Eisschnelllaufhalle der 2010 Winter Olympics, Vancouver - Dachkonstruktion

Speedskating Oval for the 2010 Winter Olympics in Vancouver, Canada

Stadio per pattinaggio di velocità 2010, giochi olimpici invernali Vancouver - Kanada

Halle du patinage de vitesse des Jeux olympiques d'hiver 2010 Vancouver – Canada

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1. Introduction

When the IOC awarded the 2010 Winter Olympics to Vancouver,B.C., architectural attention immediately turned to the building that would host the long track speed skating venue. Speed skating ovals are unique buildings that provide opportunity for striking architectural- structural expression.

Operating on a lean budget, VANOC (Vancouver Olympic Organizing Committee) decided to offload financial risk for the facility by committing the fixed sum of $60M CAD to the neighbouring City of Richmond, who would then assume ownership of the building and responsibility for the remainder of the $178M construction budget. Following an international request for proposals, Cannon Design Architects was appointed the prime consultant with Fast + Epp structural engineers the structural sub-consultant for the roof structure.

Figure 1: Richmond Speed Skating Oval, Richmond, British Columbia, Canada

2. Building Description

The speed skating oval is a roughly 100m wide by 200m long building with a total roof area including overhangs of 23,700 square metres. A full basement is situated below the ice level and houses parking, offices and fitness/changing rooms. The post-Olympic legacy use will incorporate 2 full-size ice rinks, 8 basketball/volleyball courts and a full-size dry-land running track. The building is situated on the Fraser River delta very close to Vancouver International Airport

