Philip J. Currie Dinosaur Museum

Wembley, AB

Canadian Wood Council
Conseil canadien du bois

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> "The building tells the story of the bonebed, of the scientists and researchers working there, and of the Pachyrhinosaurus lakustia – a dinosaur first found in Pipestone Creek and identified as a new species in 2008; but the building also has its own story to tell. The collaborations that made it a reality are like an old-fashioned barn raising of a very high-tech building."

Martin Baron, B.E.S., B. Arch., LEED AP, MRAIC, AIBC, OAA,
Partner, Teeple Architects

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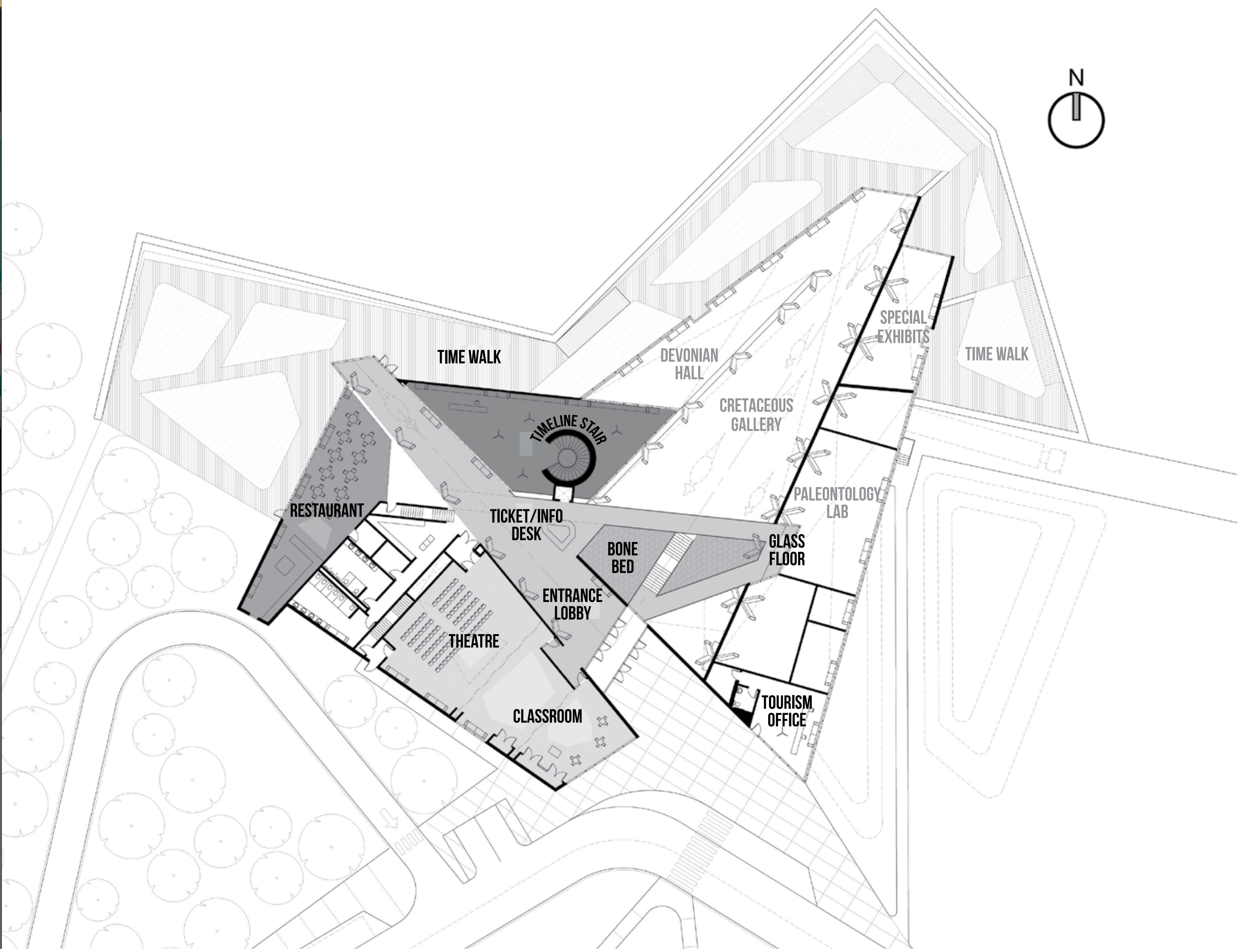
Introduction

