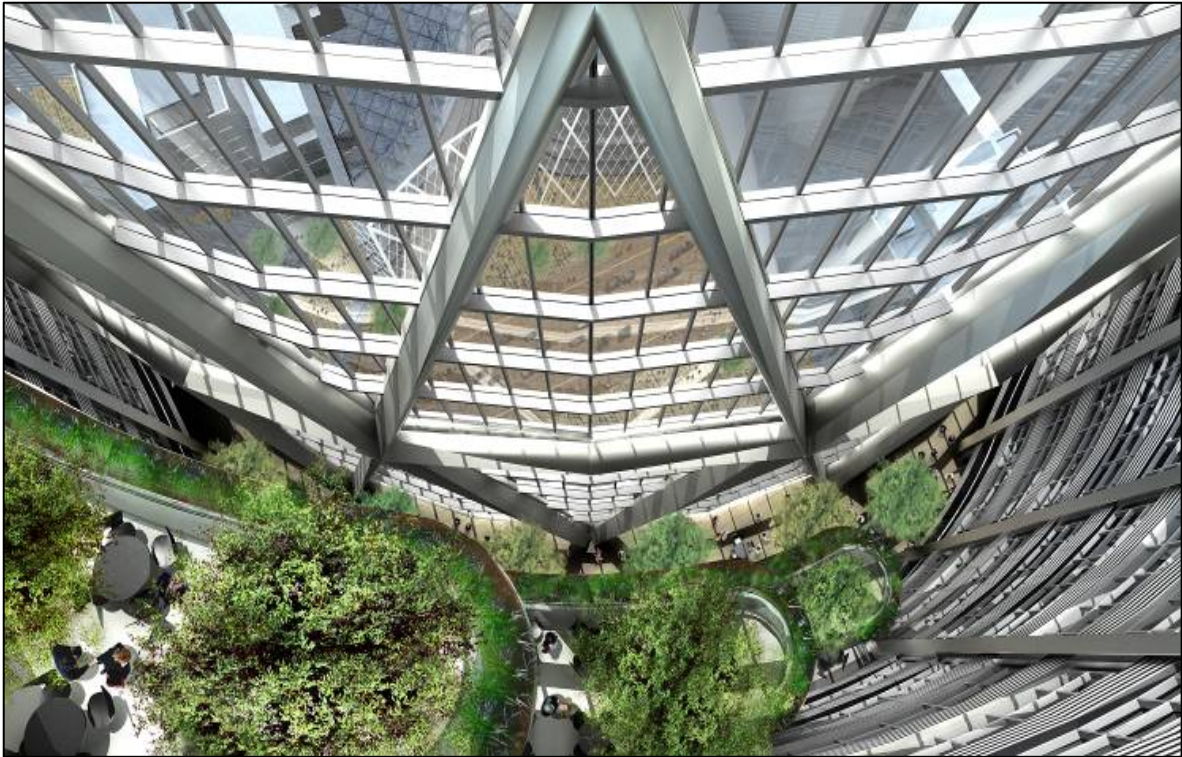
Construction Progress

Structural Steel Statistics

- Largest steel building in Canada
- Largest architecturally exposed steel atrium in world
- 50,000 metric tonnes (total)
- 37,000 pieces, 3 large cranes
- Heavy lifts ("K" node 85T)
- 800,000 structural bolts
- 5,000 field welds
- 100,000 lbs of weld material
- 200 daily workers



