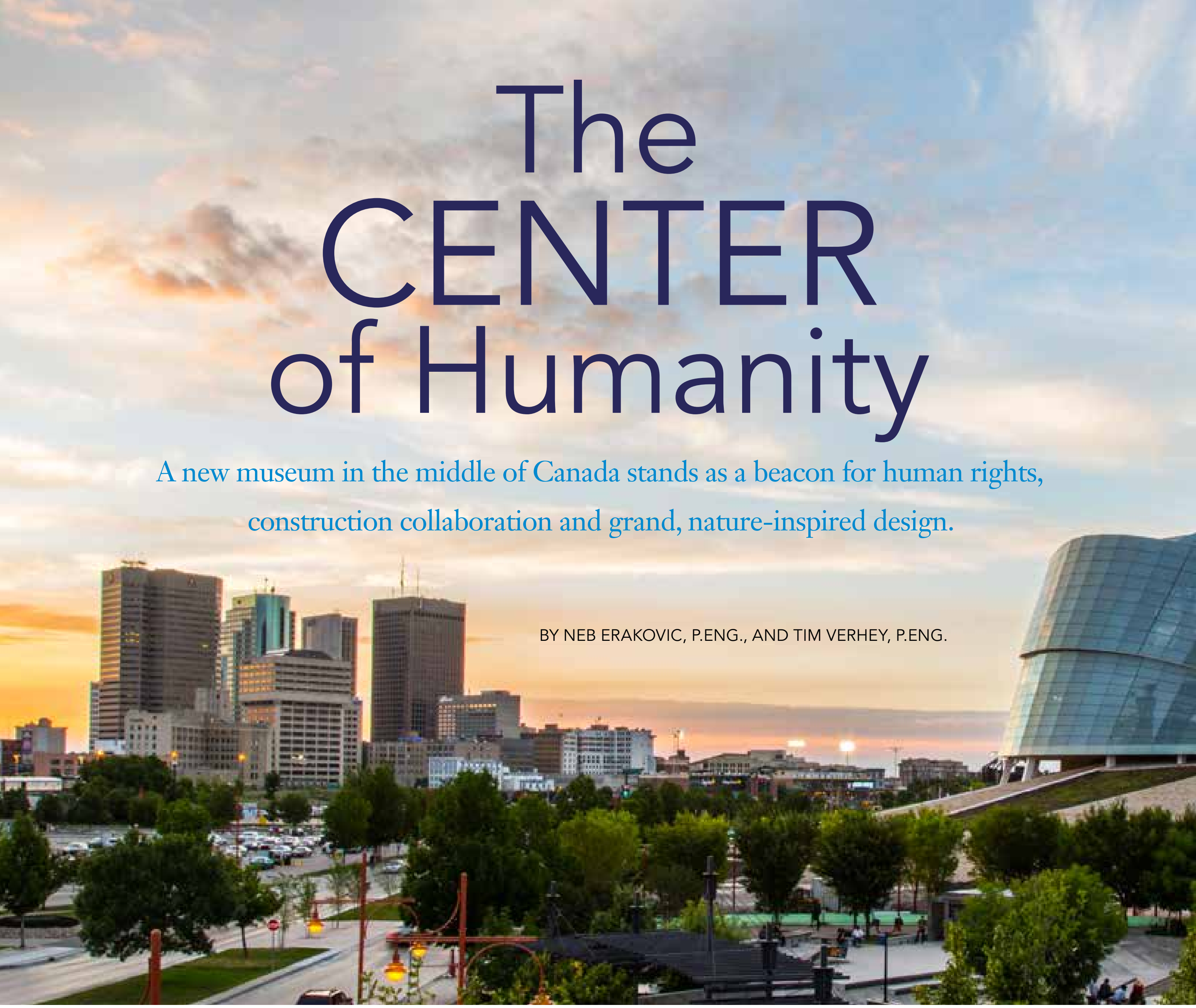

The CENTER of Humanity

A new museum in the middle of Canada stands as a beacon for human rights, construction collaboration and grand, nature-inspired design.

BY NEB ERAKOVIC, P.ENG., AND TIM VERHEY, P.ENG.

THE CANADIAN MUSEUM FOR HUMAN RIGHTS is far from the familiar.