The Philip J. Currie Dinosaur Museum is one of the world's foremost museums of paleontology and natural history. It tells the story of the Pipestone Creek Bonebed, its discovery, and subsequent excavation. The narrative of the museum parallels the discovery of the bonebed, the paleontological process of reconstructing dinosaurs, and the experience of this prehistoric time. The re-erected skeleton of the native Pachyrhinosaurus lakustai dinosaur, the bonebed's major discovery, is prominently featured at the museum entrance.

Located on a 10-acre site in northern Alberta, between Wembley and Grand Prairie, the museum attracts dinosaur enthusiasts and travellers alike with its dynamic form and unique architectural experience that traces the narratives of Alberta's paleontological and geological history.

The Philip J. Currie Dinosaur Museum is a highly interactive and sophisticated institute for experiential learning that celebrates Alberta's paleontological heritage through research, collection, preservation, exhibition, public programming, publications, and innovative outreach. The striking displays of fossil materials and casts are richly complemented with state-of-the-art digital media and augmented reality to give visitors exclusive glimpses into the world of science and ancient Alberta. Visitors are able to see dinosaurs in action, bring fossils to life, and explore the real work of scientists in the field.



Building Description

The Philip J. Currie Dinosaur Museum is a 3,905 sq.m. (42,033 sq.ft.) research and educational facility, strategically built adjacent to the Pipestone Creek Bonebed, the world's densest dinosaur bonebed and one of five most significant bonebeds revealed in modern history. The museum features extensive gallery spaces, two classrooms, a 64-seat theatre, research and collection areas, a restaurant, and a gift shop.

The unique sculptural form of the Museum was achieved through an innovative system of mass timber columns held together with complex, bespoke, timber nodes. The use of locally-sourced 'beetle kill' timber for the structure and the perforated acoustic wood finishes resulted in a sustainable building that is both warm and dramatic.

Departing from traditional black box exhibit design, the architecture itself is integral to visitors' experience of the museum's artifacts. Visitors to the museum embark on a journey through time, beginning with the accidental discovery of the bonebed by a local schoolteacher, and concluding with the Devonian Hall, a tribute to the pre-dinosaur world. The form and spaces of the building help develop this narrative.

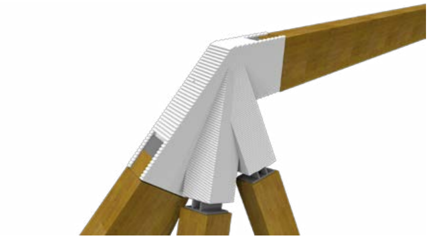
Above ground, the exposed wood and other primary interior materials reflect things that grow on earth, while concrete on the lower, below grade level evokes the weight of earth and buried fossils. Visitors moving through the museum physically descend in parallel with the timeline, moving further back in time each time they round a sharp corner. At every opportunity, displays open out onto the paleontology labs through glass floors and windows, putting the important work of the facility on display.