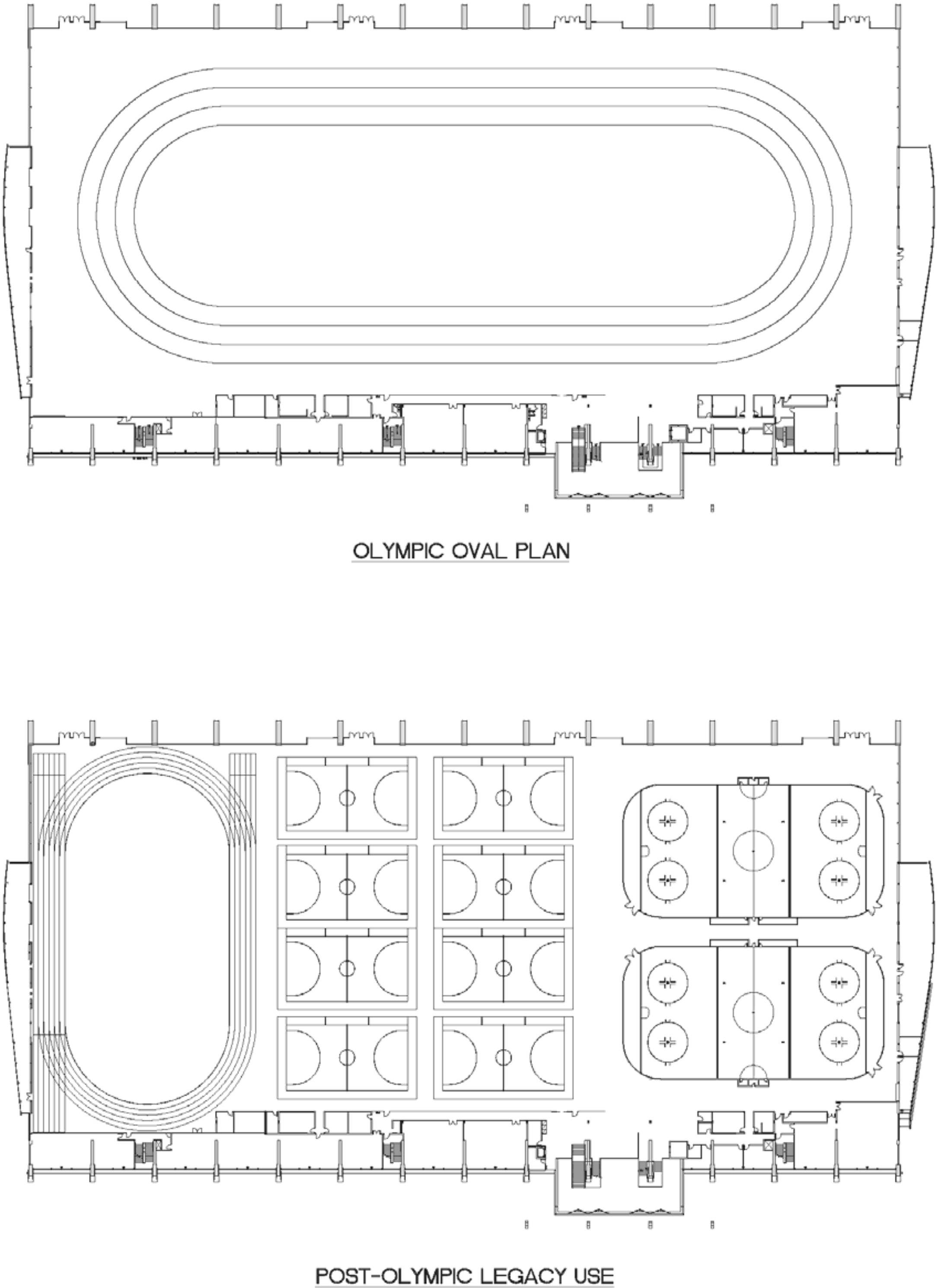


Figure 2: Building description

3. Design Criteria

The following factors and conditions informed the design of the roof structure:

- Speed skate oval roofs are atypically low, long span roofs that will be intimately experienced by spectators, hence the need for an architecturally sensitive solution.
- Maximize views to the North Shore mountain range and the immediately adjacent Fraser River to the north of the site.
- The Owner, the City of Richmond stated that the design was to be iconic, and that it should maximize the use of wood.
- Mechanical/electrical services should be concealed in order to maximize the elegance of the architectural expression.
- Many of the forests of the Province of British Columbia are currently being destroyed by a rampant pine beetle infestation which necessitates greater than normal volumes of timber harvest.

Figure 3: Richmond Speed Skating Oval Site

4. Roof Structure Concept

Having enjoyed the benefit of visiting existing speed skating ovals in Lillehammer, Turin, Erfurt, Salt Lake City and Calgary, the design team decided that a simple arch roof structural concept would yield a clean, uncluttered roof aesthetic. Furthermore, compression arches lend themselves more readily to incorporating the relatively weaker properties of wood (vs. steel or concrete) in an economical manner. In order to integrate and conceal the mechanical and electrical services, the decision was also made to develop the design of 3-dimensional arches that would create an enclosed space for housing the ducts, sprinkler pipes and electrical conduits.

