High Energy

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Canada's largest energy company will soon occupy the tallest building in the western half of the country.

BUILDINGS DESIGNED BY FOSTER + PARTNERS routinely turn out to be architectural icons. And in the case of the firm's new Bow project, a new 59-story tower in Calgary, it will be the tallest building in western Canada.

Standing 780 feet and encompassing approximately 2 million sq. ft above grade, the Bow is the new headquarters building of EnCana Corporation, the country's largest energy corporation. The crescent-shaped tower features a vast atrium partitioned in four clear height sectors of 24, 18, 12, and six stories. The façade of the atrium is an architectural exposed "diagrid" (diagonal grid) structure in six-story segments that act as one of the building's six separate systems making up the hybrid lateral force resisting system (LFRS). The other LRFS include a W-shaped rigid frame at each end of the banana-shaped structure and two additional diagrid sectors on either side of a concentric and eccentrically braced area framed through the core.

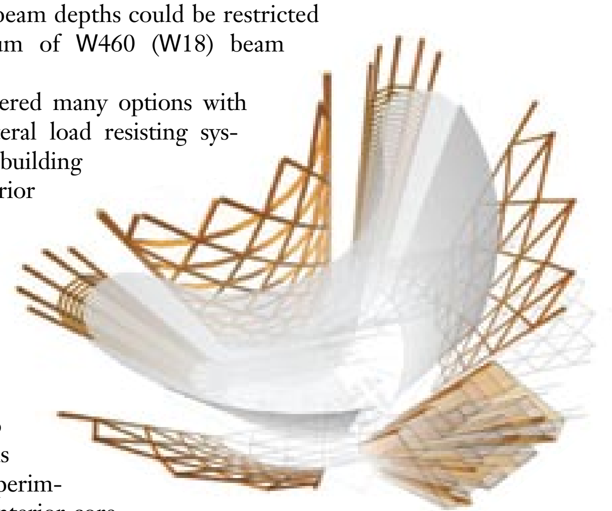
The building also features long-span composite beams creating core-to-perimeter wall open spaces.

Structural System

In early discussions regarding the structural system, it was determined that the bulk of the building structure would be reinforced concrete on composite steel deck with structural steel framing. This material option was selected because of the size of the columns, the speed of construction, and the limitations on the local concrete formwork industry with respect to the availability of labor and carpenter forces.

The gravity load-carrying system of the building was affected by the need to minimize the height of the building. The location of the building is just south of the Bow River in Calgary and as a result of this location, the urban guidelines prepared by the municipality required that the building be low enough to avoid shadowing the river during the September equinox period. Thus interior columns were added to the floor plate so that beam depths could be restricted to a maximum of W460 (W18) beam depths.

We considered many options with respect to lateral load resisting system of the building from an interior core system (supplemented by secondary cores at the "fingers") to perimeter systems to hybrid systems utilizing the perimeter and the interior core. The interior core option resulted in excessively thick reinforced concrete walls and an excessive steel braced system because of the height of the building; the height to core aspect ratio was at 15:1. This was further compounded because of the "dead" load drift issue, a result of the side core position of the core. Generally, floor loading occurred only on the inboard side of the building with only the cladding and north scissor stairs loading the north side of the core. Even in the structural steel core scheme, the resolution of the gravity load drift issue was responsible for an



The façade of the building's atrium is composed of a "diagrid" structure, in six-story segments. Renderings: Halcrow Yolles

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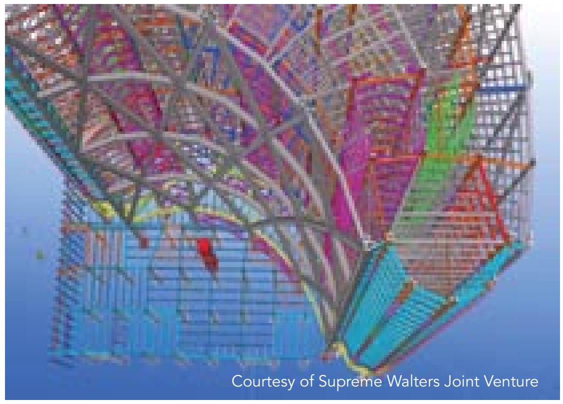
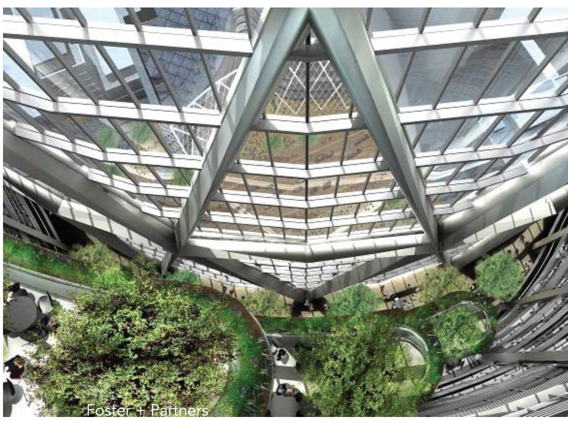

Courtesy of Supreme Walters Joint Venture

A BIM model (right) and a rendering (below) of the atrium's diagrid façade. The atrium is partitioned in four clear height sectors of 24, 18, 12, and six stories.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excessive tonnage of steel for this purpose alone. In the perimeter system option, the selection included closely spaced steel columns and various layout options including closely spaced columns and diagonal bracing schemes.