When it opened earlier this fall in Winnipeg, Manitoba, near the east-west center of the country (and roughly 50 miles north of the U.S. border), it was the first national museum to be built since 1967—and the first ever outside of the National Capital Region (Ottawa). The architectural design for the museum was selected from an international competition that included 62 submissions from 12 countries in a judicial review that stretched over a period of 18 months and included three levels of detailed submissions.

Built at a cost of $351 million (Canadian)—funded by private donations and public contributions—the 24,500-sq.-m (260,000-sq.-ft) museum is envisioned to be an iconic symbol of Canada, and Antoine Predock's winning design draws inspiration from the country's natural scenery and open spaces. It will serve as a national hub of human rights education and an inspiring forum for human rights issues, as well as a landmark building with its unique structure. Visitors will experience a museum articulating powerful stories in 11 themed galleries that bring human rights ideals to life.

CH2M HILL was selected to provide structural engineering consulting services for the building and helped the architects to support their vision of organic forms with rational structural solutions. From a structural perspective, the project highlights the benefits and importance of modern tools and technology associated with 3D modeling of complex geometric forms and the development of interfacing details for building interwoven components. It also emphasized the adaptability and limitless advantages of structural steel framing, which resulted in smaller gravity load carrying members, more economical foundations, compact connections and linkages between various building components, lightweight long-span floor framing with large column-free areas (up to 100+ ft) and greater overall flexibility in terms of adaptability to future space reconfiguration.

Natural Beauty

The building's components are reminiscent of natural forms and include icebergs, tree roots, dove wings and mountains—all with the goal of symbolizing hope for a better world. Translation of the complex geometry of these forms into structural solutions

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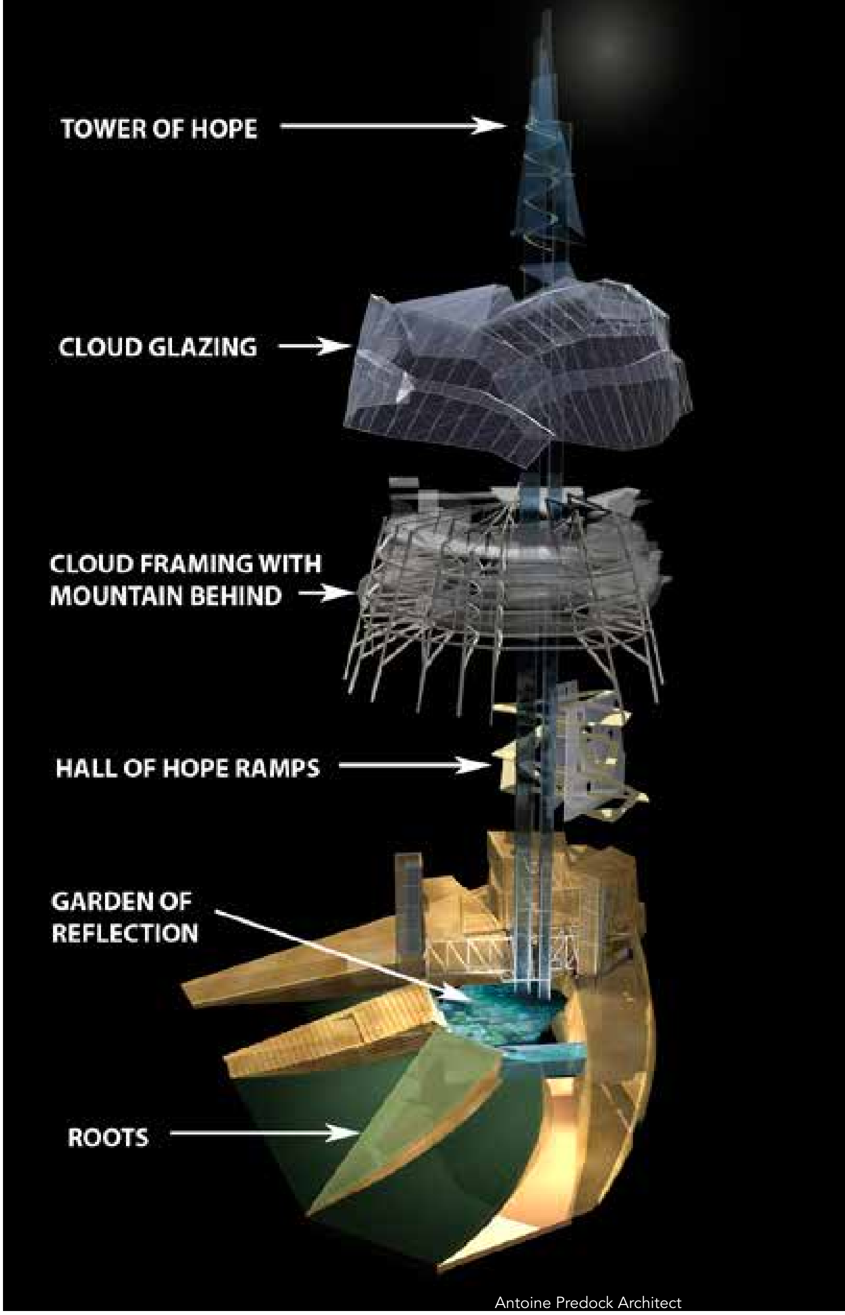

