BIM brings structural and visual optimization into Toronto's angular new aquarium.

The Life AQUATIC

BY PETER OLENDZKI, P.ENG.

LAKE ONTARIO holds nearly 400 cubic miles of water.

A few hundred yards north of the lake, in downtown Toronto, sits another body of water—tiny in comparison but impressive in terms of biodiversity for its size.

At 135,000 sq. ft—and holding 1.5 million gallons of water and more than 13,500 marine and freshwater creatures—the recently opened Ripley's Aquarium of Canada is one of the country's largest aquariums.

Designed by local firm B+H Architects in collaboration with San Diego's RJC Architects, who developed preliminary interior design, the aquarium is open 365 days a year and is expected to draw in millions of visitors annually to its permanent and special exhibits and associated educational programming.

The building's geometric complexity and programmatic requirements called for an innovative approach to project design and documentation. Key design considerations included structural accommodation of the multi-facetted aluminum-clad building envelope, large expanses of glazed façade and long column-free sightlines throughout the space.

Building information modelling (BIM) played a crucial role in the project's delivery. It served as a platform to investigate and test various structural framing solutions in a 3D environment, which ensured comprehensive capture of all complexities, and facilitated coordination and collaboration between consultants, including streamlining the overall fabrication and construction process.

Unobstructed Views

The entrance lobby of the structure was designed to represent the crust of the earth breaking open to reveal an entrance to the aquatic world. To achieve this, a 39-ft-high curtain wall façade wraps the perimeter of the entrance. The need for an unobstructed view to the interior precluded the use of any vertical bracing. Alternatively, HSS6×6 horizontal plan bracing was used, translating loads down to the braced main core through two horizontal V-braces with member sizes varying from HSS6×6 to HSS10×10 on extreme ends of the lobby for lateral stability.

The building's steel framework, incorporating 780 tons in all, provided large open spaces and long, unobstructed sightlines to the aquatic exhibitions. The placement of each steel column was carefully scrutinized, with the aesthetically optimum solution resulting in a layout of irregularly spaced columns (size optimization was performed after column locations were determined using SAP2000). To establish a vertical bracing arrangement against wind and seismic loading, the

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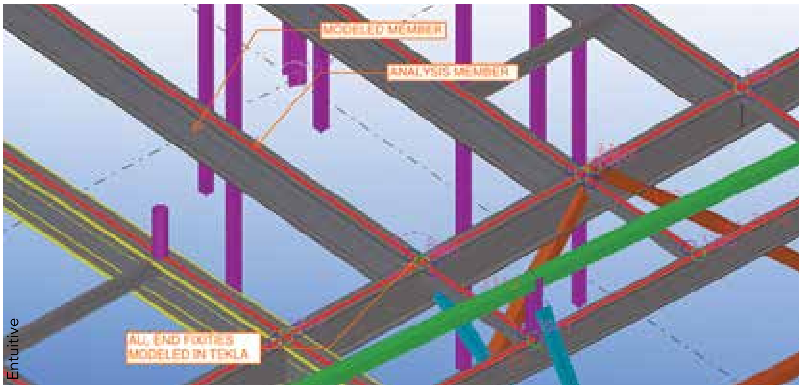
team took advantage of the architectural layout, which provided an opportunity for a braced core at an optimal location near the center of the structure. This was then augmented with carefully coordinated braces around the perimeter of the structure to address the torsional behaviour of the structure under lateral loads. HSS sections were chosen to address the high axial loads in both tension and compression loading. The long spans required to achieve column-free views within exhibit spaces were accommodated with W1000×249 (W40×149) beams reaching spans of 95 ft. The simple, cross-sectional geometry of the beams ensured an even coating of the entire surface area with a three-part, anticorrosive paint system (especially important considering the high humidity and various saltwater exhibits in the building) of zinc-rich primer, epoxy and a polyurethane topcoat.

Simplifying Complexity

Incorporating BIM into the structural design process played a crucial role in expediting the creation of the structural analysis model and accommodating changes to the framing systems. Ensuring careful modeling of the steel in Tekla allowed the engineering team to use the modeled members as part of the structural analysis