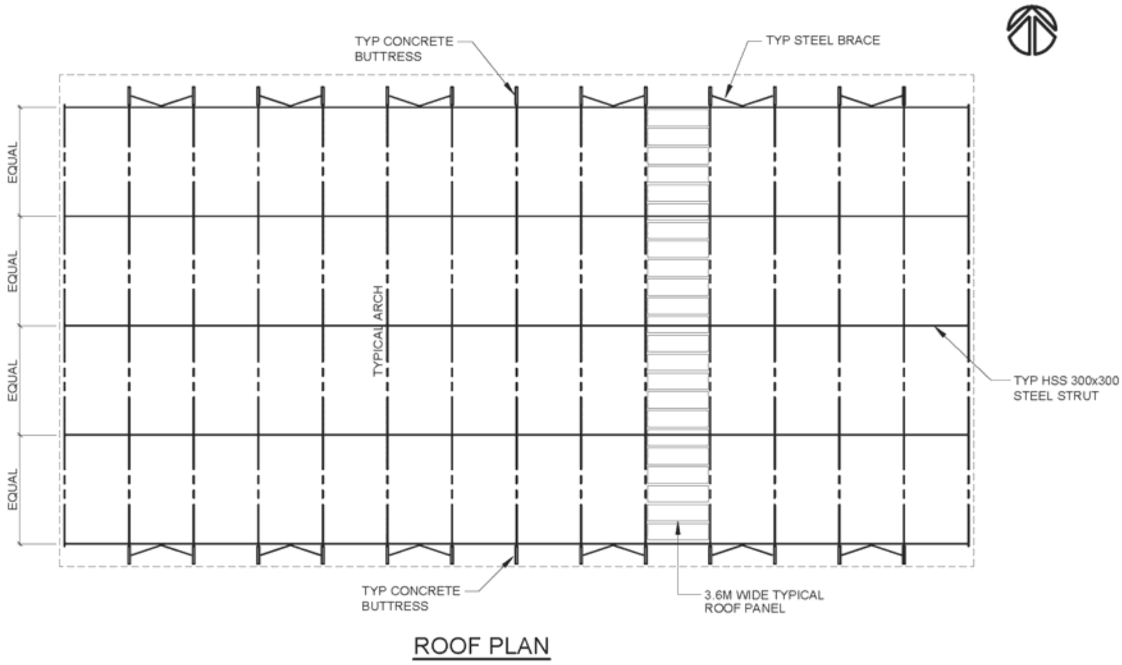


Figure 4: Roof plan

The resulting design solution consisted of V-Shaped hybrid wood-steel arches spaced at 14.2m centres spanning 95 metres between concrete buttresses. The arches are constructed using 2 slabs of 175mm x 1700mm glue-laminated Douglas-Fir wood and connecting them at the bottom with a 10mm thick stiffened steel 'blade' that metaphorically alludes to the speed skating function within the building. Fastened to the top of the glulam slabs are 150mm deep steel wide flange beams that lift off of the wood at the north end to maximize stunning views to the Fraser River and North Shore mountains. The steel beams also lift off at the south end to accommodate a longitudinally oriented mechanical distribution duct. The beams are braced with steel bracing to provide stability for the V-shaped composite arch section. The arches are pinned to the concrete buttresses using spigotted steel end nosings with a 250mm diameter solid steel pin.