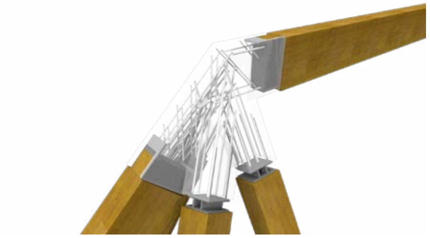
Use Of Wood

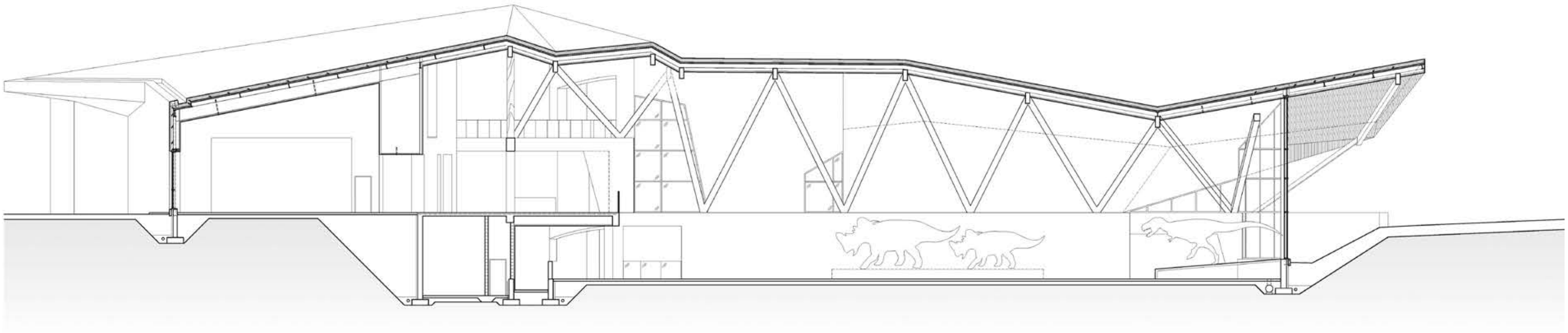
The Philip J. Currie Dinosaur Museum is an example of cutting edge wood design. The innovative structural connections that were custom designed and fabricated for the project enabled the team to realize a unique and dramatic wood roof structure that defines an architectural style which is distinctly "Prairie". The architecture, perfectly suited to the landscape and purpose of the building, is an intriguing form at the side of Highway 43 that beckons all passers-by to stop and visit.

The use of mountain pine beetle lumber from nearby forests and mills is a strategic effort to mitigate the impact of this devastating infestation. If left to decay in the forest, beetle killed trees would decompose and release carbon dioxide (a key component of greenhouse gas emissions) into the atmosphere. Instead, when the wood is harvested and incorporated into buildings, it stores the carbon that was sequestered during the life of the tree for the life of the building.

The unique wooden connections, called nodes, are the structural highlight of the project. They are the result of a close collaboration between the structural engineers and fabricators. The architectural team undertook complex 3D modelling and detailing of the nodes at column intersections and worked with the fabricators to develop a system to slice the complex forms into workable, CNC-cut, 2D pieces that were laminated together to form the massive final pieces. Internal tensile steel hardware was inserted into the nodes during off-site fabrication and then attached to the columns on-site. The resulting structure is essential to the spatial expression of the Museum, and represents significant advancement in sustainable wood technology.







Building Section 1

Architecture

The design of the Philip J. Currie Dinosaur Museum draws on an abstraction of the paleontological excavation experience, with two massive retaining walls of poured concrete and gabions pushing back the earth to reveal the main gallery wall. Viewed from the exterior, the museum's angular, asymmetrical form brings to mind the flapping tents and other impromptu structures erected over dig sites. Inside, the exposed heavy timber structure fits perfectly with the local vernacular, echoing the wooden barns and other agricultural buildings of the region.

The highlight of the project is a geometrically-complex roof supported by exposed timber beams and struts that are a metaphor for the dinosaur bones that populate the museum. A preliminary cost analysis of the wood option looked to be cost-prohibitive, so an alternate proposal in steel was considered, but the steel option was ultimately dismissed because the design team felt the wood option was not only more appealing but also the best fit for the organic nature of the structure.

The use of heavy timber for the supporting members of the roof was fairly straightforward, but the complex geometry and varying angles resulted in complex structural nodes where the members intersected.

Early on, the vision for the use of wood, even in the connections, was to represent the bones of the structure more realistically, and provide a visually inspiring skeleton. For this reason, large steel connections would not work visually. Connecting together as many as eight large (up to 1.6m deep), rectangular, glulam members with varying 3D angles and structural forces, while still achieving success visually, was a significant undertaking.

