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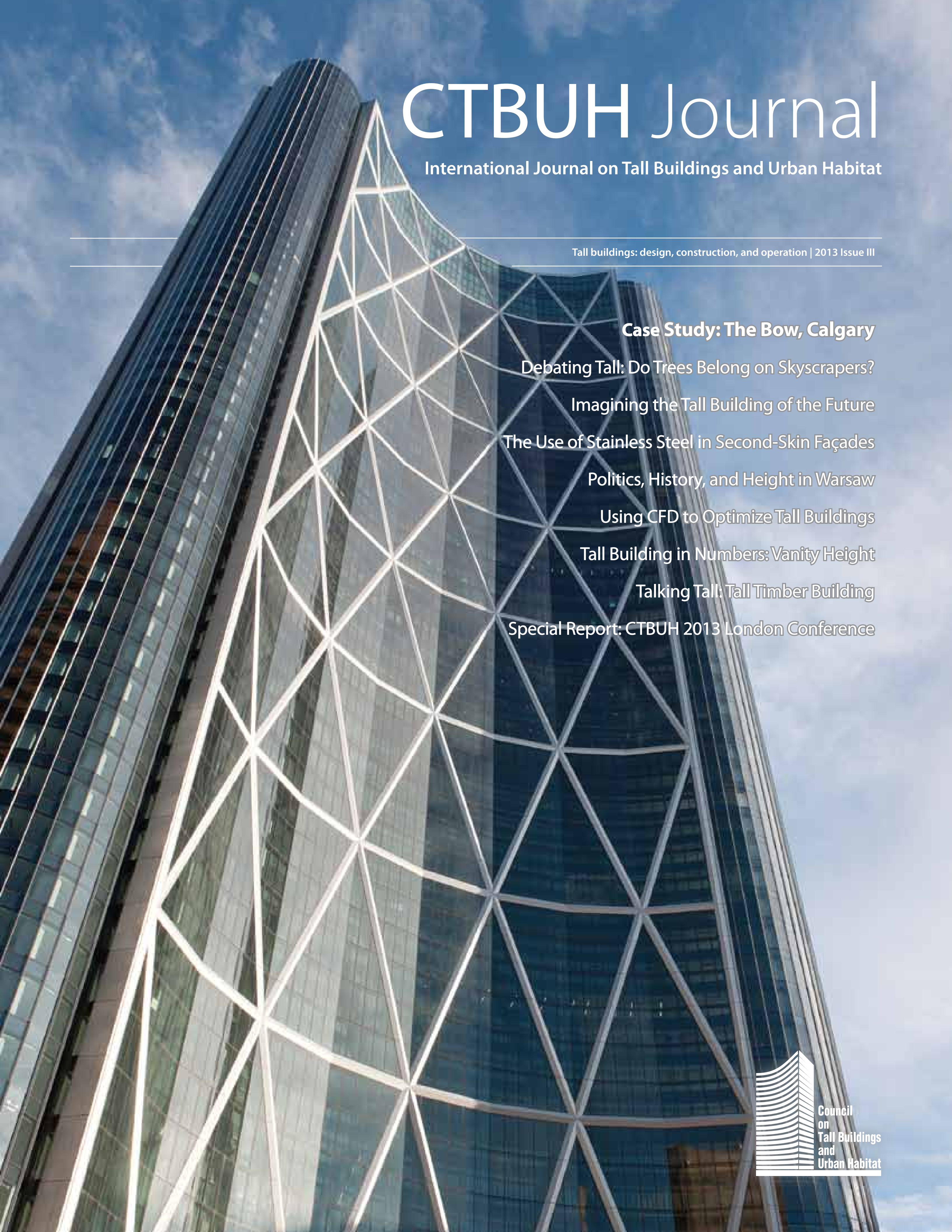

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Rising Above and Bending Aside To Make Space and Place


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James Barnes
James Barnes is a partner at Foster + Partners and was project architect for The Bow, a major new high-rise landmark for Calgary and an environmentally sustainable headquarters for one of Canada's leading energy corporations. He joined Foster + Partners in 2001 and became a partner in 2008. His current role extends to the procurement and management of work across North America and the Middle East, where he is involved in a range of projects, including the competition-winning design for a new skyscraper at 425 Park Avenue, New York, and a new development within the King Abdullah Financial District, Saudi Arabia.