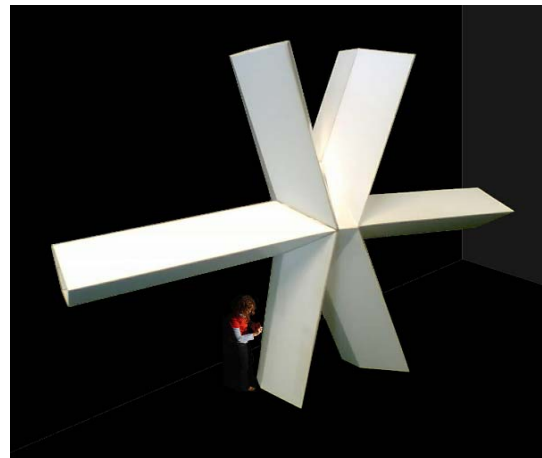
Weather Limitations

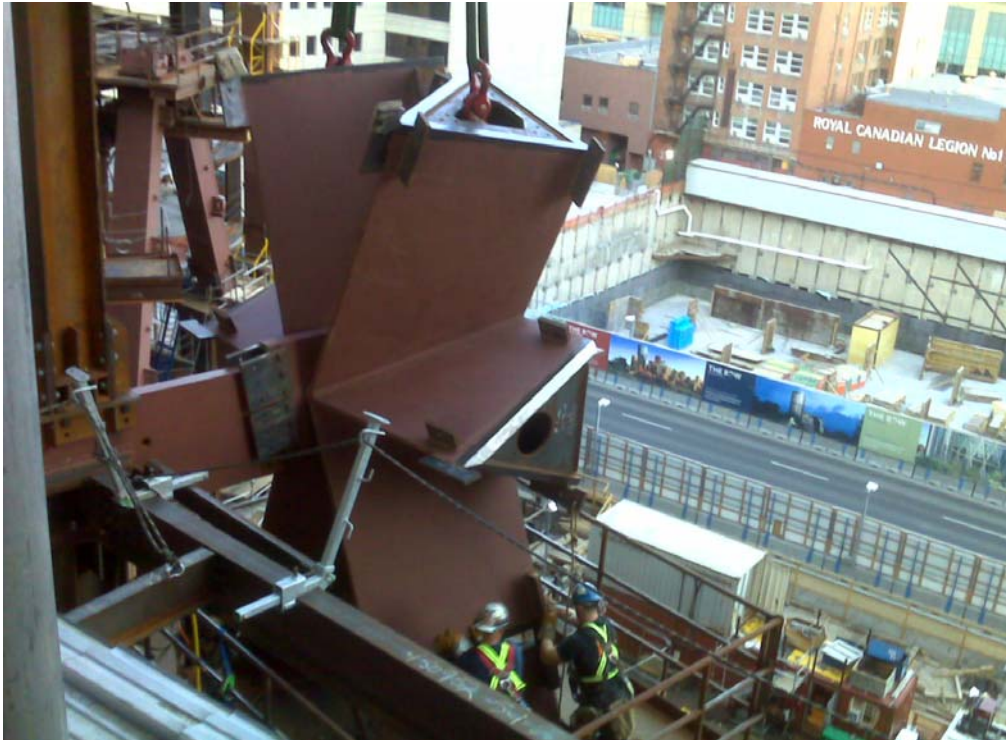


An Early Atrium Concept

Atrium Framing Statistics

- Largest AESS diagrid in the world
- 7000+ metric tonnes
- Fully welded connections
- Tied back every six storeys
- Triangular elements
- Complex nodal geometry
- Tight fabrication-erection tolerances

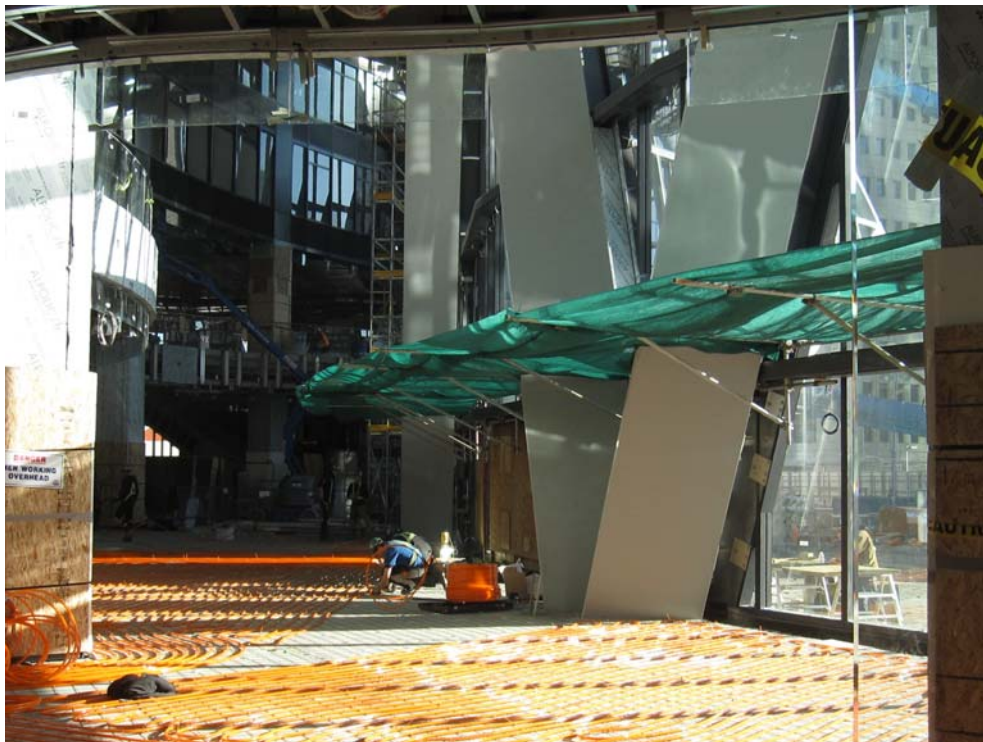




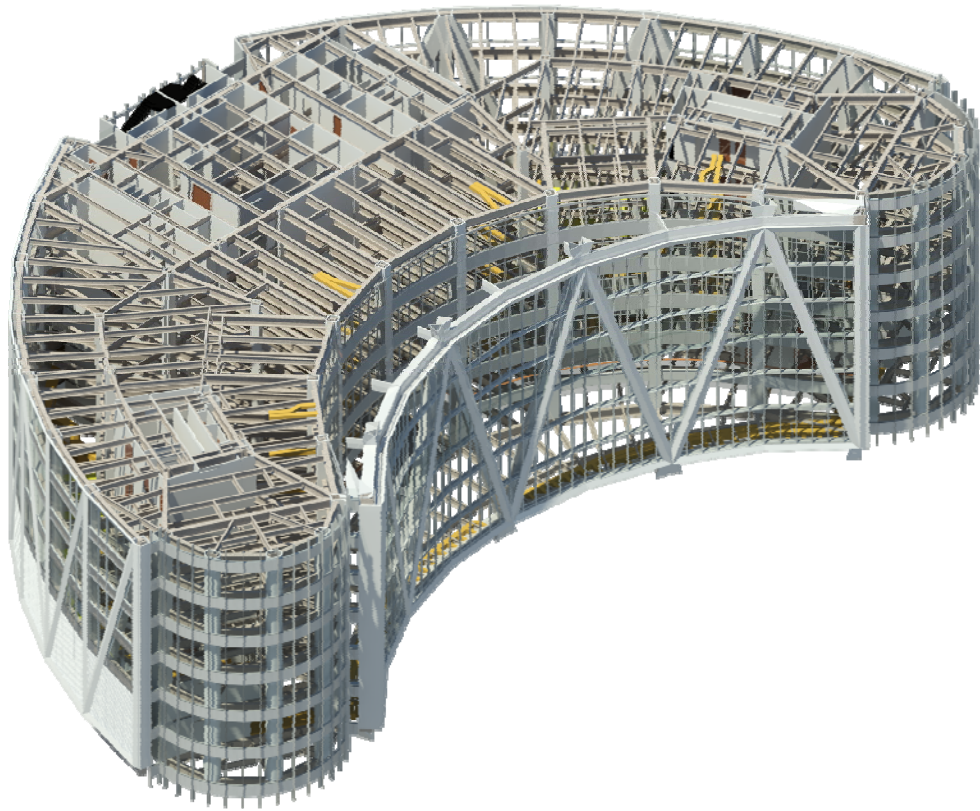
Standard Triangular Diagrid Node



AESS 'K' Node (65 tonnes)