Antoine Predock Architect

Assembly of the primary programmatic zones.

was achieved by breaking the structure into separate components that could be modeled independently and sequentially integrated into the overall structural model of the building.

The structure is generally composed of four base "Roots" radiating out from a central great hall and a Garden of Reflection beneath a suspended "Mountain," a "Cloud" and what is known as the Tower of Hope. A 50-m-tall (164 ft) Hall of Hope atrium at the back of the building cuts into the mountain and roots like a canyon and houses circulation ramps between the galleries. The roots contain the functional spaces of the museum and are constructed of sloping, segmented, reinforced concrete walls with sloped steel roof framing. The diagrid-framed mountain contains the bulk of the exhibition spaces, and the vertical and horizontal steel truss-framed cloud encapsulates office spaces and a large atrium. Projecting above the cloud roof, the steel-framed Tower of Hope, which soars to 100 m (328 ft)

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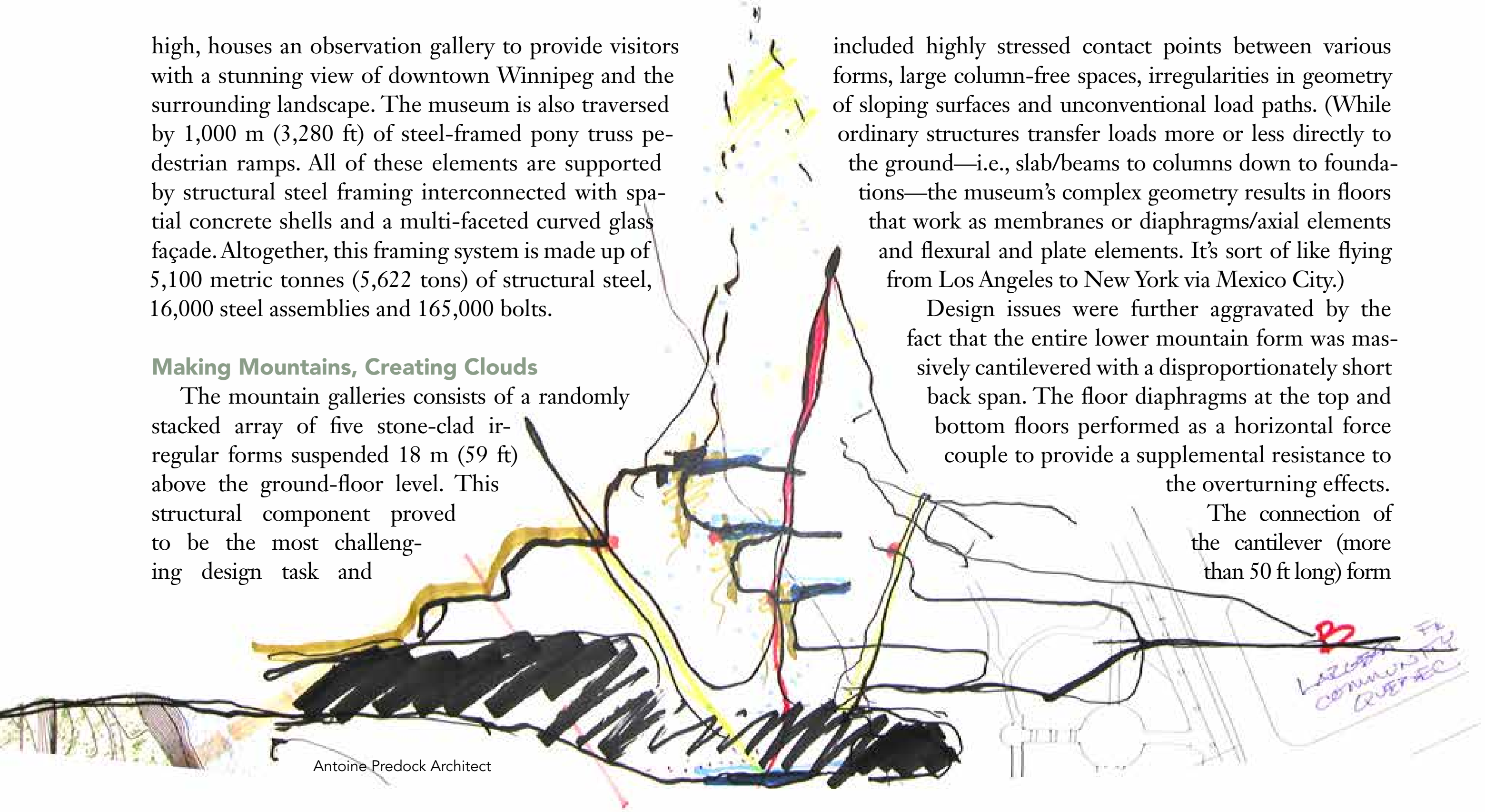
high, houses an observation gallery to provide visitors with a stunning view of downtown Winnipeg and the surrounding landscape. The museum is also traversed by 1,000 m (3,280 ft) of steel-framed pony truss pedestrian ramps. All of these elements are supported by structural steel framing interconnected with spatial concrete shells and a multi-faceted curved glass façade. Altogether, this framing system is made up of 5,100 metric tonnes (5,622 tons) of structural steel, 16,000 steel assemblies and 165,000 bolts.