Jonathan Hendricks
Jonathan Hendricks is a Senior Principal at Yolles, having worked with the firm for 20 years from bases in Toronto and London. He has been privileged to have had the opportunity to collaborate with some of the world's most renowned architects such as Foster + Partners, Rogers Stirk Harbour + Partners (formerly Richard Rogers Partnership), Raphael Viñoly Architects, Pelli Clarke Pelli (formerly Cesar Pelli Architects), and others, on a full range of project types in Europe, North America, and Asia. Jonathan acted as the Structural Design Principal on The Bow, and contributed to the structural design concepts that define the building.

The Bow, which opened officially in June, is the latest and most ambitious high-rise development in the Canadian city of Calgary, designed for the energy companies Encana and Cenovus. The client's aim was to create a world-class building that would be a defining landmark on the city's skyline. Today, with its distinctive curved diagrid steel structure visible from far away, its "sky gardens" and dramatic full-height atrium, the scheme has delivered on those goals. Not only has this 237-meter giant set records as Canada's largest steel-framed building, Calgary's tallest tower, and the highest Canadian tower outside Toronto; Calgarians have already adopted it as a symbol of their city.

In these pages we explore the origins of the Bow, and how the design met the challenges of the brief. We look at its complex engineering and construction, and consider its contribution to the city that surrounds it.

A Tall Order

In 2005, Foster + Partners were selected to design new headquarters for Encana Corporation, a North American energy giant based in Calgary. With its employees formerly housed in a number of buildings around the city, Encana needed a landmark building that would bring its staff together and, in providing a superb working environment, help the company to attract and retain the most talented people. Their vision translated into a brief for almost 186,000 square meters of office accommodation, along with abundant retail and public space.

The client and local planning authorities envisaged the building as a major presence: The first spectacular marker in a masterplan to develop a new zone of the city, it was also expected to meet city policy goals for sustainable development.

Above all, the building would be a commercial headquarters for several thousand staff. As well as requiring space for a great many people, Encana had a particular way of dividing up their teams which would need to be reflected very precisely in the design of the building. The budget was strict, the schedule was demanding and there were real obstacles to overcome, including planning restrictions affecting the height of the building. But for

Figure 1. The Bow, Calgary.

Figure 2. View to the city.

the design team, this was an opportunity to design a new star in the world's high-rise firmament.

The City

The province of Alberta, where Calgary is located, is epic in the scale of its landscape, agriculture, and mineral reserves. From its first settlement in 1875 and its history of pre-eminence in the cattle trade, Calgary has grown into one of Canada's largest cities and is a magnet for big business, particularly the global energy industry. It is "an optimistic city, a city on the rise," as Mayor Naheed Nenshi described it during the Bow's opening ceremony – an exciting place into which to introduce an iconic tower.

The city is surrounded by wide-open spaces, so that The Bow announces itself dramatically, from far away, and from many vantage points (see Figure 1). It sits at the confluence of the rivers Bow and Elbow. The great prairies roll eastwards and, stretching out toward the snowy caps of the Rockies to the west, is Banff National Park. The views from within the building are magnificent on every side (see Figure 2).

The climate is dry, with the highest number of sunny days in Canada. The summers are pleasant, while winter temperatures plummet far below freezing, occasionally rocketing upwards when the warm Chinook wind arrives. Alberta is a place of strong winds, and Calgary boasts a wind-powered rapid transit system. A leader among Canadian cities for energy efficiency, it has set out a sustainable development plan for a whole century, and was the first Canadian city to impose a Leadership in Energy and Environmental Design (LEED) certification policy on all public buildings.

The Site

The Bow is an important catalyst for renewal, and forms the first phase of a masterplan covering two city blocks on the east side of Centre Street, a major axis through downtown Calgary, south of the Bow River. A new quarter, the East Village, will be developed nearby, extending from the downtown district into a neglected area that was once, before its decline, the center of Calgary.

Design Process

Early in the design process, the client visited London for a two-week workshop. During this time, the design team created a shared "working studio" dedicated to the project, with daily design reviews from Lord Foster, the architects' design board, and the client team. By the end of the period, the team had worked through hundreds of potential layouts and had agreed a concept to take forward. The collaborative approach continued throughout, with regular meetings held in Toronto, Calgary, and London.

The curved shape of the building was chosen because it made best use of the site area, provided the most perimeter accommodation and created a well protected outside public space within the arc's south-facing embrace (see Figure 3). It also shed wind load far better than an equivalent-sized rectangular building, reducing stress on the structure.