Atrium near Completion



BIM Model - 6 Storey Building Module

Key Project Delivery Challenges

- Structural steel tender scheduled 8 months early and based on sketches
- Integrated designs combined with complex geometry
- Sophisticated and advanced designs required to satisfy technical design challenges (floor diaphragms, stability during construction, staging etc.)
- Major design changes (top-down basement and atrium revision, 2007)
- Economic turbulence stalled project in 2008
- Continual fast track design and client approval process
- Massive drawing and model production with over 50,000 hrs and over 370 structural drawings
- Contractor design assist should have been limited in time and scope



The Bow on the Calgary Skyline

The Key to Success

- The end user on board early for design input
- High calibre design and construction teams
- Collaborative approach
- Shared vision by all participants
- Talented individuals playing to their strengths
- BIM and technology
- Design assist process

The image is a detailed architectural rendering of a modern skyscraper. The building's most striking feature is its curved, faceted facade, which is composed of a complex network of triangular and quadrilateral panels. The rendering is presented in a wireframe style, with white lines on a dark background, highlighting the structural elements and the building's unique geometry. The skyscraper is set in an urban environment, with other buildings and a street with a car and pedestrians visible at the base. The overall aesthetic is clean and technical, typical of architectural visualization.

Supplement: NASCC 2012 The Bow Article

Yolles

A CH2M HILL Company

THE BOW TOWER - CALGARY AN ICONIC SKYSCRAPER REVISITED



NEB ERAKOVIC, M.A.SC, P.ENG, PRINCIPAL
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WALTERS GROUP, HAMILTON, CANADA

Neb Erakovic After joining Yolles in 2006, Neb's career progression as a senior engineer advanced to include design management and technical roles on some of the firm's largest and most notable buildings in Canada, the United States of America and overseas. As a Principal, Neb Erakovic is involved in all major building sectors with focus on complex structures and collaboration with signature architects. His responsibilities include design tasks from concepts to construction documents and site reviews, specialized numerical studies, and advancement of technology and material knowledge. As a voting member, Neb serves on CSA Technical Committee S806 for Design and Construction using Fibre Reinforced Polymers.



Tim Verhey Tim is Vice-President, Engineering and Operations for the Walters Group, a steel constructor located in Ontario, serving Canadian and US markets. Tim leads a large team of engineers, BIM modellers, steel detailers and construction experts that focus on developing innovative solutions to simplify and rationalize fabrication and construction of steel structures. Tim has served as engineering lead on numerous award winning steel buildings. Tim has Bachelor and Master's Degrees in Structural Engineering from McMaster University, Canada and serves on the Technical Committees for CSA W59 "Welded Steel Construction" (Vice-chair) and CSA S16 "Limit States Design of Steel Structures" – the two standards that govern steel construction in Canada.

Abstract

The Bow is a striking presence on the Calgary skyline, with its iconic crescent-shaped, inversely curved form. Designed by Foster + Partners of London, UK this innovative 59-storey tower is a groundbreaking structure featuring six-storey atria with the façade integrating an architectural exposed "diagrid" (diagonal grid) structure in six-storey segments. The perimeter diagrid frame acts as one of the building's structural systems making up the hybrid lateral force resisting system (LFRS). All project team members successfully fulfilled roles in addressing unique design and constructability challenges; the irregular floor plate with long span structures, a sophisticated lateral system, the project delivered as fast track on nearly every aspect of design and construction, and the building constructed in a dense urban center with harsh climatic conditions. Significant construction challenges included the analysis and design of temporary structures required during construction, super-elevation and elastic column shortening, extremely tight erection tolerances, and a very high standard of quality for the 8,000 ton AESS atrium. The development is near completion and the building occupancy scheduled for the second half of 2012.

Keywords: Diagonal grid, perimeter tube system, structural steel structure, atrium, high-rise building, construction, modular washrooms.

1. INTRODUCTION

Opening in 2012, the Bow Tower located in downtown Calgary will become the new headquarters of EnCana Corporation, the largest Canadian based energy corporation. The site occupies two city blocks in central downtown Calgary and, at 238 meters (780 feet), the tower will be the tallest building in western Canada and one of the tallest commercial office building in the country. The gross constructed area of the tower above grade is 195,000 sq. metres (2.1 million sq. feet) and 97,000 sq. metres (1 million sq. feet) at six levels below grade, including 1,375 parking spaces along with the loading dock and service areas. At the early stages of the project, EnCana acquired the land for the development, selected the architect and consulting team, and developed the concept of the project up to the schematic drawing phase. Following a developer/owner proposal, H&R REIT were successful in negotiating the purchase of the property and the project, with EnCana signing a long term lease for their space. The conceptual development of the project started in late 2005, with the assignment of Foster + Partners of London, UK as the signature design architect and Zeidler Partnership Architects of Toronto and Calgary as the executive architects. Halcrow Yolles was retained as the structural engineer on the project. Ledcor Construction Limited is the construction manager for the project, with Matthews Developments Alberta as development managers. SWJV (an equal joint venture between Supreme Group of Edmonton and Walters Group of Hamilton) were the fabricators and erectors for the structural steel, and also responsible for temporary works and construction engineering.

This paper revisits the development of design concepts with a particular reference to the building architecture and structural systems with focus on specific design and construction details of the perimeter diagonal grid and the lateral system. Construction logistics issues are examined, in the context of a “top-down” construction technique used for the substructure to accelerate the construction schedule. Finally the above grade tower superstructure construction is discussed; characterized with large and heavy building components and reflected in the fabricator’s perspective on production and erection of complex AESS elements to tight tolerances along with a tight construction schedule.



