The Richmond Olympic Oval

THE RICHMOND OLYMPIC OVAL

Canadian Wood Council
Conseil canadien du bois

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Project of the Canadian Wood Council

The Richmond Olympic Oval

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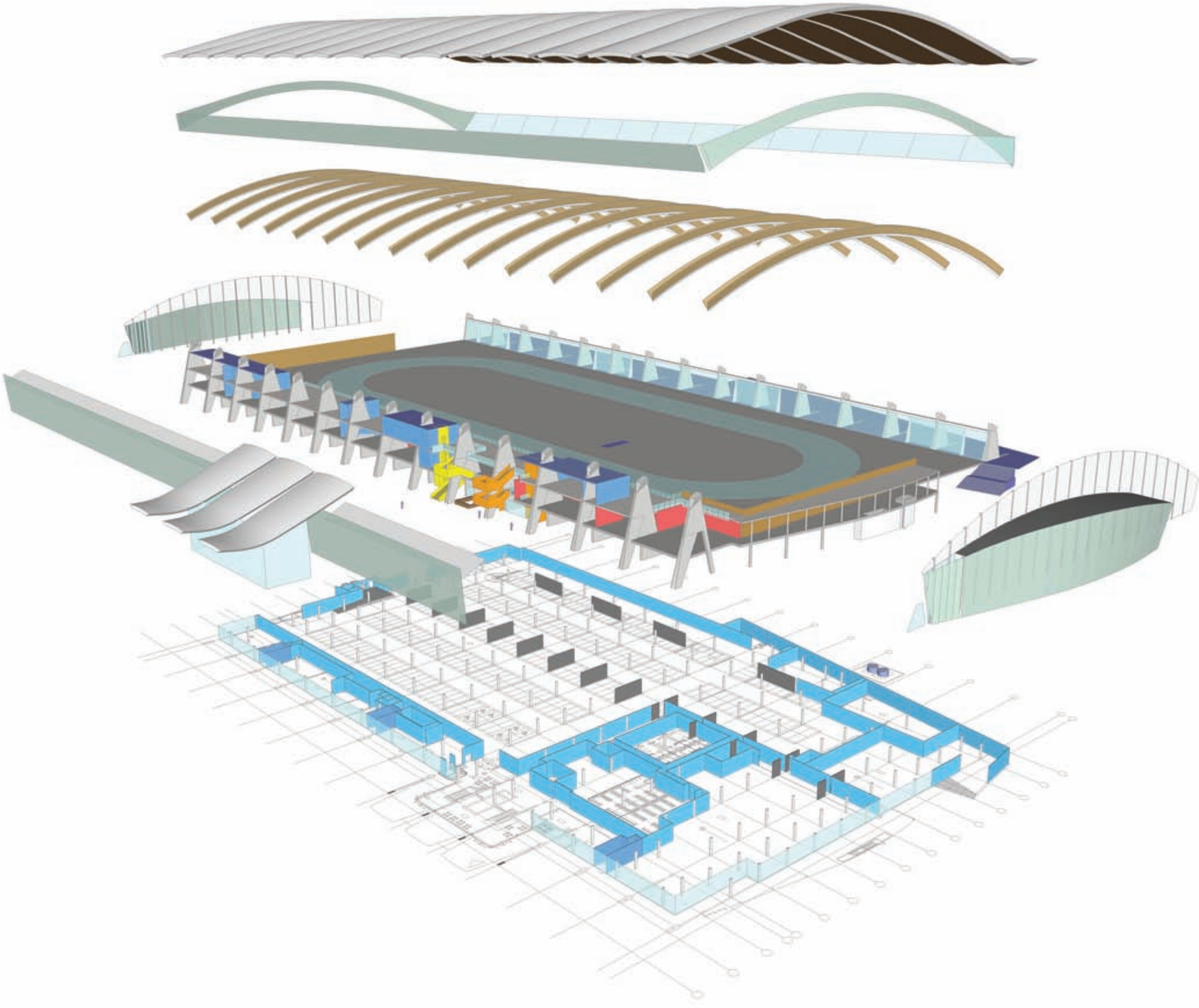
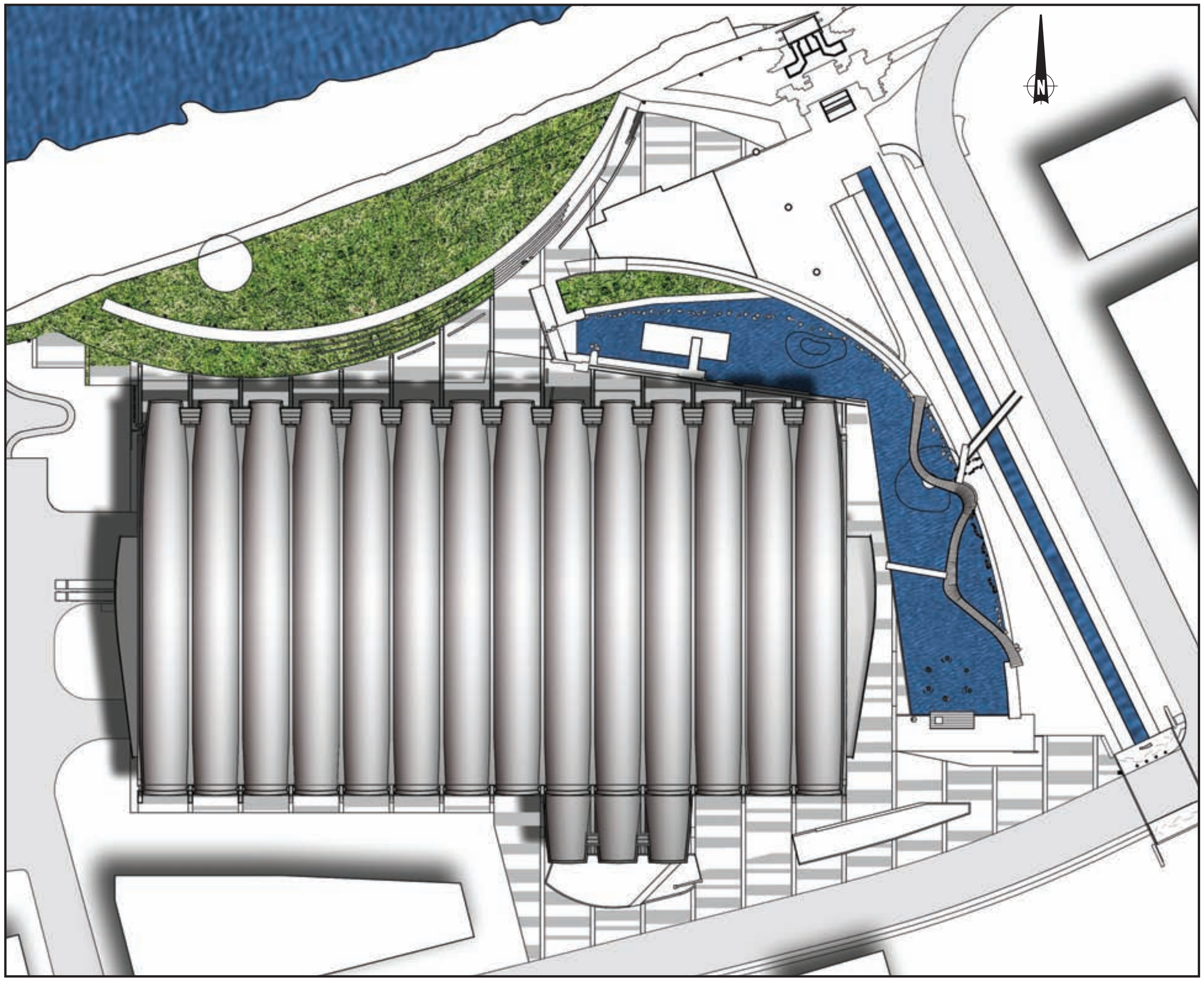