The form of the nodes reflects the natural extension of each member into the joint. The initial plan was to carve the nodes from large pieces of solid timber, but the necessary sizes and associated costs made it clear this was not feasible. The fabricators had to devise a method for constructing the massive, complex nodes in a way that seamlessly tied the structure together while supporting the architectural intent.

The end result was a fabrication process not unlike that of 3D printing. The nodes were sectioned into workable 2D shapes that were stamped in an optimized configuration onto ordinary 4'x8' sheets of plywood and cut using a CNC machine. The flat plywood layers were then built up and laminated together to form the final geometries of the nodes.

Carbon Summary

Philip J. Currie Dinosaur Museum

Results:

Volume of wood products used (glulam & nodes):
210 cubic meters (7,409 cubic feet)

U.S. and Canadian forests grow this much wood in:
1 minute

Carbon stored in the wood:
171 metric tons of carbon dioxide

Avoided greenhouse gas emissions:
66 metric tons of carbon dioxide

Total potential carbon benefit:
237 metric tons of carbon dioxide

Equivalent to:

50 cars off the road for a year

Energy to operate 25 homes for a year

Results from this tool are based on wood volumes only and are estimates of carbon stored within wood products and avoided emissions resulting from the substitution of wood products for non-wood products. The results do not indicate a carbon footprint or global warming potential and are not intended to replace a detailed life cycle assessment (LCA) study. Please refer to the References and Notes for assumptions and other information related to the calculations.

www.cwc.ca/carboncalculator

Sustainability

The museum makes extensive use of wood, a renewable and sustainably managed local resource. Because of its low embodied energy, low toxicity, and the carbon sequestered within it, wood makes a significant contribution to the overall environmental performance of the building.

A highly insulated building envelope comprised of efficient, prefabricated wall and roof panels also contributes to the building's environmental performance. There is a low window-to-wall ratio and the walls have an effective insulation value of R-25. The triple-glazed windows have two low-E coatings and an extra-wide thermal break.

The museum also benefits from displacement ventilation – a high volume, low speed system that dramatically reduces the ductwork and fan requirements. It maintains comfortable temperatures in the 'habitable zone' (from the floor to just over people's heads) and doesn't waste energy maintaining temperatures above this zone. The minimal ductwork maintains the beauty of the exposed structure and keeps it uncluttered.

The museum's natural surroundings are enhanced by a sophisticated cistern system that collects rainwater and redistributes it to irrigate the surrounding landscape. In the beginning, the project targeted LEED Gold and, although formal LEED certification was ultimately not pursued, the design substantially complies with LEED Gold requirements.

Carbon Calculator

Compared with other functionally equivalent buildings made of non-wood materials, wood-frame buildings typically generate less embodied greenhouse gas (GHG) emissions during their life cycle. In other words, there are fewer GHG emissions associated with a wood-frame building than other building types. This difference can be quite large and can be taken as a carbon credit for the amount of CO_2 emissions that were avoided (displaced) by choosing wood over other more GHG-intensive materials.

A free, easy-to-use online carbon calculator is available to help you determine the estimated carbon benefits of your wood building project. Access the tool at: **www.cwc.ca/carboncalculator**

Photo © Stephan Pasche

The Nodes

The nodes were designed in Rhino, with close collaboration between the structural engineer and fabricator. Complex 3D models were generated before each piece was fabricated. The nodes were shaped so that all layers not only respected the desired form but also kept the size within material constraints.

Figuring out how to make the nodes was only half the challenge. Once this issue was solved, the engineers had to analyse the structural capacities of these unique connections. Even using the latest finite element software, the complexity of the nodes meant that full-scale analysis and testing was required to determine their capacities.

Tests were performed in the workshop using beams made of built-up layers of plywood that were glued and stapled together in a manner similar to the make-up of the nodes. This enabled the engineering team to examine the loading capacity and failure mechanisms of the nodes. Screws up to 19mm in diameter and 1200mm in length were used in a 'strut-and-tie' fashion much like rebar in concrete. The stress parameters of the nodes were determined by testing with and without screw reinforcement and these parameters informed the structural analysis of the nodes themselves.