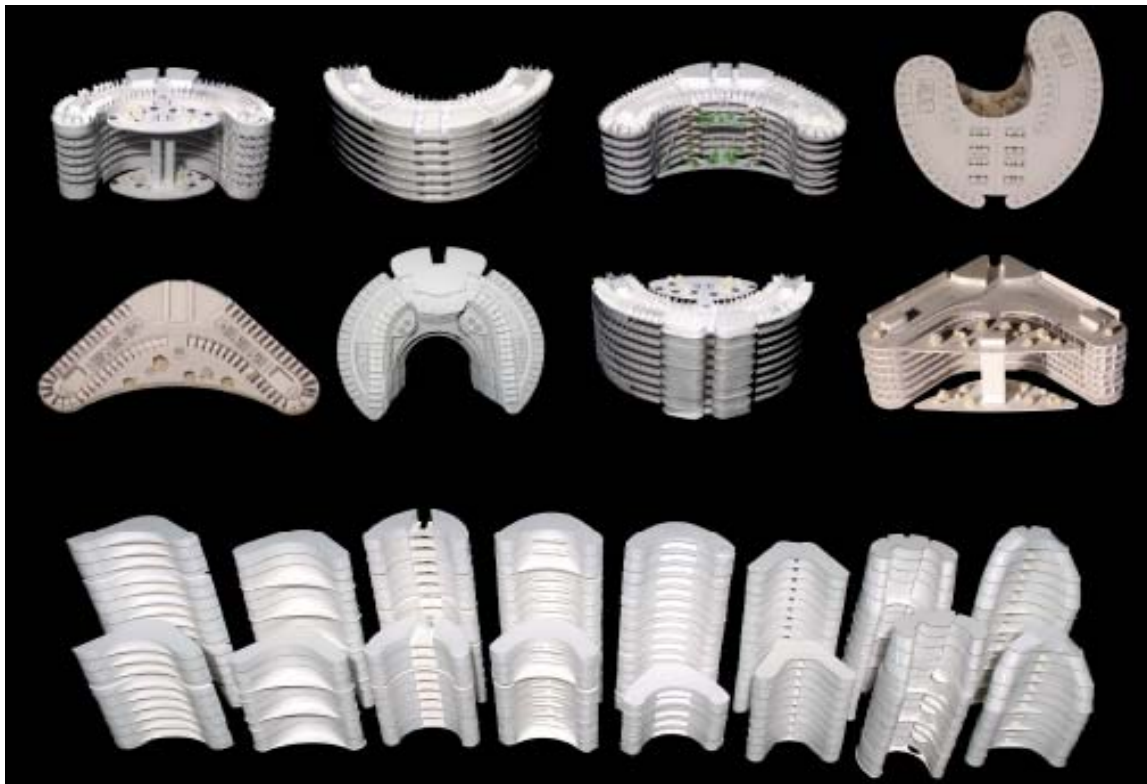
*The BOW in Dec 2011
(Image provided by Matthews / H&R REIT)*

2. ARCHITECTURAL CONCEPT OF THE BUILDING

As one of the first examples of a truly modern and sustainable high-rise tower in Calgary, The Bow successfully fulfills the owners' goals of a distinctive tower that is both a progressive and sustainable office space and a vibrant cultural, civic, and shopping destination for Calgary residents and visitors. Sky gardens divide the building into distinct zones, forming a series of destination floors with lobby areas, meeting rooms and communal spaces.

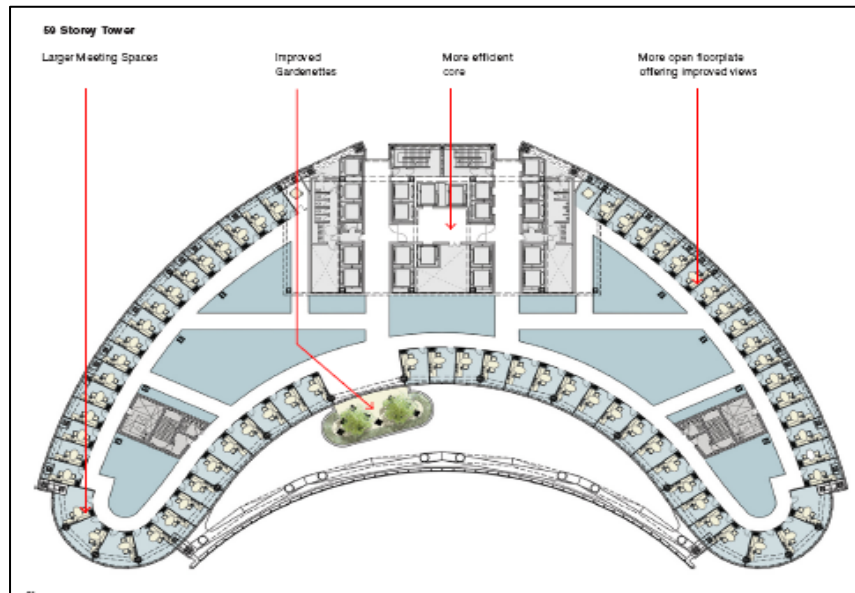
Early design meetings with EnCana identified the prime objectives for the development. These included a distinctive image, a "home away from home" ambiance, a desire to transform the local area in downtown Calgary and tie into the enclosed pedestrian path through downtown buildings, and to introduce landscaping at the base of the building to facilitate interaction with the public.

An assessment of the space planning and business units became the basis for the building's architectural design. Foster + Partners explored various floor plate configuration and layouts for consideration by the client. Each of these configurations were studied for building efficiencies, functionality, economics and aesthetics. Pictured below are some of the final contestants in the design process, along with options to the vertical profile of the building.