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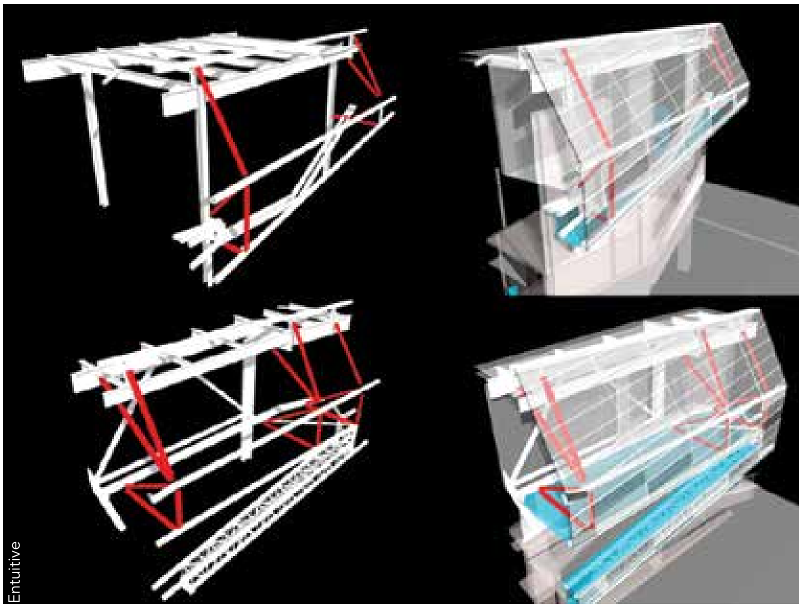
▲ Careful modeling of the steel in Tekla ensured the finite element members would also be properly modeled. The analysis model was then exported directly to SAP2000 via an application programming interface (API).

◄ The building incorporates 780 tons of steel and 1.5 million gallons of water.

▼ At left: repetitive framing at columns, shown with infill girts, achieves the required geometry. At right: architectural models shown with transparency relative to proposed framing.



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model. This model was completely developed in Tekla, including fixities and preliminary loading, and was then exported via an application programming interface, API, to SAP2000 for analysis and design. Changes in the model could easily be exported throughout the project as updates were made, a process that ensured the BIM model, analysis model and contract documents were constantly in sync.

Coordination was especially challenging. In addition to the traditional architectural, mechanical, electrical and structural coordination, additional life-support systems (LSS) and electrical systems unique to the exhibits had to be integrated throughout the building. Preconstruction modeling, done in Revit and Navisworks by the consultants and contractor, ensured systems were properly in place virtually before being installed on-site.

While the primary structure created its own design complexities, the real challenge was in framing the perimeter cladding systems. The main goal was to identify a form of repetitiveness in the framing, considering the seemingly random geometry that surrounded the structure, to simplify fabrication and erection. The architectural Revit model was imported into Tekla, creating a 3D-based blank canvas for which our engineering solutions could be developed. After reviewing the position of the cladding relative to the primary structure in various areas, a framing scheme emerged in which some form of repetitiveness could be achieved. Framing for the cladding system girts was attached to the main perimeter structural columns in order to achieve the desired geometry. This scheme allowed the use of a small number of relatively similar connection details that were typical for each frame. Double angles were used for the frames to allow simpler connection back to the main structure.

Two architectural "legs" branching off the structure, forming walkways into two separate entrances, also created unique framing challenges with their non-orthogonal geometry, providing another opportunity for BIM to facilitate development of a framing scheme. A finite-element analysis showed the legs attracted much more lateral and gravity forces than initially assumed. This was mitigated by providing sliding bearing plates at the base of both legs.

As it sits in the shadow of the CN Tower, a special design criteria for the aquarium was to ensure any ice falling from the tower would not penetrate the roof. In addition to concrete pavers on the roof, intended to break up the ice, the steel deck was specially designed to withstand the force exerted by the impact of falling ice.

BIM Snapshots

An interesting structural challenge was encountered in the project at the contract documentation phase. Many months were spent developing and modeling the intricate detailing required for the cladding framing, but when the time came to translate these designs to traditional 2D sections and elevations, no number of sections could fully capture the complex geometry. Each new section cut required more sections to capture the framing in this area, which is why we chose to use isometric details throughout the project.

Initially, significant time was invested in creating various traditional 2D sections of areas with complex framing. Sections cut from Tekla were exported to AutoCAD to clean up line work, as the non-orthogonal and sloping framing was not clear. It was quickly determined this method was very ineffective for two reasons: First, trying to accommodate minor architectural tweaks in the structural framing was inefficient, as each section needed to be re-exported and cleaned up; and second, it seemed that every section called for another two sections to clearly illustrate that area.

We eventually decided to use 3D isometric detailing and elevations to present the required framing; in essence, "snapshots" were taken from our BIM model. All connection forces and additional information typically shown in 2D sections were also included. The challenge now was to communicate the geometry of the building to the fabricator.