The team explored six alternative themes for the main structural configuration for the tower. Along with internal diagrams, they looked at a perimeter tube system and at a number of different diagrid patterns. The most efficient diagram was provided by a hybrid solution, which is described in the section on structure.

Figure 3. Diagrid structure.

"A Calgary bylaw restricts the degree to which buildings may shade the Bow River – the September equinox is chosen as the date when no shading whatsoever is allowed. The designers needed to find a way for the building to achieve the required area without going above a height that would cast shadows on the water."

The design had to marry together both an "outside-in" approach, adapting the design to reflect external inputs such as wind, sun, site, and views, and an "inside-out" approach, aligning itself to the demands arising from the way its future occupants organized their workforce. Thanks to "dimension-driven design" (DDD) software, the architects and engineers were able to consider numerous options for the floor plate, and eventually came up with solutions that met both sets of requirements.

The sale of the development in 2007 to Canadian real estate trust H&R REIT did not affect Encana's planned occupancy of the Bow. However, an adjustment to the arrangement of space did occur in 2009 when Encana set about dividing its natural gas and oil businesses into two independent firms. Encana became a "pure-play" natural gas company, while Cenovus emerged as a leading integrated oil company. Despite these changes, the client body supported a sustainable, civic approach throughout the design. The Bow now accommodates both companies together, with the building divided between them vertically: Cenovus is on the third through 28th floors, while Encana occupies the 29th through 55th floors.

Planning

Most important among the planning considerations was a Calgary bylaw that restricts the degree to which buildings may shade the Bow River – the September equinox is chosen as the date when no shading whatsoever is allowed. The designers needed to find a way for the building to achieve the required area without going above a height that would cast shadows on the water. This, combined with the allowable floor area ratio (FAR) for the site and the constraints of the boundary, presented a real challenge.

Part of the solution was to dig 20 meters deep into the ground, releasing six subterranean stories for a 1,400-car public parking garage. But above ground, it was the crescent shape that solved the space problem, providing far more perimeter accommodation than an orthogonal shape would have allowed. It also allowed for a much lighter structure and offered good wind resistance and shelter from cold weather. The Bow's sensuous curved form, which gives the building its sculptural impact, is the result of genuinely tough planning challenges that led to a graceful design synthesis.

In response to height and footprint restrictions, the architects found a way to step the floor plate forward as the building rises. This measure, which increases the internal building size by an impressive 10%, is achieved without expanding the supporting structure. Instead, the soaring south-facing atrium space narrows as it goes upwards (see Figures 4 and 5), while still leaving enough space for the atrium to function as a main contributor to the building's energy efficiency.