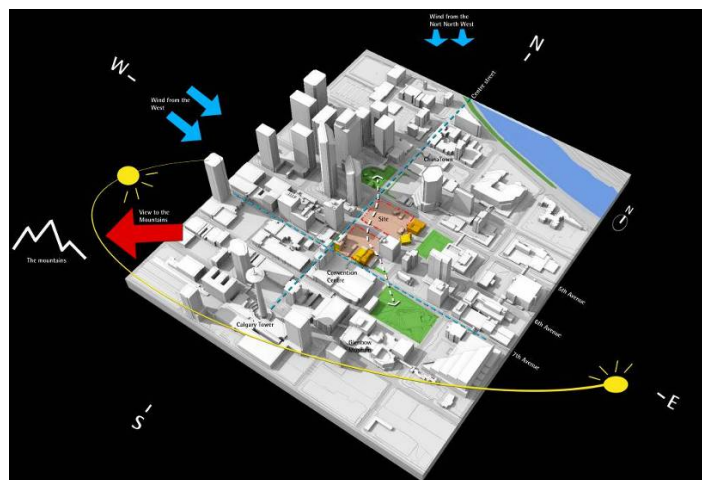
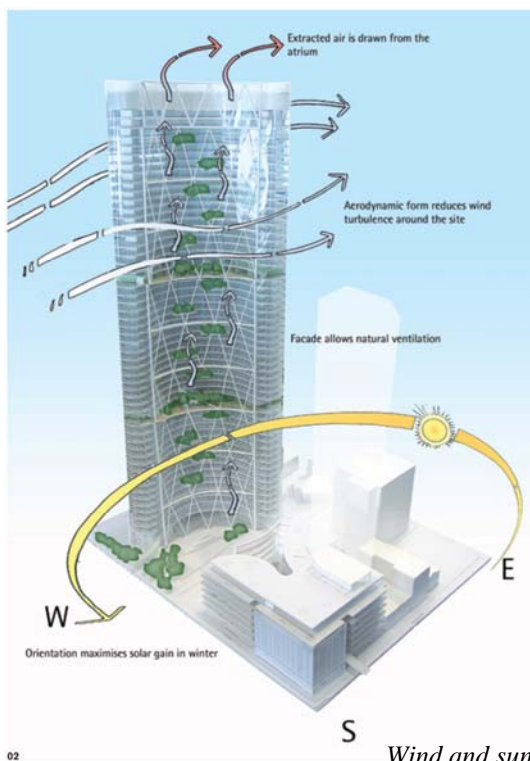
*Floor plate options and building models
(Image provided by Foster + Partners)*

As a result of EnCana's office culture, there was a significant requirement for perimeter offices, as opposed to the recent trends in office layouts with "seas" of office cubicles or systems furniture. Conversely interior areas were needed in order to provide meeting rooms and support facilities. The most typical office floor concept is shown below, with the elevator banks shown in a side core position clustered with the washrooms and the north facing stairs. The shape selected also had the benefit of minimizing the length of the perimeter and interior wall system surrounding the atrium area, and capitalizing on the spectacular view of the Rocky Mountains.



*Early concept of the typical office floor
(Image provided by Foster + Partners)*

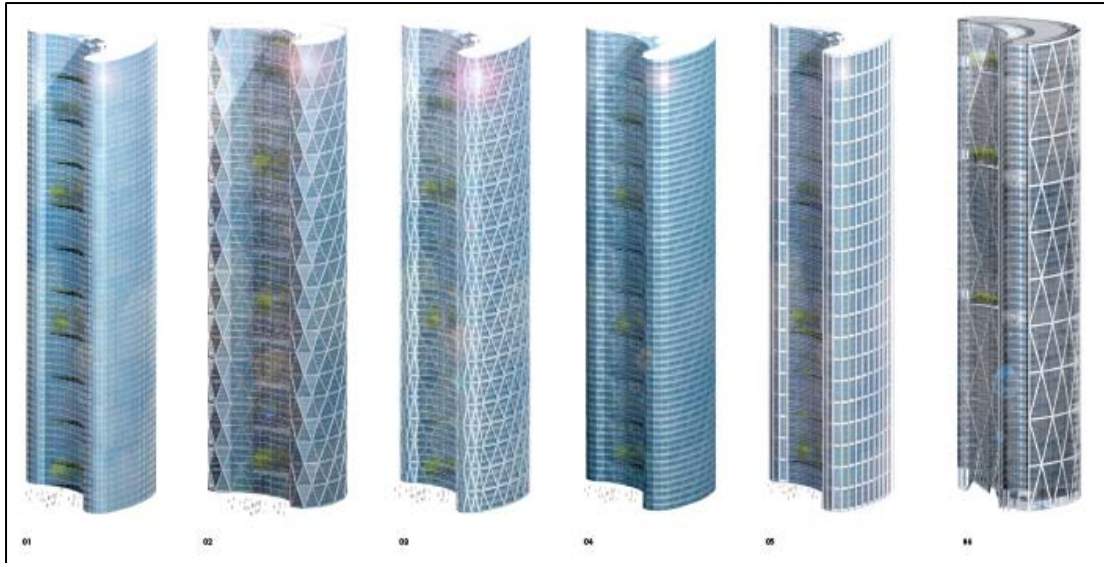
The design of the tower enthusiastically pursued sustainable design goals. As a result of the curving bow shape, wind loads were reduced when compared to a rectangular building. This improved the economies of the building resulting in effective use of building materials. Studies were carried out to position the building to maximize sunlight to the office space and to internal gathering locations. These studies partially helped determine the crescent or bow shape with the interior curvature facing to the south west; using this interior curvature to capture sunlight. The bow shape gave rise to the locations of the atrium along the south west elevation. This atrium or plenum type buffer zone is designed to absorb the heat from daily sunlight and use it to partially warm the building in the winter and buffer the solar gain in the summer, minimizing the environmental impact on the city. This orientation had the added benefit of maximizing unobstructed views to the majestic Rocky Mountains.



*Wind and sun study / Diagrammatic site plan
(Images provided by Foster + Partners)*

3. STRUCTURAL DESIGN CONCEPTS

The development of structural systems and corresponding selection of materials were driven not only by the building geometry and objectives set out by the client, but also through close collaboration between the design team members to create a truly iconic building, one in which the structural systems were integral and natural parts of the overall architectural expression.