“The challenge was this: how to bring up to eight different large cross-section members into a single joint in a way that is aesthetically natural, using wood, and able to handle the complex structural forces and eccentricities inherent in the geometry. The answer was to carve simple sheets of plywood using a computer into efficiently nested shapes that could be glued and screwed together into the required unique 3D form most natural for each unique node.”

Gerald A. Epp, M. Eng., P.Eng., Struct. Eng., P.E., M.IABSE, FIStructE
President and Chief Engineer, StructureCraft Builders Inc.

Fabrication

The use of 3D modelling software ensured material optimization, accurate screw placement, quality control, and also ensured the nodes were made as efficiently and cost-effectively as possible. Rhino 3D provided the initial geometric understanding of each piece, while Grasshopper, an algorithmic modeling plug-in for Rhino, drove the entire process, resulting in a true digital fabrication design paradigm.

Scripts were created to automate the virtual development of each node. The scripts generated the individual profiles of the plywood layers, greatly speeding up the analysis and modeling process. Each 2D profile of every node was unique and multi-faceted. CNC was the clear choice for fabrication.

The largest nodes are more than 1500mm tall by 2400mm wide and were made with roughly 180 CNC pieces. Every layer of each node was cut from a standard, 16mm thick 4'x8' sheet of plywood; each piece had its own global node number as well as a part number relative to its position in the node. 1250 unique layers were cut from just 250 sheets of plywood to create the nodes.

The 3D automation software also enabled small, precise holes to be drilled in each layer so that 150mm long wood dowels could be inserted to perfectly stack the layers of each node. Once the layer assembly was completed, the reinforcing screws were installed.

Each node has its own diagonal reinforcing screws with different orientations and sizes; no two are alike. The screw installation required a close collaboration between the shop floor and the 3D model. The software was used to accurately locate each screw without hitting any other screws or hardware.

Throughout the entire fabrication process, engineering reviews and extensive Quality Control monitoring were performed to ensure tolerances were met for the overall node as well as for each node’s metal extension to which the beams and struts would later be attached.

"A heavy timber solution was the perfect fit for this project; it achieved the desired fire rating, contributed a warm and pleasing aesthetic, and was a cost-effective method of framing the complex roof geometry."