Making Mountains, Creating Clouds

The mountain galleries consists of a randomly stacked array of five stone-clad irregular forms suspended 18 m (59 ft) above the ground-floor level. This structural component proved to be the most challenging design task and included highly stressed contact points between various forms, large column-free spaces, irregularities in geometry of sloping surfaces and unconventional load paths. (While ordinary structures transfer loads more or less directly to the ground—i.e., slab/beams to columns down to foundations—the museum's complex geometry results in floors that work as membranes or diaphragms/axial elements and flexural and plate elements. It's sort of like flying from Los Angeles to New York via Mexico City.)

Design issues were further aggravated by the fact that the entire lower mountain form was massively cantilevered with a disproportionately short back span. The floor diaphragms at the top and bottom floors performed as a horizontal force couple to provide a supplemental resistance to the overturning effects.

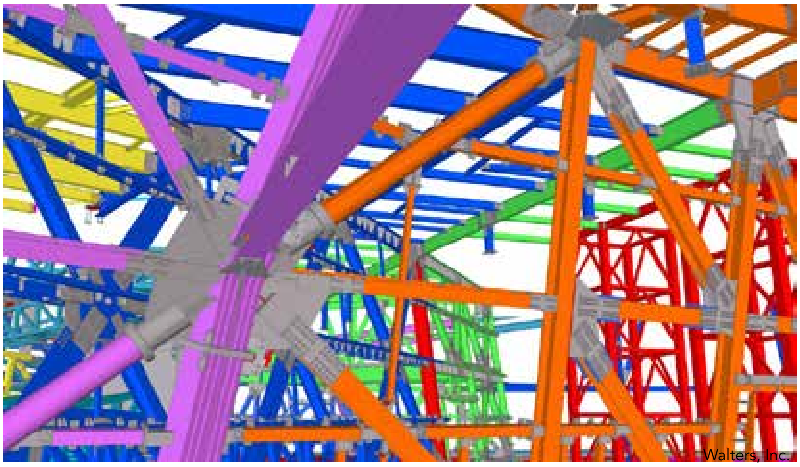
The connection of the cantilever (more than 50 ft long) form



Antoine Predock Architect

▲ Architect Antoine Predock's initial vision for the museum.

▼ Mountain assembly "A" being connected to the concrete core.



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▲▼ A shared node with a 19.7-in. × 23.6-in. laminate diagrid member.