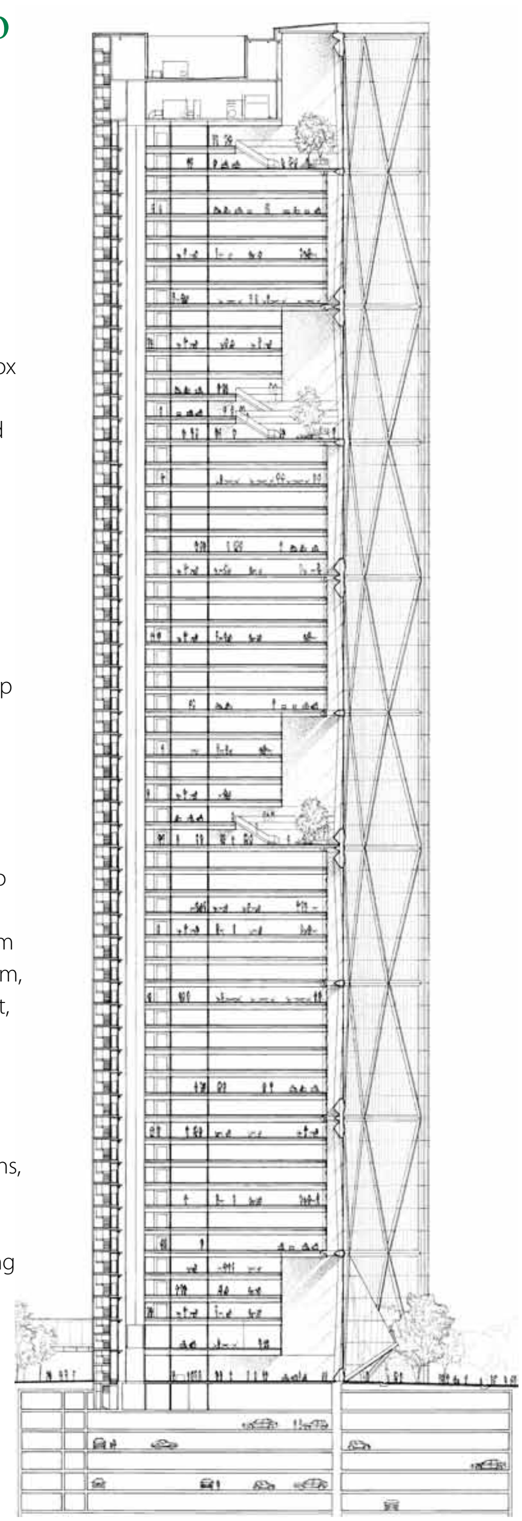

Figure 4. Typical section. © BPR / Foster + Partners

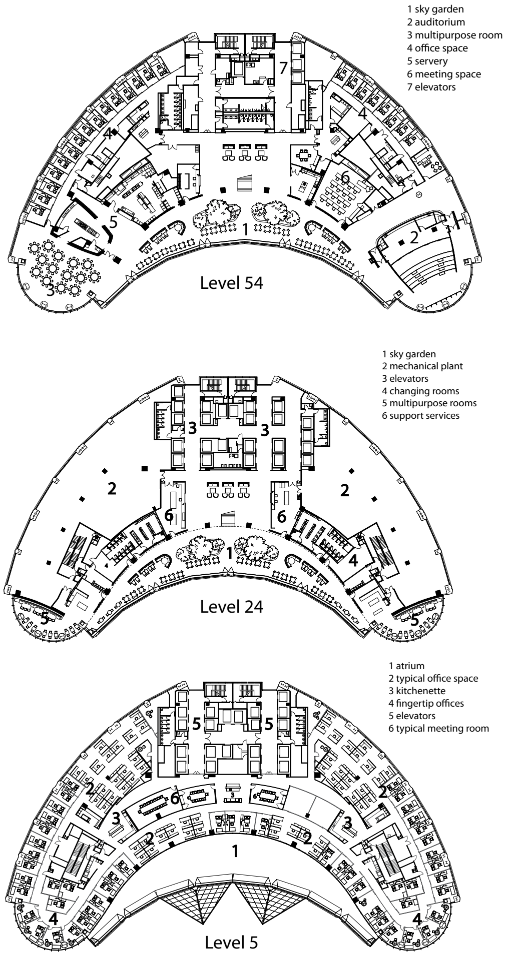

Figure 5. Typical floor plans showing increasing floor plates and decreasing atrium area with height. © Foster + Partners

Figure 6. South entrance and atrium.

Building Organization

Encana and Cenovus generally work in divisions of around 200 people, with each division housed over three floors. Each floor plate of the Bow is sized to accommodate a business unit of 70 people in each division. The companies' organizational structure was fundamental to the way the building was conceived: hence the decision to divide it vertically into multiples of six floors, within three segments overall. Above grade, the lowest segment has 24 levels, the middle segment 18 levels, and the top 12. The total number of stories is 57, with the two top floors reserved for services.

The entrance to the Bow is from the south-facing plaza. Visitors approaching from the plaza can gaze up through the atrium (see Figure 6). Inside the entrance, a six-story lobby contains reception, elevators, and escalators leading to the public Level 2. At this level, along with shops and cafés, there is access from two points to the Plus 15 Network, Calgary's weather-defying enclosed network of pedestrian walkways, which covers over 14.4 kilometers of the city. The Bow completes this vital pedestrian link, while a third pedestrian connecting point from the building to a future development south of 6th Avenue is also planned.

The key to efficient movement around the building is the elevator system. Express elevators take staff to lobbies at Levels 24 and 42, at each of which are two floors of restaurants, meeting, and recreational spaces, linked by a generous staircase. All of this is set in and around the building's signature sky gardens. It is from these stunning atria spaces – which encourage more communication between business units than elevators to each level would allow – that local lifts take people to their own floors, within their segment of the building.

Four stories of offices look out to each of the six-story-high sky gardens. All office floors have corridors running between the north and south façades, with rooms to either side. With translucent partitions and frameless doors, even the internal corridors have natural light. At the very top of the tower, under a glazed roof, is a raked auditorium and conference room.