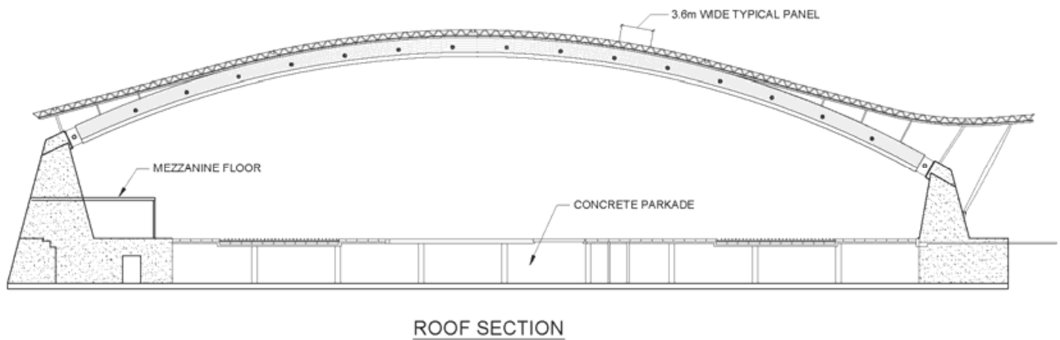


Figure 5: Roof section

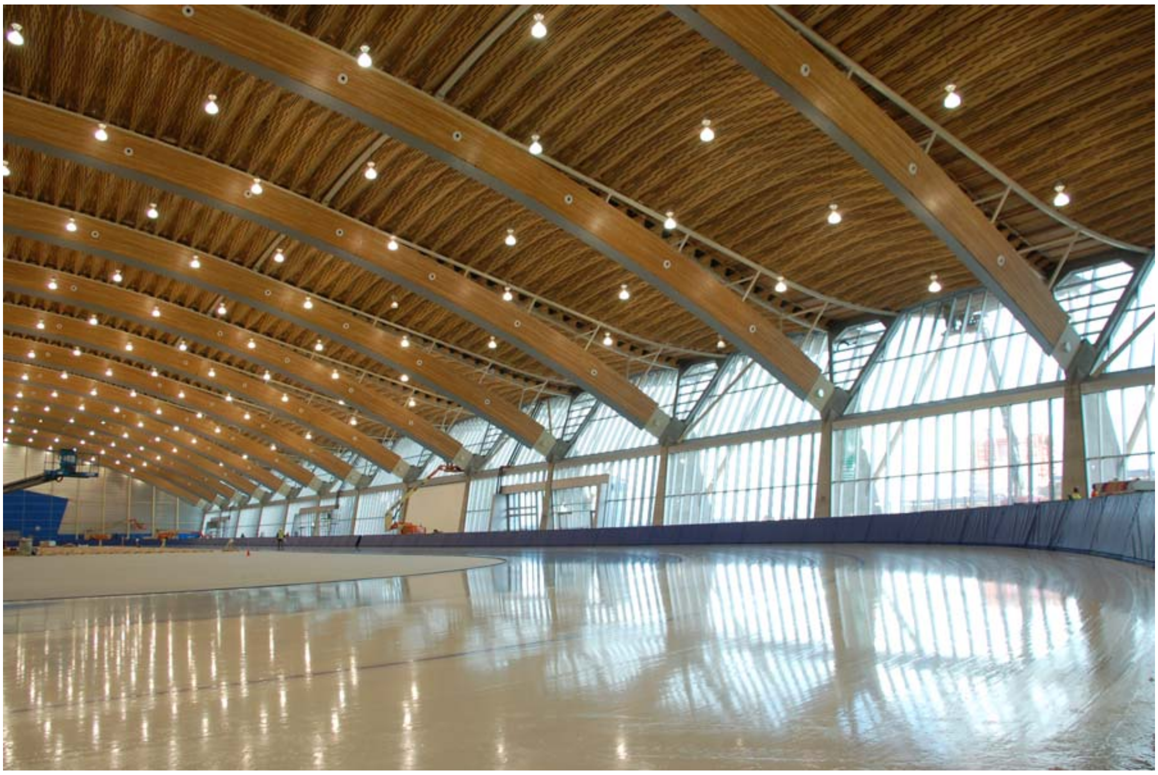