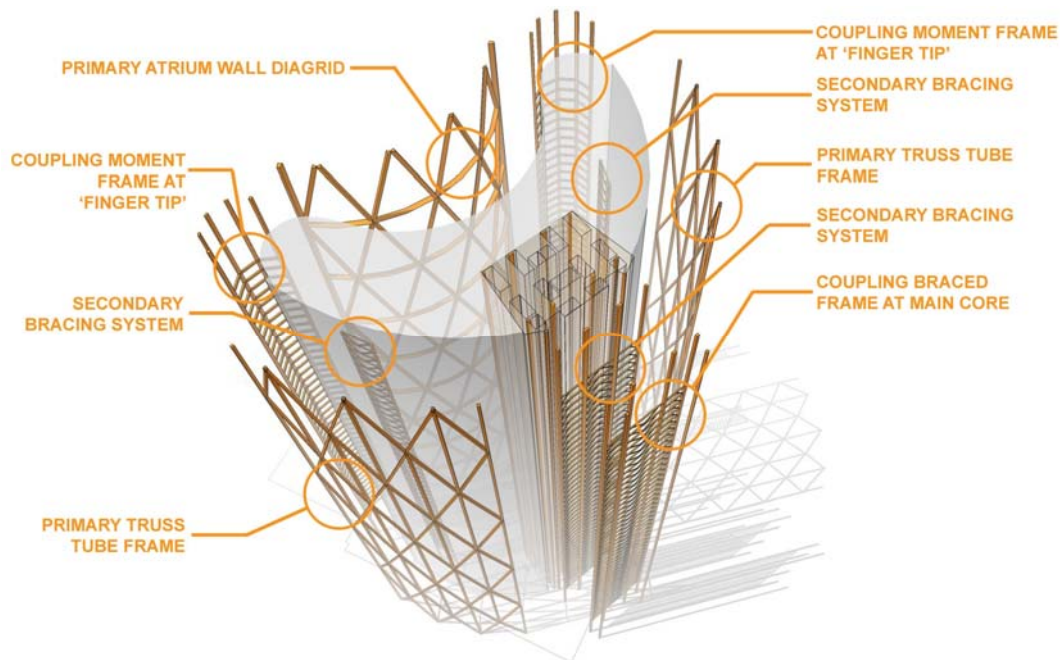


*Architectural interpretations of structural alternatives
(Image provided by Foster + Partners)*

Structural steel was a natural choice given the overall design objectives and building requirements, the developed geometry, and the importance of achieving sustainability goals. The high strength of structural steel generally offers advantages to steel over other construction materials in that its use results in smaller vertical load carrying members (allowing for more open occupied spaces), more economical foundations, lightweight long-span floor framing (leading to larger column-free areas), and greater future flexibility in terms of adoptability to future occupancies, additional loads and tenant improvements.

After considering various structural solutions for the building lateral force resisting system (LFRS), a dominant perimeter 'diagrid frame' coupled with other systems was selected as the building hybrid LFRS. A six-storey vertical module was used for the diagrid, as it related very well with EnCana's internal space planning requirements. This hybrid LFRS involved three primary braced frames on the curved south elevation and the two northerly facing elevations, "coupled" together with steel moment resisting and braced frames. In addition, and to augment the lateral stiffness of the tower between the six-storey-spaced 'nodal floors', a secondary bracing system consisting of conventional steel braced frames at two remote finger core stairs and around the main central elevator core were also provided. As a result, the lateral system consists of the following four principal components:

- At the north-west and north-east sections of the perimeter, six-storey high diagonal grids are faceted along the building perimeter;
- The "diagrid" elements are inter-connected through the core with a series of braced frames between the elevators and the north stair shafts;
- Along the south atrium screen wall face, a similar six-storey modular diagrid spans outside of the atrium and is connected to the bulk of the building by horizontal axial-force members, "drag-struts", at the ends of the atrium;
- The two dominant diagonal grid elements are inter-connected at the ends of the building ("fingertips") with a series of rigid frames.



Exploded view of components of the hybrid system

A central mega core alternative, perimeter systems with closely spaced steel columns and variations of diagonal bracing schemes, and other hybrid systems including “outrigger” frames and “belt” trusses were all studied prior to the selection of the above hybrid LFRS. The architectural interpretation of alternate LFRSs is shown in the image at the top of this section. The curvilinear geometry of the floor plate, the cladding design, exterior and interior aesthetics, space planning and access to natural light, and economics of the steel framing scheme were primary decision making factors for the building primary structural system.

The lateral system, and hence the atrium wall, was designed under wind, seismic and thermal loads – with wind being the governing case. Wind tunnel studies were performed to obtain the wind loads on the tower by creating a 1/400 scale model in a 600-metre radius environment. A separate test was performed on the atrium wall to determine the impact of the wind loads on the long, unsupported atrium wall members. The resulting wind and seismic loads were applied to a finite element model. In total, 180 ultimate limit state (ULS) and 64 serviceability limit state (SLS) load combinations were used. The deflection criteria considered were a maximum of $H/400$ at the top of the building, as well as a maximum inter-storey drift of $h/350$. For seismic loads, the inter-storey building drift was limited to $h/40$.

The gravity load carrying system of the building was affected by the need to minimize the height of the building. As the location of the building is just south of the Bow River in Calgary, the urban guidelines prepared by the municipality required that the building is low enough to avoid shadowing the river during the September equinox period. As a result, a network of interior columns was added in a layout to ensure a depth of the floor beams below 485 mm (19 in), underneath a composite floor slab construction consisting of 75 mm (3 in) concrete cover on 75 mm (3 in) steel deck. High-strength steel 450 MPa (65 ksi) was used for all W-shape gravity columns above level 24 and for the heavy W360 members of the diagrid below level 24.