Hybrid options included activating "outrigger" frames and "belt" trusses at the garden floors, which occur approximately every twelve floors. This option was developed using full-floor trusses at the top floors of the atrium areas, which also contained a large mechanical plant area as well as the mechanical equipment rooms for the elevator lift areas. This system, while structurally efficient, negatively impacted the use of the floors.

The largest wind load on the building generally hits it from the northwest or southeast. This "broadside" loading generally hits the building where the depth of the structure is the smallest. We proposed an internal diagonal element that would reach from the core to the outside by the atrium over a six-story diagonal. While the floor by floor impact of this diagonal was relatively small, it proved to be unacceptable for the tenant's space planning.

Ultimately, a perimeter diagrid system was selected. This decision was made based on economics of the steel framing scheme, the functionality of the tenant space, and the aesthetics of the architecture. The lateral system consists of four principal components:

1. At the northwest and northeast sections of the building's perimeter, six-story-high diagonal grids are facetted along the perimeter.
2. These diagonal grid elements are connected through the core with a series of braced frames between the elevators and the north stairs.
3. A similar six-story diagonal grid spans outside of the south portion of the atrium and is connected to the bulk of the building by drag-struts at the ends of the atrium.
4. These two dominant diagonal grid elements are connected at the ends of the finger areas with a series of rigid frames.

These elements generally occur at the perimeter of the building. Because of the nature of the six-story diagonal grid, there was an issue of the global stability of the building between the node levels. To achieve the secondary stability, bracing was added with a wall of the finger core throughout the height of the building. Added bracing at the back of the elevators was required in the lower 24 floors to supplement this secondary bracing.

Atrium Screen Wall

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

The design options included rectangular shaped steel elements, round hollow structural sections (with possible concrete fill), and triangular-shaped steel elements. Various studies were carried out the three options—including the impacts on aesthetics, intrusion into the atrium, and ease of connection; support of secondary mechanical electrical and plumbing systems and the perimeter curtain wall; and constructability of the structural system.

On a material cost basis the round HSS with flange plate splices proved to incur the least structural cost but with consideration of the other aspects, particularly the aesthetics, a decision was made to use the triangular elements.

Construction Logistics

The design at the bid stage was based on the six-story basement being constructed of reinforced concrete with the structural steel commencing at the ground-floor level. Decisions by the project managers and the construction managers led to the incorporation of the structural steel to start from the raft foundation and with the concrete basement framing following after the steel was erected at grade. The steel was also extended most of the north block to provide "umbrella" steel to assist in the structural steel erection of the tower over the deep basement. The intent was for the tower steel to proceed above while the slower paced reinforced concrete basement backfilled off the main critical path schedule.

To achieve this "up-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 was reinforced to support the building until such time as the permanent below grade shear walls and ground floor diaphragm could be constructed. In some cases this temporary bracing was embedded within the final shear wall 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 diagrid node locations to facilitate the erection of the long diagonal members of the atrium screen. 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 the 10.2 meter offset of the atrium wall from the edge of slab of the office space.

Until the atrium screen wall could be erected, temporary frames were constructed to span the atrium plenum at various levels as a means of stabilizing the entire wall. These temporary frames were removed and reused as the construction of the atrium wall progresses up the height of the building. Generally the atrium wall erection was approximately six stories behind the office area construction. This delay in the atrium wall erection also helped to avoid some of the gravity load creep from the office areas that could be expected with a structure of this nature.

Current Status

As of this January, the structural steel erection has been completed to grade with the tower framing proceeding to the sixth floor in a staggered profile. The present schedule has the tower structural steel topping off in 2010 with the early occupancy of the building scheduled for 2011. MSC

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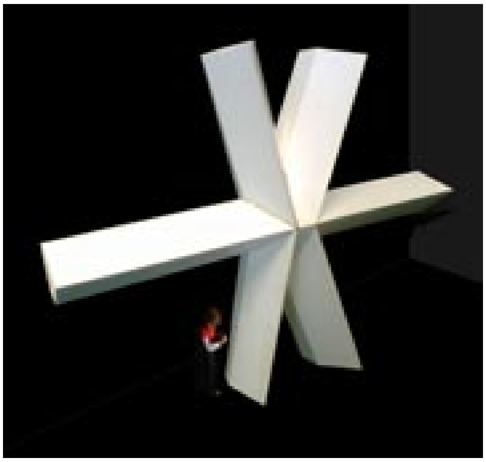

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Up close and personal with one of the diagonal grid nodes.