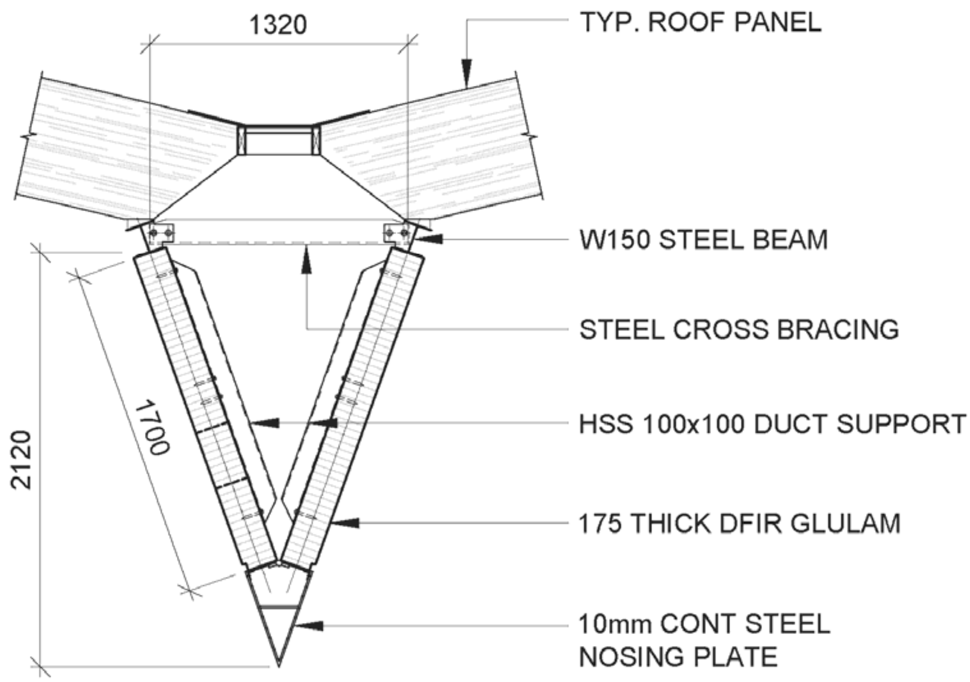
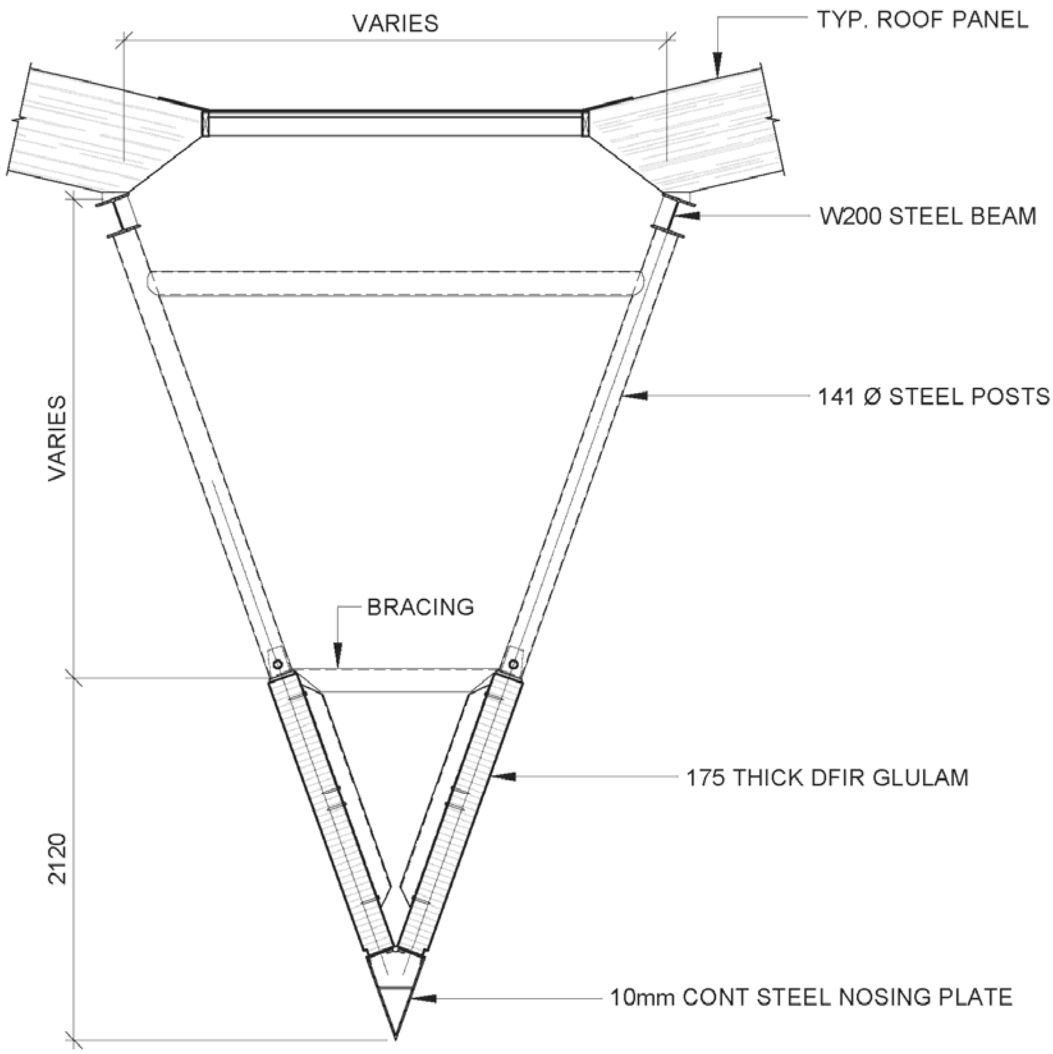