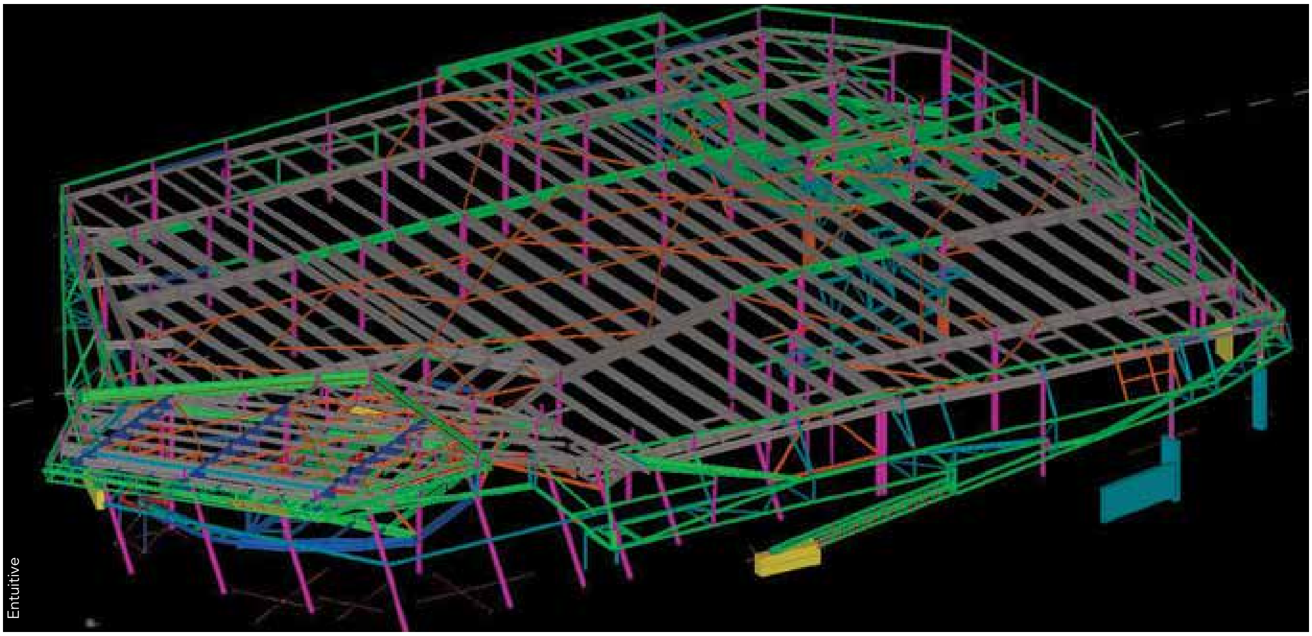
B+H Architects developed a clever solution by documenting the 3D coordinates of all points where cladding panels met (these values were extracted from the Revit model). This allowed any trade with 3D modelling capabilities to model the planes of the cladding defined by the given coordinates. In the case of the fabricator, once the planes were modelled, a cladding thickness was provided to ensure the steel framing was offset by the proper amount. Using our drawings and the Tekla model, the fabricator was able to develop shop drawing-ready framing with minimal problems.

Pushing the Envelope

The emergence of BIM as a commonplace tool for designers is leading the conversation on best practices for optimum, cost-effective and client-focused solutions. Visualizing, developing, creating and delivering projects in a 3D environment provides significant opportunities for project delivery, setting a new standard that enables rapid testing of solutions that generate the best options for project goals. Cutting-edge software and technology enable architects and engineers to envision and create design solutions that were previously unattainable, opening new doors to the imagination and pushing the envelope of what is possible in the built environment. This was certainly the case with Ripley's Aquarium of Canada. ■

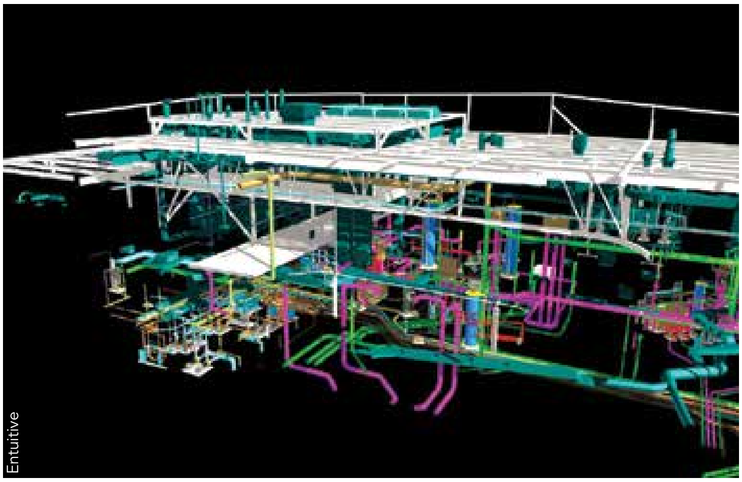
Ripley's Aquarium of Canada is just a few minutes' walk from the Metro Toronto Convention Centre, which will host NASCC: The Steel Conference March 26-28.

▲ The entrance lobby (framing above) was designed to represent the crust of the earth breaking open to reveal an entrance to the aquatic world.



▲ A Tekla model of the primary and secondary structural systems.

▼ An overlay of the structural, mechanical and life support system models.



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RJC Architects, San Diego

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General Contractor
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