Sky Gardens

While the clients wanted cellular offices, they also wished for an environment that would actively encourage sociability and interaction – an element in the design that would get people to come out of their rooms and congregate naturally. The sky gardens fulfilled this role perfectly, and developed further an idea of "gardens in the sky" the architects had initiated during their Commerzbank project in Frankfurt some 20 years earlier. The sky gardens in the Bow are each six stories high (see Figure 7). They are filled with fresh air, light, plants, and mature trees. Like many aspects of the building, the gardens fulfil several functions through the execution of a single idea. With the bottom floor of each sky garden reaching out into the main atrium, they divide the tower into its three vertical segments. These gardens literally make the building more green, and are in effect its "lungs." They channel movement around the building in the most efficient way, act as social spaces and enhance interior and exterior aesthetics.

Figure 7. Sky garden.

Figure 8. The plaza.

These sky gardens are thus part of daily life in the building; as employees routinely cross them as they change from express to local elevators. Since people must pass through them at least twice a day, the sky gardens become a natural stopping place for meeting, refreshment, and time out.

Public Space

The Bow is a focus for future development on the east side of Calgary. Beginning this process, it contains a highly permeable public level with a lively new hub of shops, restaurants, and cafés. At the base, the building's arc hugs a beautiful south-facing plaza, sheltered from the prevailing winds and warmed by sunshine, triangular entrance canopies beckon visitors inside. Thanks to a collaborative approach between client, design team, and city, this public space establishes a civic presence and features a large contemporary sculpture; a wireframe head by the Spanish artist Jaume Plensa (see Figure 8).

The public realm around the Bow extends beyond this main plaza, and provides a connection between James Short Park to the northwest and Olympic Plaza to the southeast. To the northwest of the site, there is another small plaza (with a second sculpture by Plensa).This sits diagonally across from James Short Park, from which one is guided into and through the lobby of the Bow, and then out through the front entrance into the main plaza.

Structure

The curved shape of the Bow made the best possible use of the site and provides the client with the highest number of perimeter offices. In addition, strategically orienting the building on the site measurably reduced both the wind load on the building and the demands on the structure. However, determining the most effective lateral load-resisting structure to stabilize this large building took careful research and analysis.

The architects and engineers looked at a variety of internal and perimeter systems, including perimeter tubes of closely spaced columns and beams, a few large mega-braced diagonals, diagrids of numerous interlaced diagonals, and hybrid solutions combining different elements. As the engineers explored the options, the architects investigated the potential of each one, seeking the ideal balance of structural efficiency while supporting interior organization and aesthetics (see Figure 9).

The Bow is the first building in North America where any version of a diagrid system has been applied to a curved tall building design. However, it became clear that The Bow, which has faces with a variety of different curvatures (including very tight curvature at the "fingertips" that cap the short dimension of the floor plate) demanded an approach incorporating both diagrid and orthogonal tube systems. The solution was a hybrid diagrid perimeter system, in which the tower is braced by three separate diagrid faces (see Figure 10), which, when laced together by other connecting elements, form a highly efficient closed-perimeter structure.

On the curved northeast and northwest sides of the perimeter are the primary truss diagrid tube frames – six-story-high bays comprised of both diagonal braces (to resist the wind loads) and vertical columns (to carry the high gravity forces). To the north, at the main core, is a braced tubular frame that couples the northeast and northwest primary diagrid frames. These braced faces connect through the core with a series of secondary braced frames that lock the structure in place, between the elevators and the north stairs (see Figure 11).

On the south side is the atrium wall diagrid. This is a similar six-story diagonal grid, but it lacks vertical columns, dramatically spanning the outer face of the atrium. It is connected to the floors of the building by drag struts at each end. Stretching from the "fingertips" to either side of the atrium wall is a series of rigid-tube moment frames that couple the three primary diagrid frames to each other. The atrium diagrid is made up of elegant triangular sections to minimize the visual impact of the framing when viewed from the interior.

The atrium wall presented a particular challenge because of the strong curvature of the floor plate on its south face. The engineers proposed slightly flattening the primary atrium wall diagrid, so that it would take a shortcut across the south face, and thus close the system with maximum strength. This not only solved the difficulties of the tight curvature, but was also the gesture that formed the atrium void: where the building curves inwards, the glazed façade is pulled