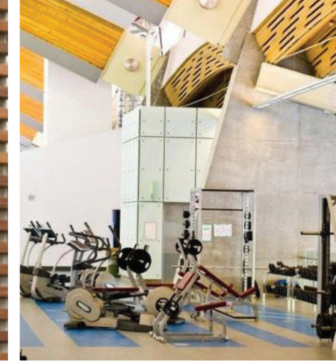
Site plan

Introduction

The Richmond Olympic Oval is the largest structure to be built for the Vancouver 2010 Olympic Winter Games. Designed to accommodate the long track speed-skating events before an audience of more than 8000 spectators, the building features a 6 acre (2.5 hectare) free spanning roof that is a precedent setting example of British Columbia's and Canada's advanced wood engineering and prefabrication capabilities. The building is located a short distance from Vancouver's International Airport in the City of Richmond, where after the Games, it will be transformed into a multi-sports training and recreation facility at the centre of a new residential and commercial neighbourhood. Construction of the project began in 2005, and the building was opened on time and under budget in December 2008.

Main entrance canopy





Design Approach and Objectives

With a plan area of 270,000 ft^2 (25,000m^2) and a total floor area of more than 500,000 ft^2 (47,000 m^2)) the complexities and scale of this building, and the need to reconcile them with the client's requirement to achieve Leadership in Energy and Environmental Design (LEED) Silver certification, meant that a truly integrated approach to design was essential from the outset.

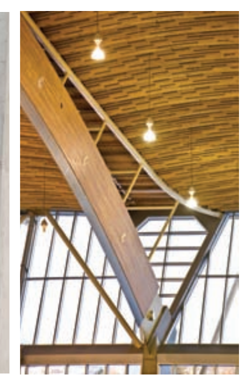
The project is also being assessed using the Green Globes rating system which includes a Life Cycle Assessment tool, in its approach.

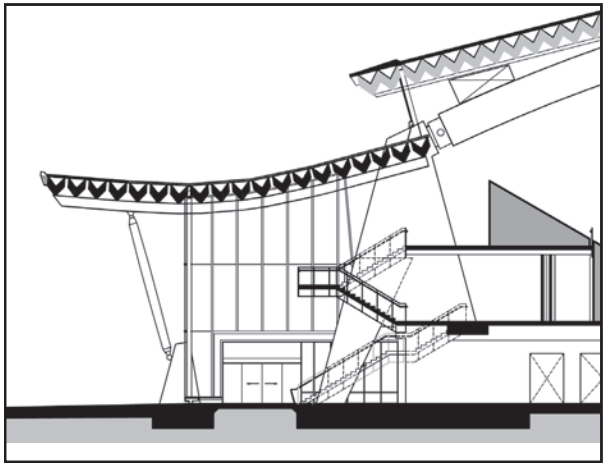
The process began with goal setting meetings and continued at regular intervals throughout the project, at times bringing together a team of more than 25 design and building consultants.

From the start, the Richmond Olympic Oval was designed for adaptive reuse. Following the Vancouver 2010 Olympic Winter Games, the speed skating rink will be reprogrammed, and the entire building converted to a multipurpose health and wellness facility, which is expected to attract both national and international athletes of many disciplines.

The City of Richmond wanted an iconic building to draw people and development to the site overlooking the river and the mountains beyond, while providing much needed community and sport services to its residents long after the conclusion of the Games.

Accordingly, the design team of this very large building was assigned the task not only of accommodating the Games and Legacy programs, but also incorporating the culture and history of the area, protecting the very sensitive riparian environment, creating urban sites and new development context and establishing a visible point of reference for one of the most prominent sites in Richmond.



Main entrance lobby section

The design concept of *flow, flight and fusion* was inspired by the surrounding environment of where city meets nature. Elements of curved and linear forms were taken from the nearby Fraser River and the wild birds that inhabit its estuary.

CannonDesign architect, Larry Podhora, described the Richmond Olympic Oval in the following way: *"The architectural design of the Richmond Olympic Oval emanates from several poetic images based in the cultural history of the site and the surrounding geography. For example, the articulation of the Oval roof evolved from the image of the Heron, being a native bird in that community. The roof has a gentle curve which peels off on the north side of the facility emulating the wing of a Heron, with its individual feather tips extending beyond the base arched wood structure. This allows for the opening of the facility's interior to a view of the north shore mountains and the Fraser River at the North Plaza."*