Figure 6: Indoor



TYPICAL SECTION



NORTH / SOUTH END SECTION

Key arch design considerations include:

- unbalanced snow loading (in accordance with wind tunnel test results) and effect on global and local element buckling.
- warping of the glue-laminated wood to achieve the triangular shape.
- potential shrinkage effects on steel –wood hybrid construction.
- differential temperature effects on steel-wood hybrid construction.

The arches were analysed using SAP software. Governing the design were combined bending/axial wood compression stresses that occurred near the quarter points of the arch under unbalanced snow loading, dead load and out-plane bending arising from forming the arch to a triangular shape.

Several options for the infill framing between the arches were considered including a steel purlin/steel deck solution, a hybrid wood purlin/steel deck solution and a prefabricated wood panel solution. Following much design discussion and pricing exercises and with the help of a $1.5M research contribution from the BC government and forest industry, the decision was made to incorporate the wood panel option. Not only was it an economically viable option with the help of the industry grant, but it also offered a unique made-in-BC solution that would meet the wood/ pine beetle use design criteria and provide striking aesthetic character, warmth and superior acoustic performance to the building.

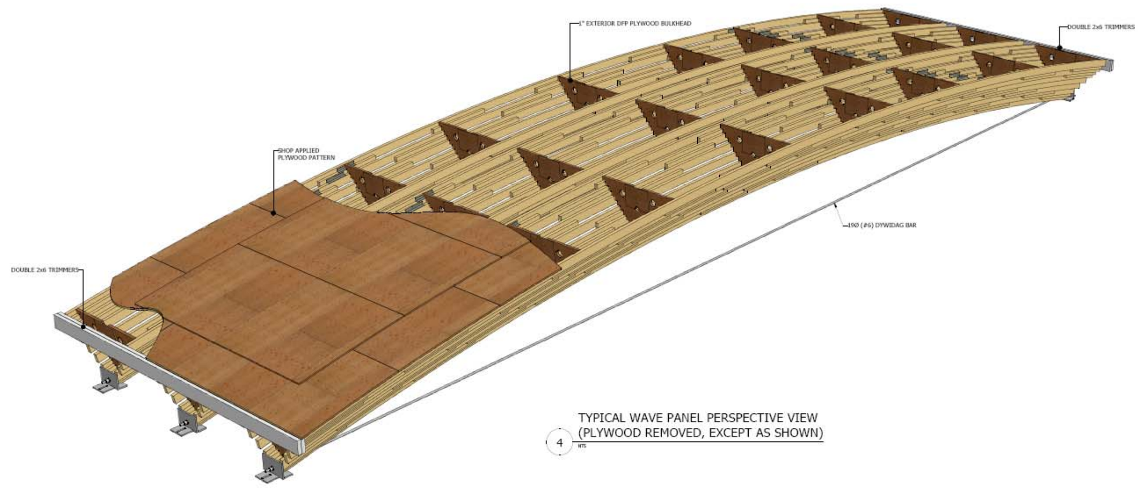


Figure 7: Typical Wave Panel - Perspective view

The panels are 3.6 metres wide and on average roughly 13m long They consist of standard dimensional ‘2 x 4’ lumber (38mm x 89mm) that is bowed 600mm high longitudinally and assembled in section as a wave pattern – hence the name ‘Wood Wave’ panels. The 2 x 4’s are fastened and spliced to one another with screws and nails. Interior plywood diaphragms and two layers of 15mm/13mm exterior surface plywood provide overall stability. Three Dywidag tension rods hold each panel in a permanent bow-shaped form.

As can be appreciated, the Wood Wave panels are an entirely custom design solution with inherently complex and difficult to predict structural behavior. The SAP software was used to analyse the structural response of the panels. This analysis was augmented by full-scale structural testing in order assess stiffness characteristics and assumptions in the computer model. Following an extensive iterative process of prototype testing and analysis, a final design was achieved that not only optimizes connection design but also results in a ductile (vs. sudden buckling) failure mode. The panels are typically designed for a snow load of 1.25kPa, and for 4.5kPa at a low roof snowdrift condition.