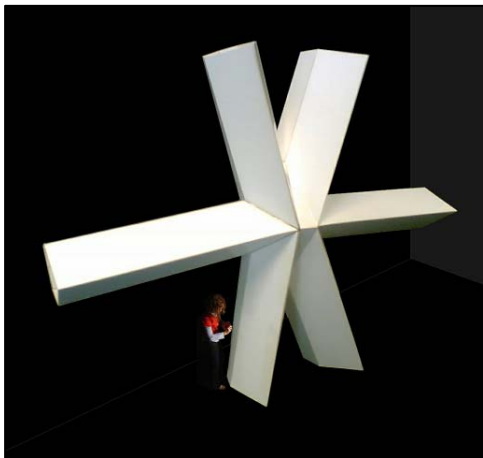
4. ATRIUM WALL DIAGRID

The atrium screen wall is a very dramatic element in the architectural design of this building as it is exposed to all EnCana staff. Structurally the wall is an important component, as the diagonal grid is involved in completing or closing the perimeter lateral load resisting system. Complicating the structural aspects of the screen wall is the large unsupported length of the compression elements and the tendency of the screen wall to attract gravity load from adjacent floor plates.

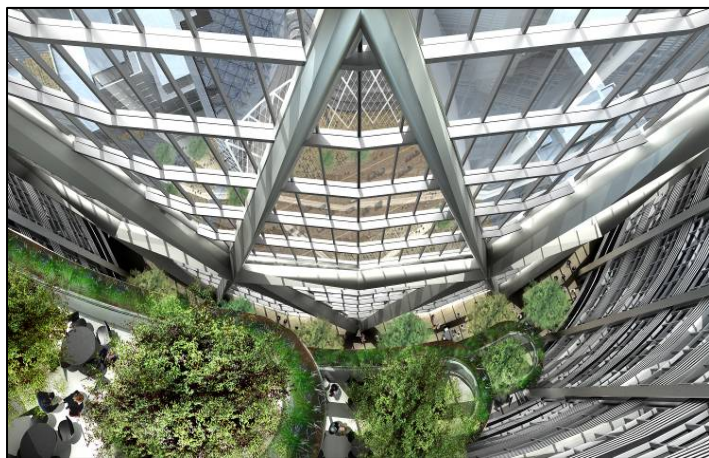


*Expression of the diagonal elements of the atrium screen wall
(Image provided by Foster + Partners)*

The design options included rectangular shaped steel elements, round pipe (with possible concrete fill) and triangular shaped steel elements. Various studies were carried out for these three options including impact to aesthetics, intrusion into the atrium, ease of connections, support of secondary building services, support of the perimeter curtain wall, fire proofing system, and constructability of the structural system. On a cost of material basis, the round pipe with flange plate connections proved to be the least structural cost but with consideration of the other aspects, particularly aesthetics, a decision was made to utilize the triangular shaped elements. These elements are shown in the following BIM figures.



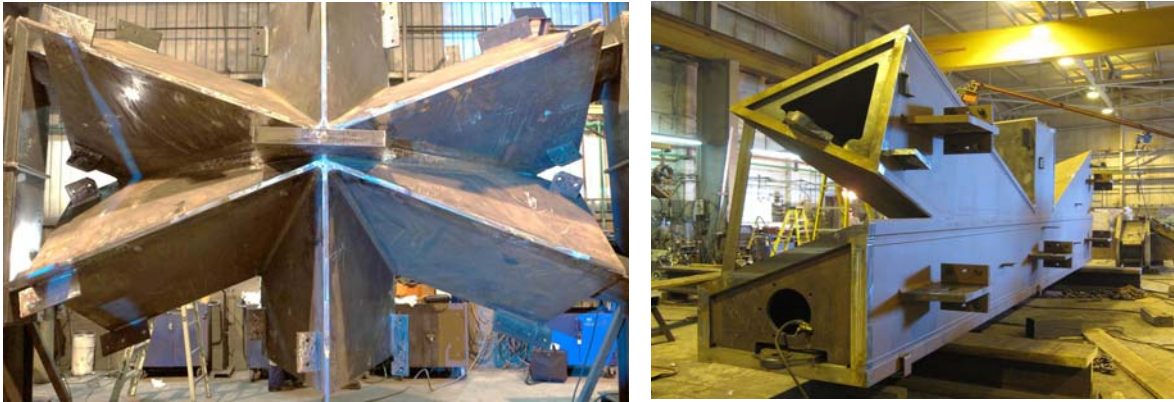
Diagonal grid node



*Rendering of the atrium looking at the screen wall
(Images provided by Foster + Partners)*

The concepts of connections were initially developed by the structural design team through a series of hand drawn sketches, and details were then further refined and fully engineered by the steel contractor. Having dimensions of approximately 2.8 metres in width and standing 4.2 metres tall, the nodes were not only challenging to design but also to fabricate. Welding of thick plate followed specific procedures that involved preheating of the elements before welding. Internal stiffening plates were employed to contribute to an efficient load transfer through the node. This added to the complexity of the system and created additional challenges for fabrication.

The nodes were fabricated in the Walters Hamilton shops and then field-welded to the diagonal and horizontal diagrid members. The use of triangular built-up sections had its challenges; in the modern engineering era with computer-aided design tools used extensively, these sections and nodes, and their connections needed to be designed 'by hand'. The engineer and the steel fabricator had to go back to engineering first principles to design these structural elements.