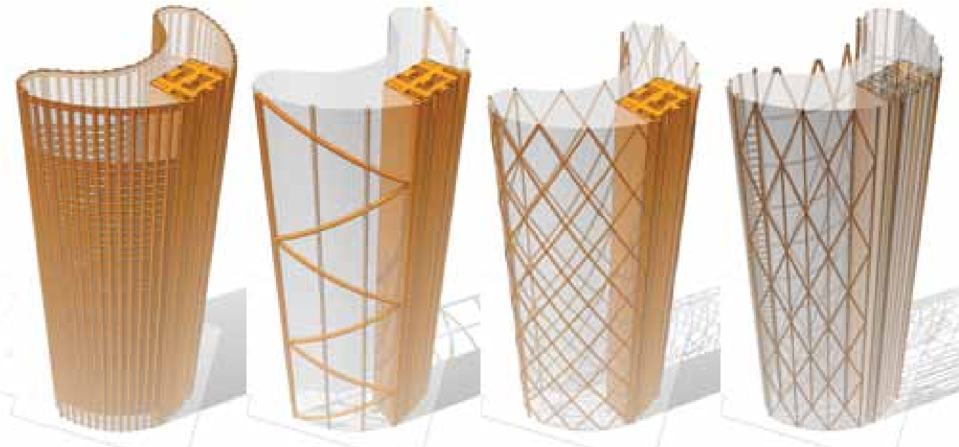

Figure 9. Structural expressions of perimeter systems. © Yolles

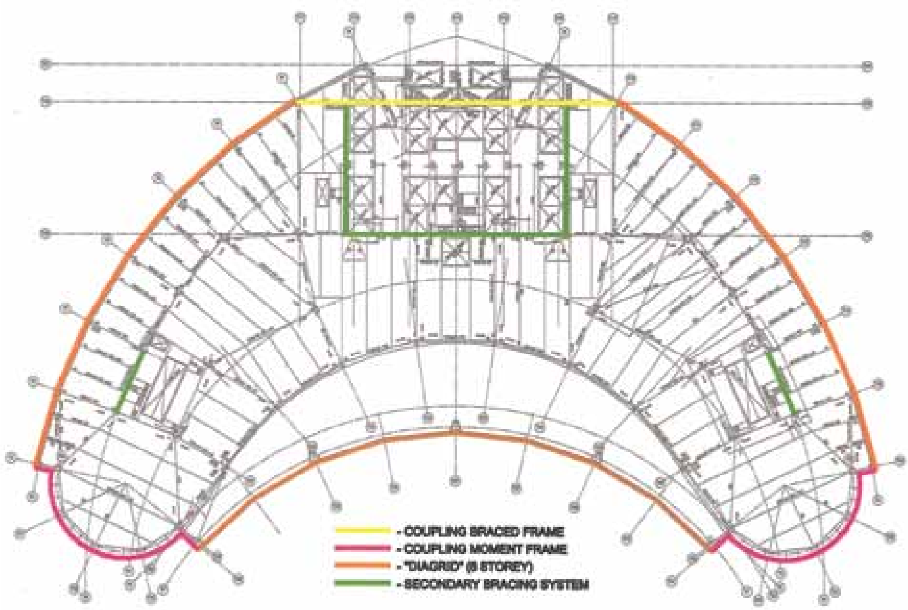

Figure 10. Plan view of component elements of hybrid stability structure. © Yolles

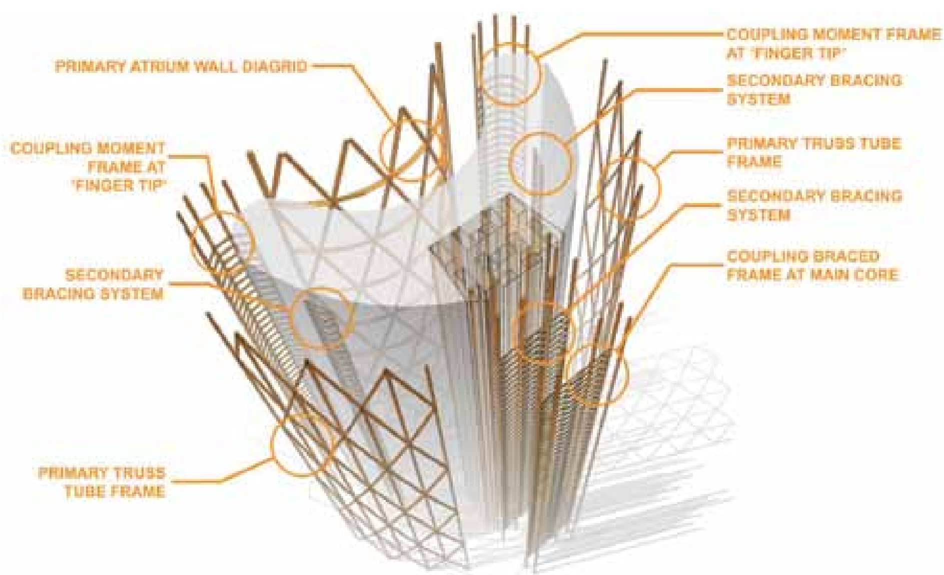

Figure 11. Exploded view of lateral load resisting structure. © Yolles

forward. Tied back only every six stories, the atrium is a stunning feature of the building.