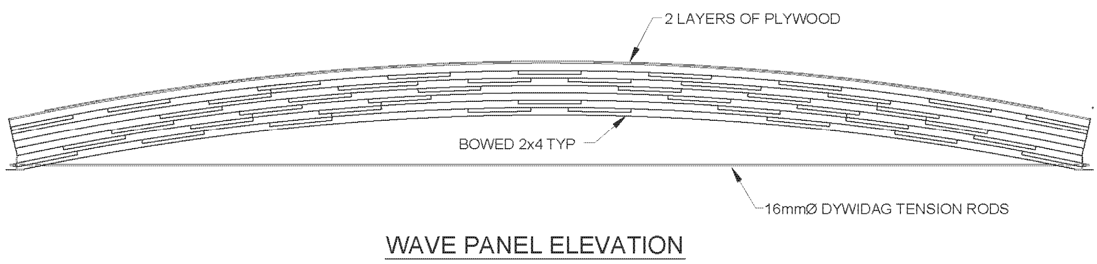


Figure 8: Wave panel elevation

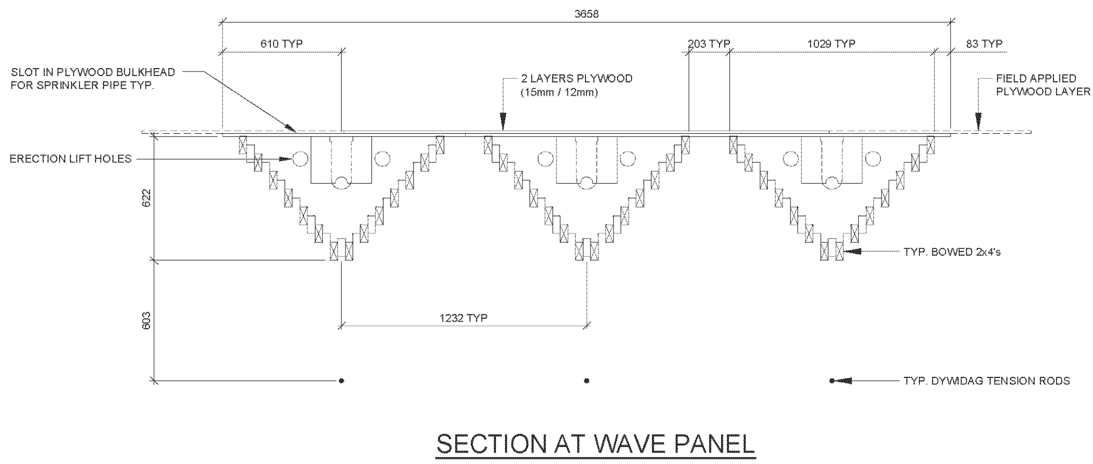


Figure 9: Section at wave panel

Figure 10: Wave panel

5. Construction

The roof construction contract was assigned and awarded as three separate components:

Package #1 :

Supply of glue-laminated arch components by Structurlam Inc. , a glulam fabricator located in the interior town of Penticton, B.C., roughly 300 kilometres from Vancouver.

Package #2:

Assembly of wood and steel arch components and erection of arches by G. Third and Sons, an established steel fabricator located near Vancouver.

Package #3:

Design, fabrication and erection of Wood Wave panels by StructureCraft Builders Inc., a company affiliated with and owned by the partners of Fast + Epp structural engineers.

It should be noted that it is highly unusual to divide a roof construction contract into three components. It is also almost unheard of to witness a steel fabricator under unionized shop conditions receiving large volumes of timber into his shop and screwing steel components to wood components. However goodwill and cooperation governed the process, 3-D computer models were shared by all and result was a relatively smooth and seamless fabrication and erection process.

5.1. Arch Fabrication and Erection

The individual arches were fabricated in four roughly 24.0 metre long components. Mechanical ducting was also installed in the steel fabricator's shop. The arch sections were then wrapped and shipped to the site. Two temporary scaffold towers were erected on site at the quarter points of the arch. The two end sections were then erected between the concrete buttresses and the scaffold towers. The two interior arch sections were connected on the ground and then lifted as a double length piece into place between the free ends of the outboard arch sections. The bottom steel blade featured a slip-resistant bolted connection at splice points, the top steel wide flange beams were temporarily bolted and then welded and the wood components were spliced with screwed shear connection plates. Epoxy glue was applied to the ends of the glue-laminated wood to ensure a uniform end bearing condition.

Three rows of longitudinal 300mm x 300mm curved hollow steel sections were also installed to provide temporary and permanent lateral arch stability. Steel braces were also installed at the longitudinal north and south building faces to transfer wind and seismic diaphragm forces to the concrete buttresses.

Figure 11: Arch Fabrication

Figure 12: Arch Erection

5.1 Wood Wave Panel Fabrication and Erection

Custom, automated fabrication equipment was designed and developed to improve production efficiency for the 450 wood wave panels. A nailing machine was developed to nail splice thousands of 2 x 4's and a hydraulic press was designed to bow the spliced 2 x 4's prior to installation of the permanent Dywidag tension rods. The double layer of plywood was glued and screwed onto the sub-frame assembly prior to being wrapped and shipped to the site. The exception was at the panel edge zones where only one layer of plywood was shop-installed in order to facilitate an overlapping field installed plywood layer at all adjoining panel edges. Fabrication also involved installing acoustic and fire insulation as well as two sprinkler branches in each panel. Peak production resulted in the completion of 4 panels per day.