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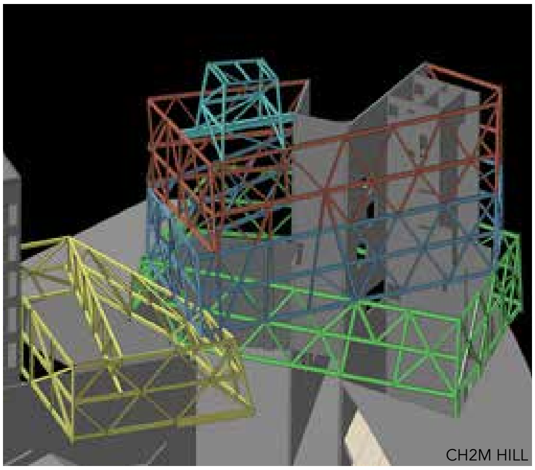
➤ HSS and wide-flange framing for the exterior shape.

➤ Development of the early structural concept for the mountain diagrid.



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to the concrete vertical shaft also proved to be a challenging task that required complex tie-in connection details. The steel elements were designed to physically engage the concrete through a series of shear transfer elements that protruded into the concrete. The massive supported weight of the stone cladding, along with the heavily loaded exhibition and plant floors—with the cloud roof and the Tower of Hope rested at the top—required the mountain form to be superelevated during erection to ensure flat floors in the final condition. Extreme loads also require six 500-mm × 100-mm (19.7 in. × 3.9 in.) solid steel plates to be built up to form a solid 500-mm × 600-mm (19.7 in. × 23.6 in.) steel diagrid member. The structural steel that cantilevered off this core was also cambered to ensure that it would be "level" once the dead loads were applied. This area of the structure was erected on shoring towers with hydraulic jacks carefully released once all steel was erected and concrete floors poured.

The glazed cloud encapsulates the large central atrium, the museum offices and the Garden of Reflection. The cloud curvature is framed with a series of curved 610-mm-diameter (24 in.) HSS supported by raking built-up HSS columns that span over 30 m (98.4 ft) from the roots up to the cloud roof. Balcony-like partial-perimeter office floors encircle the atrium at three levels and act as diaphragms to provide lateral stability to the raking columns.

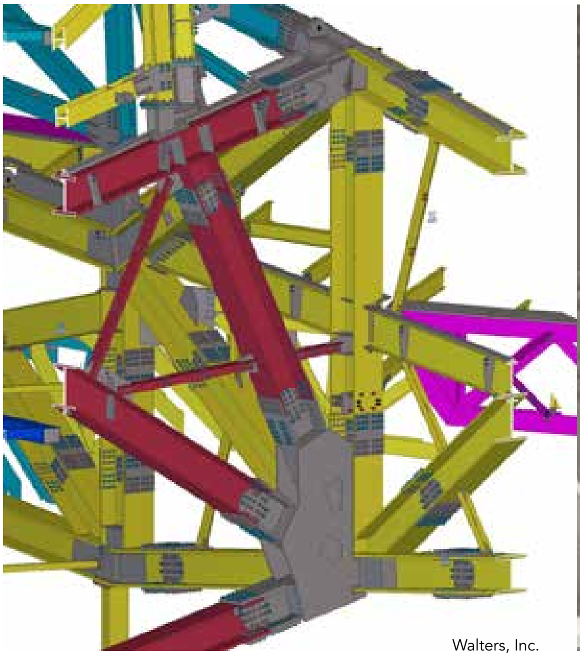
Connection design for these assemblies had to take into account the mix of section types, the magnitude of the forces and the sheer number of members that converged together, as well as the constraints imposed by architectural finishes and building services. After being modeled in 3D space (using Tekla Structures) the assemblies were presented as traditional 2D shop drawings for further use in the fabrication and fitting process.

The complexity of the steel framing also required extremely high-precision fabrication. Various surveying and measurement techniques were used to ensure that the complex 3D curves and other geometrically sensitive components were fabricated accurately, and the overall geometry was carefully monitored during construction. Maintaining the vertical and lateral locations of the key structural steel elements necessitated the use of three mega-shores supporting up to 4,500 kN each (500 tons) per location and secondary temporary shoring/bracing, and also governed the methods for building construction including super-elevations and cambering of the steel frame, sequence and timing for placing the floor concrete and the installation schedule for the building finishes and cladding. Owing to the local climate, it was anticipated that the structure will experience a temperature differential of at least 60 °C prior to being enclosed. As expansion joints for the building in its final condition were not possible due to the structure's inherent need for continuous floor diaphragms, locking various steel components within the supporting concrete walls during construction was not possible due to unacceptably high thermal restraint forces. As such, temporary steel slip connections with slab separation strips were used to disconnect selected structural elements and release thermal stresses until the building was environmentally enclosed and ambient temperature controlled. The steel structure was successfully erected over 16 months and met all objectives required to ensure structural stability and dimensional control during construction.