Marrying the external structure with the required internal accommodation presented a major issue. Most North American companies, including Encana and Cenovus, require individual office spaces of approximately 3 by 4.5 meters. In addition, the way the companies organize their teams made it logical to divide the levels of the building into multiples of three and six. So it is not by chance that the diagrid pattern repeats every six stories, with the structural meeting points of those pieces of steel – the nodes – occurring at six-story intervals. Together with Yolles, Foster + Partners' in-house Specialist Modeling Group found a way to resolve the complex geometry of the diagrid and its nodes, and their relationship with the curtain wall, so that they would correspond with the 3-by-4.5-meter office spaces inside the building, and groups working together across three stories.

While slightly steeper than the optimum structural solution, the chosen angle of the diagonal allows for the internal layout of the offices to be standardized, while also greatly increasing the repetition in the curtain-wall panels. This significantly reduced both cost and construction complexity. However, because of the geometry of the triangular elements, the structural nodes would only line up exactly with the addition of small wedge-shaped sections on the interior face. This beautifully resolved detail allowed the exterior cladding to node out perfectly. It is

“The Bow is the first building in North America where any version of a diagrid system has been applied to a curved tall building design.”

this kind of engineering precision that led Bill Christensen, Senior Project Manager for Matthews Southwest to say, "Compared to typical North American office tower construction, The Bow is built like a Swiss watch."

The height restriction imposed by the planners impacted not only the form of the building, but its structure as well – particularly the gravity-load carrying system. Interior columns were added to the floor plate so that beam depths could be restricted to a maximum of 460 millimeters. The floors were constructed of reinforced concrete on composite steel decks with structural steel framing. This system minimized the size of the columns and the depth of the foundations. It also increased the speed of construction and suited the labor capacity of the local concrete formwork industry.

In summary, The Bow's structural system is both beautiful in its articulation and highly effective, as it reduced both the overall weight of the steel that would normally be needed to support a building of this size, and the number and size of columns required.

Sustainability

Sustainability is built into The Bow in every way possible, from its form and its structure down to details.

A raised floor system allows optimum control over the heating of the building and adds considerably to its efficiency, enhanced by localized climate control.

The south side of The Bow curves toward the sun. This creates a warm enclosure for the plaza and makes the most of daylight. The tower presents its narrowest profiles to the northwest and southeast, deflecting strong prevailing winds from those directions and minimizing the structural loading. Wind resistance is inherent in its orientation and plan, with its curves directed to shed wind loads efficiently. By any standard, The Bow incorporates a large amount of steel. But its aerodynamic design, along with its efficient lateral load-resisting structural system, reduced the amount of steel needed to support it by 30% over a conventional structure.

While the full-height southwest-facing atrium wall is one of the building's most spectacular features – indeed, it is the largest architecturally exposed structural steel wall of its kind in the world – it actually employs the minimum possible amount of heavy materials. The atria provide an opportunity for several sustainable strategies that help reduce energy consumption. These spaces act as climatic buffer zones, insulating the building and helping to reduce energy consumption by approximately 30%. Excess heat from the office floors is channeled into the atria, while at the same time the sun's energy (given the atrium's orientation) is harnessed. The atrium spaces act as a buffer zone between offices adjacent to the atrium and the exterior atrium glass wall, dramatically reducing energy consumption and the need for heating/cooling by exhausting heat upwards in summer and trapping heat in winter. Offices adjacent to the atrium have the ability to open windows into the atrium during the mild seasons. In winter, it gathers sunlight to augment the building's heating systems (see Figure 12). In addition, the sky gardens, which touch the atrium wall at three points, encourage natural ventilation, bring oxygen-producing plants on a grand scale into the building, and save energy. Thus, the various sustainable strategies work together complimentarily.

Above all, the Bow represents a completely integrated approach to architecture and engineering that makes the building innately responsive to environmental conditions: it embraces sunlight, resists solar gain, deflects wind, collects warm air as it is needed, and funnels out warm air when it is not.