Figure 13: Fabrication

Figure 14: The arch

The panel erection closely followed the arch erection which generally proceeded at the rate of approximately one arch every two weeks. All field installed plywood was glued and nailed at splice locations and at perimeter steel drag strut locations. Mechanical ducts, electrical conduits and sprinkler lines all required a coordinated effort of field splicing.

The total cost of the roof construction is roughly $18M CAD.

Figure 15: Installation of the Roof

6. Conclusion

The design and construction of the 2010 Olympic Speed Skating Oval in Richmond, B.C. presented Vancouver designers and contractors with the challenge of a lifetime. The building, which is currently 99% complete and already being used by Team Canada for training is receiving many favourable reviews and has been described by the Executive Director of VANOC as a 'piece of magic'. Vancouver is looking forward to welcoming international visitors to the 2010 Olympics and hosting the speed skating venue at its unique made-in-BC Oval in Richmond, B.C.

Figure 16: The Building site

Figure 17: Another view of the building site

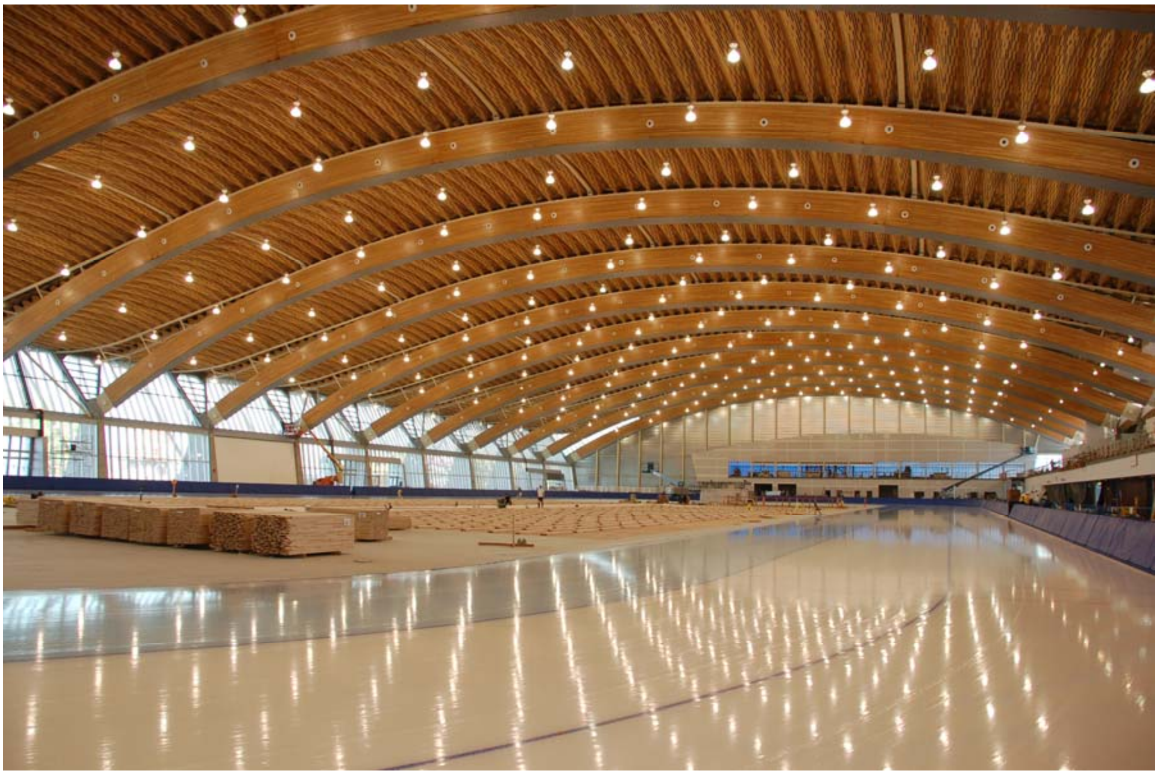


Figure 18: Before the opening

Figure 19: Indoor speed-skating rink