Stephan Pasche, P.Eng., Senior Associate, Fast+Epp

Fire Safety

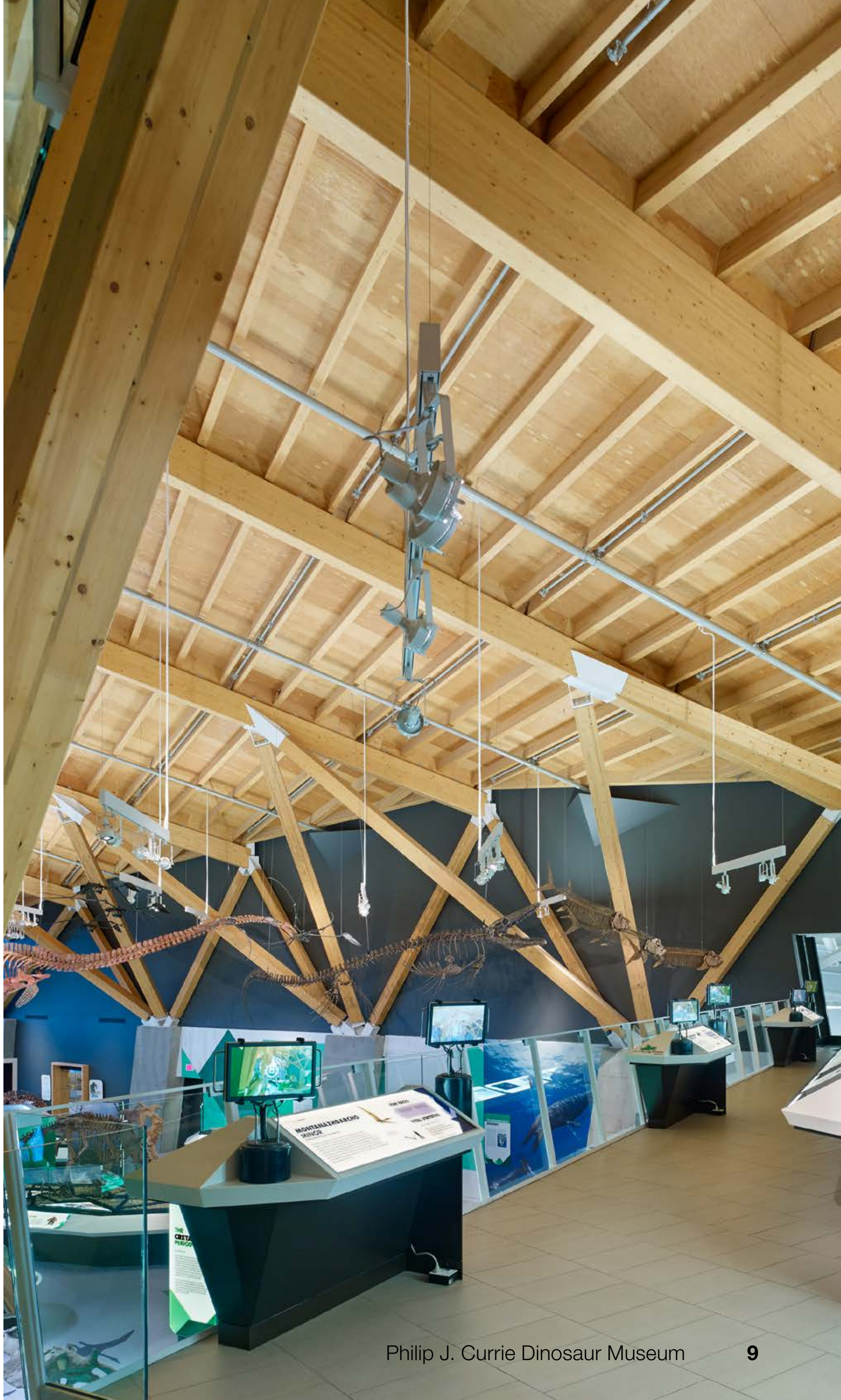
The building's major occupancy classification is Assembly Group A, Division 2, which required the museum to be of non-combustible construction. The Alberta Building Code allows heavy timber roofs in non-combustible buildings of one or two storeys. The architect's vision for a heavy timber roof fit within the existing code and did not require an alternative solution. To comply with the requirements for heavy timber construction in a non-combustible building, the wood members in the roof system have a minimum dimension of 64mm.

The museum building is fully sprinklered, with special pre-action fire sprinklers installed in sensitive areas. Pre-action fire sprinkler systems employ a dry pipe system where water is withheld from the pipes by an electrically operated valve called a pre-action valve.

Two separate events must happen to initiate sprinkler discharge. First, the detection system must identify a developing fire through a smoke alarm, heat alarm or pull station. This opens the pre-action valve to permit water to flow into the pipes, effectively creating a wet pipe sprinkler system. Then, the individual sprinkler heads can be triggered to permit water flow onto the fire.

The dual action required for water release provides an added level of protection against inadvertent discharge. This system is important in museums and other buildings where an accidental discharge would cause severe damage to valuable artifacts.