Sharing Information

The high-tech collaboration tools and virtual models used for the project were unconventional in the beginning but were quickly recognized as essential elements in developing the design for this unique building. By now the advantages of BIM are well documented in the construction industry—but at the time of design initiation this technology was relatively unfamiliar to the design team and introduced a cultural change to the consulting design and client review processes. For the complex 3D curved and sloping geometry of the building, CH2M HILL developed a sophisticated workflow to capitalize on BIM software, in-house custom programs and expertise developed on past projects of similar complexity.

Starting with CATIA in 2004 and moving toward full Revit integration in 2008, various building models were used as contract documents along with conventional 2D drawings and specifications. As design moved into construction, the BIM process carried forward by the steel fabricator, Walters, Inc., continued to capitalize on the firm's expertise gained in executing complex buildings in the past and supported by reliance in capabilities of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AESS cloud roof framing details (in the 3D model and erected in the field).


Patrick Coulie Photography

A key detailing consideration was ensuring that the ramp connections did not show through the alabaster cladding when backlit from within.

The HSS pony trusses of the pedestrian ramps as they begin to span the Hall of Hope.


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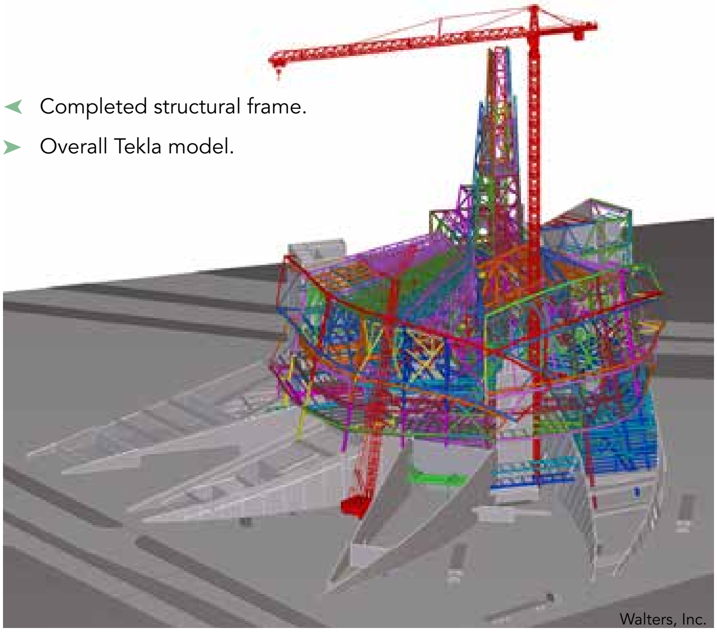
Tekla Software to define and control geometry, evaluate structural steel connection solutions, develop temporary construction engineering solutions, optimize the erection and fabrication process and coordinate work with other parties. Using 3D models from the design team as the sole source of geometric definition minimized the tedious process of geometric model rework and coordination through the typical RFI process, which significantly increased efficiency when producing thousands of steel shop drawings. Tekla-generated 3D models of the structural steel frame were used to accompany the shop drawing submissions. This workflow allowed the design team to efficiently verify the structural steel frame conformance with the design intent and also to expedite shop drawing review.

Ultimately the benefits of BIM—excellent 3D visualization, sharing of information for coordination and clear contract documentation—were realized by all parties. Not only was it the best approach to managing the design phase, it also demonstrated the true power of models in the construction phase by addressing all aspects of preconstruction planning, estimating and procurement, project management and actual site implementation. As a result, the museum has been recognized as the first large-scale Canadian project of extreme complexity where interdisciplinary, real-time collaboration throughout design and construction was successfully achieved using virtual models. This collaboration took place between groups from different geographic locations—40 companies located in eight cities in North America and Europe—all with the goal of making a magnificent building worthy of representing the advancement of human rights. ■

This project was the focus of a 2014 NASCC session (N63), which you can access at ***www.aisc.org/2014nascconline****.*

Antoine Predock Architect



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◄ Completed structural frame.

► Overall Tekla model.

PCL Constructors

▲ The museum uses more than 5,600 tons of steel.

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