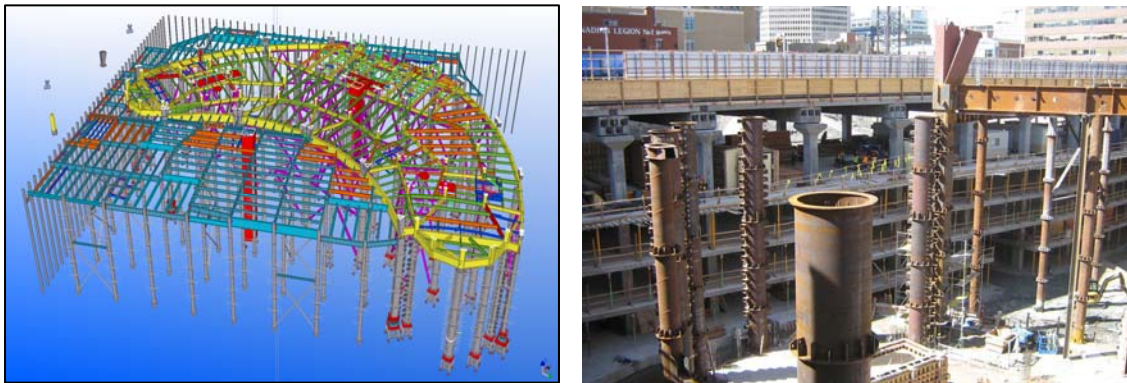


Triangular steel section of the diagrid node in the shop

5. CONSTRUCTION LOGISTICS

5.1 Top-Down Below Grade Construction

The design and construction schedule requirements of the project had an aggressive time table. As a result, the client decided to bid the structural steel with a unit price contract based on schematic design phase documents. This design was based on a six-storey basement being constructed of reinforced concrete with structural steel commencing at the ground floor level. Decisions by the project and construction managers led to the sequence incorporating structural steel columns to start from the raft foundation level and with the concrete basement framing following after the steel framing was erected at grade. The steel was also extended to most of the north block to provide the “umbrella” framing to assist in the tower erection over the deep basement. The intent was for the tower steel to proceed above, with the slower paced reinforced concrete plates taken off the main critical path schedule.



BIM model and construction progress photo of ground floor and apron construction

To achieve this “top-down” construction, the lowest lifts of columns were augmented with tie down anchors into the raft design for the lower level floors. Added bracing located within the basement area provided reinforcement to support the building above until such time as the permanent below grade shear walls and ground floor diaphragm could be constructed. In some cases this temporary bracing was intentionally left embedded within the final shear wall construction.

5.2 Tower Construction

The construction logistics developed by the fabricator and erector required the general office area with the service core and outside “finger” cores to be constructed in advance of the atrium “screen” wall. This base construction could be used to establish the column and diagonal grid node locations to facilitate the erection of the long diagonal members of the atrium screen. SWJV also determined very early on that the project required three tower cranes to provide full coverage to the vast project site, provide sufficient crane lifting capacity for the mega-nodes and atrium framing (up to 65 ton lifts), and also to support an aggressive construction schedule. All three cranes were internal climbers supported by temporary vertical braced cores that provided lateral support.

Unlike conventional structures with a reinforced concrete or structural steel core, the perimeter system of the diagonal grid did not have the advantage of a central erection base to which the perimeter framing could be anchored and adjusted. It was also anticipated that the erection of the atrium screen wall would take longer than erecting the office portion due to a 10.2 metre offset of the atrium wall from the edge of slab of the office space. In design studies it had been found that a strong core scheme triggered a dead load drift of the tower as a result of the side core location.

To achieve the erection of the atrium screen wall at a later date, temporary frames were constructed to span the atrium plenum at various levels as means of stabilizing the entire wall. These temporary frames were removed and re-used as the construction of the atrium wall progressed up the height of the building. Generally, the atrium wall erection was approximately six storeys behind the office area construction. This delay in the atrium wall erection also helped to mitigate some of the gravity load creep from the more heavily loaded office areas which commonly occur with a structure of this nature.



Various stages of the tower construction

5.3 Construction Tolerances and Atrium AESS

Fosters + Partners had established a plan tolerance for all slab edges and the atrium diagrid structure of +/-25mm of the theoretical position over the full height of the tower. This criterion is to a large extent more stringent than the

traditional +50 / -75 mm AISC specified tolerance for high-rise buildings, and thus required highly accurate shop fabrication and special measures in the field. To ensure the atrium was constructed to this tolerance, each of the AESS members that connected the atrium to the tower were custom trimmed prior to erection, and the entire height of atrium was ultimately installed within 15mm of the theoretical plan location.



Various stages of the tower construction

As a Class “A” office tower, the finished floors were also required to meet very stringent floor flatness criteria. Due to the tendency for the more heavily loaded interior columns to “shorten” to a greater degree than the more lightly loaded perimeter framing, the interior columns were super-elevated by approximately 2mm per storey. Adjustments to column elevations were made by adding shims to the bolted or welded column splice locations.

The architect required a very high standard of fit and finish for the exposed Atrium diagrid framing structure. This was achieved by developing a system of jigs and fixtures at the fabricator’s manufacturing plants to ensure seamless joints where the members joined in the field.



Expression of the AESS diagonal elements of the atrium screen wall

5.5 Modular Washrooms

Another unique aspect of this project was the provision of over 100 fully pre-fabricated modular washrooms. Steel frames were custom designed by Feature-Walters (a member of the Walters Group of Companies) and fit-out with all interior finishes, vanities, ceilings and services. These modules were then shipped from the manufacturing facility in Ontario to the site and hoisted by crane to the appropriate floor level and moved into position. This cost-effective solution ensured the highest standards of fit and finish but more importantly moved a significant body of work off-site to help ease job site congestion and accelerate construction progress.



BIM image and on site hoisting of the modular washroom

6. CONCLUSION

As of January 2012, the construction of the main building structure and the envelope was complete, with the interior fit-out work, completion of the landscaping areas and pedestrian path link bridges proceeding at a quick pace. The present schedule has the building occupancy scheduled for the second half of 2012. From the design team perspective, this unique building will prove to satisfy the vision and objectives that EnCana Corporation had when they entered into this venture. Challenging design aspects of the project on the structural side include the distinctive crescent-shaped floor plate, sophisticated hybrid lateral system of the building, the exposed atrium screen and numerous construction logistics aspects.

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