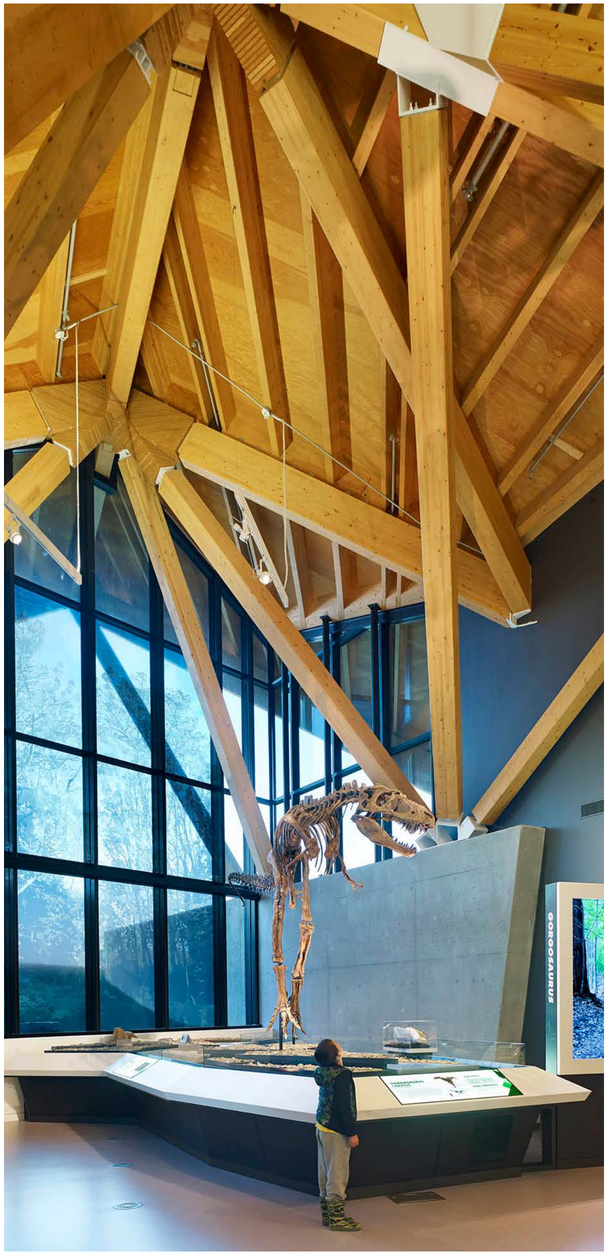
In this building, pre-action sprinklers were installed in the gallery at the north end of the building, a room designed to exhibit organic materials with very strict temperature and humidity controls. The owner realized a cost savings by installing standard sprinklers in the remaining, less sensitive areas.



Structure

Building Information Modeling (BIM) was used extensively to estimate earthwork, layout, surveying, concrete foundations, glue-laminated timbers, and structural steel. The tender was tailored to the building's design and requested that the formwork, structural steel, and glulam members incorporate the use of modeling and collaborate with the designer's Rhino model to achieve the geometry.

Each team used a form of modeling that the construction manager was able to bring together in one collaborative model, allowing the teams to check the geometry, connections, and transitions. This resulted in minimal errors during the construction of the concrete foundations and slabs, structural steel, and glue-laminated timber framing. This also enabled comprehensive planning. Questions that arose from the digital creation and amalgamation of the four models were answered before activity started, resulting in continuous work with no downtime spent waiting for answers.



"Buildings that draw international attention tend to be located in the larger urban centres of the world where there are the resources to pull off bold and expressive projects, but small cities and rural towns deserve excellent design as much as large cities do. This museum proves that when communities unite behind projects, they can create great things."

Martin Baron, B.E.S., B. Arch., LEED AP, MRAIC, AIBC, OAA,
Partner, Teeple Architects

Conclusion

The Philip J. Currie Dinosaur Museum sits proudly beside the Pipestone Creek Bonebed surrounded by timeless, rolling plains. It is one of the world's foremost on-site paleontology centres; it is also a feat of timber engineering.

New technology was developed to construct the wood structure and, in particular, the nodes where up to eight large beams meet at a single point. The design team pioneered a technique of laminating plywood to fabricate connections that create an intriguing and structurally sound building.

The wood nodes are a revolutionary structural solution that has never been seen before, not unlike the native Pachyrhinosaurus lakustai dinosaur skeleton discovered at the site and featured in the museum. For timber architecture and connections enthusiasts, the museum building itself is a must-see attraction that rivals the relics it houses.

Project Team

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Heavy-timber Design-build Contractor

StructureCraft
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Museum Consultant

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