Construction

A major challenge to the program revolved around accommodating the annual Calgary Stampede's opening parade in July 2012 – not a movable feast. It was essential that the parade be able to cross the site as usual, while the base of the building was under construction. As a result, the ground floor in the affected area had to be excavated six stories deep and rebuilt on stilts within one calendar year. The decision was taken to dig the entire site to this timescale – an extraordinarily aggressive schedule.

In parallel with the work under the road, the structural steel for the tower was sprung from the raft foundation, quickly framing the ground floor "umbrella." This steel floor provided the necessary staging area, from which the tower superstructure could rise, while the concrete basement floors were being infilled below (see

Figure 12. The top of the atrium – looking up.

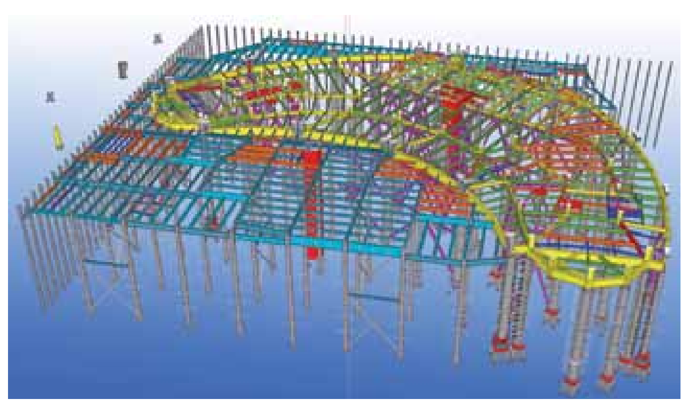

Figure 13. Rendering of ground and apron framing allowing the tower construction to commence. © SWJV

Figure 14. Commencement of the raft pour. © Yolles

Figure 15. Placing of the atrium node. © Yolles

Figure 13). The tower steel construction raced ahead above ground, while the reinforced concrete basement was backfilled at a slower pace, separate from the main critical path schedule.

To achieve this "top-down" construction, the lowest lifts of columns were constructed of massive pipe sections spanning, unbraced, the full 18.2-meter basement height. These were augmented with anchors tied down into the raft for the lower-level floors. Extra bracing in the basement area helped support the building until 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 three-meter-thick raft foundation was the third-largest continuously poured concrete foundation in the world (see Figure 14). It took almost 40 hours of continuous pouring and used 14,000 cubic meters of concrete. To minimize the impact on the city caused by the 94 concrete trucks bringing 1,436 loads to the site, this phase of construction took place over a weekend from May 9 to 11, 2008.

Perhaps the greatest construction achievement was the lifting and puzzling together of the intersecting triangular sections of the south atrium wall and their complex nodes (see Figure 15). The huge component elements weighed up to 80 metric tons each and had to be positioned precisely and held in place until the final welded connections could be completed. As the entire wall structure is exposed to view, the wall had to be built to within 25 millimeters of tolerance over the full tower height.

Completion

The Bow was commissioned in December 2005, with a groundbreaking ceremony on June 18, 2007. It was completed in late 2012 with 3,000 staff moving into the building by January, and fully occupied when the official opening events took place in June 2013.

For the client, the project has delivered an exceptional workplace, with active social spaces and a high degree of flexibility and energy efficiency. Staff feedback is already extremely positive.

The tower appears effortlessly resolved. But its creation involved new and ingenious solutions on the part of many participants. ■

Unless otherwise noted, all photography credits in this paper are to Nigel Young / Foster + Partners.

Editor's Note:

The Bow is the recipient of the CTBUH 2013 Best Tall Building Americas, to be conferred on November 7 (see page 59).

Project Data

Completion Date: 2013
Height: 237 meters
Stories: 57
Total Area: 199,781 square meters
Use: Office
Owner: H+R Real Estate Investment Trust
Developer: Matthews Southwest Developments
Architect: Foster + Partners (design); Zeidler Partnership (architect of record)
Structural Engineer: Yolles
MEP Engineer: Cosentini Associates
Main Contractor: Ledcor Construction
Other Consultants:
Altus Group (cost), Brook Van Dalen (façade), Carson McCulloch (landscape), Cerami (acoustics), Claude Engle Lighting Design (lighting), Gensler (interiors), Kellam Berg (civil), KJA (vertical transportation), Leber Rubes (fire), RWDI (wind), Sturgess Architecture (planning consultant), Transsolar (environmental)