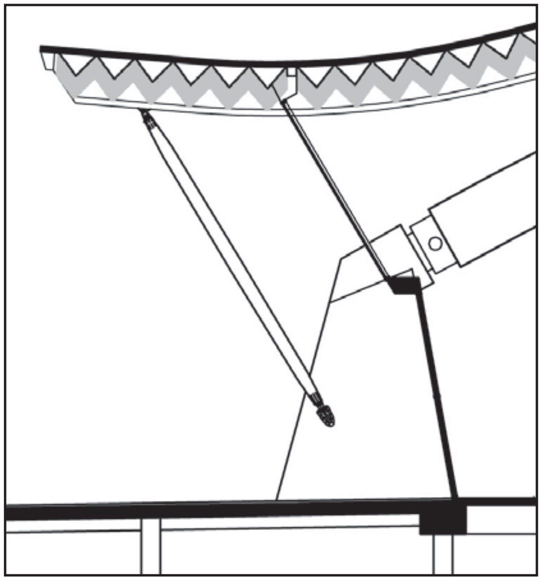
The building is arranged on three levels, a basement parking garage, a ground-oriented entry, circulation, service and amenity level, and above them the breathtaking vaulted sports hall with its unique wood roof and expansive views north to the Fraser River and Coast Mountains.

Supporting Structure

The Richmond Olympic Oval is situated on a river delta where soft compressible soil extends to a depth of 700 ft (213 m). The challenge for structural engineers and geotechnical consultants was to design a foundation system that could meet the specifications for international speed skating venues while addressing the unstable soil conditions.

An exceptionally flat structural surface is required for preparing high performance speed skating ice. The structural surface must vary no more than 1/8 in. (3 mm) in 10 ft (3 m) with a total maximum deviation of no more than 3/4 in. (20 mm) over the entire length of the ice surface – a distance of more than 1300 ft (400 m).

Analyses had indicated that, for optimal performance, the ice slab should be raised above surrounding ground level to achieve better control of the internal environment of the building. Instead of an earth berm, the engineers devised an innovative two-level structure on a partial raft foundation and partial piled foundation in densified soil using a soil-structure interaction analysis to produce an ice slab whose surface variations are less than the required tolerance. The two-level solution is designed not only to achieve excellent ice flatness but also provides additional space for 450 car parking stalls, athlete services, retail outlets, and a paddling training facility.



North elevation section

The slabs of the two structural levels connect the opposing pairs of concrete buttresses that support the shallow arched roof and resist the large spreading loads, which would otherwise be directed into the poor soils. The buttresses sit on pile caps that distribute buttress loading to pile resistance points that have zero net eccentricity, and so minimize the chance of differential settlement. Between the arch supports, the structural columns are evenly spaced to distribute the gravity loading on the soils as uniformly as possible.

Internal shear walls serve a dual purpose, resisting seismic loads as well as any unintended eccentricity of gravity load that could translate into differential settlement. This is particularly important given the shallow vaulted form of the roof, which is susceptible to eccentric snow loading due to pressure differential between the windward and leeward sides of the roof.

Stability is provided by more than 400 shallow expanded base piles penetrating to a depth of 50 ft (15 m). In this particular application, a shaft was drilled to the required depth, filled with crushed, recycled concrete, which was then compacted to force it outward into a bulbous shape at the base of the shaft. Next, a reinforcing cage was inserted in the shaft, the hole was filled with concrete and finally the concrete raft slab was poured to form bases for the buttresses supporting the roof arches.

Wood Roof Structure

The design of the main roof structure resulted from the cooperative efforts of the architects, structural engineers and the City of Richmond.

Composite glulam and steel arches spring from the tops of the inclined concrete buttresses to free span the 330 ft (100 m) width of the arena. The composition of the arch cross section is unique, using two narrow 5 ft 3 in. (1.6 m) deep curved glulam beams joined together by a steel frame and at the bottom where the frame meets, the steel is exposed to create a ‘skate blade” element.

To achieve this, Structurlam Products Limited from Penticton, BC, had to camber the beams in the conventional manner and George Third & Sons, a steel fabricator from Burnaby, BC, had to warp them in the vertical plane. The geometry is maintained using a horizontal steel truss constructed by the steel fabricator that results in a very stable structure and a hollow space inside, which conceals electrical conduit, sprinkler system mains and the mechanical ducting used for heating and ventilation.

The resulting arch appears very compact, as the steel flanges assist in carrying the bending stresses resulting from any unbalanced snow loading.

Each of the 14 arches contains 4 pairs of glulam members each about 81 ft (24.7 m) in length. The centre sections have a 14 in. (350 mm) diameter hole drilled through them to accommodate mechanical services.

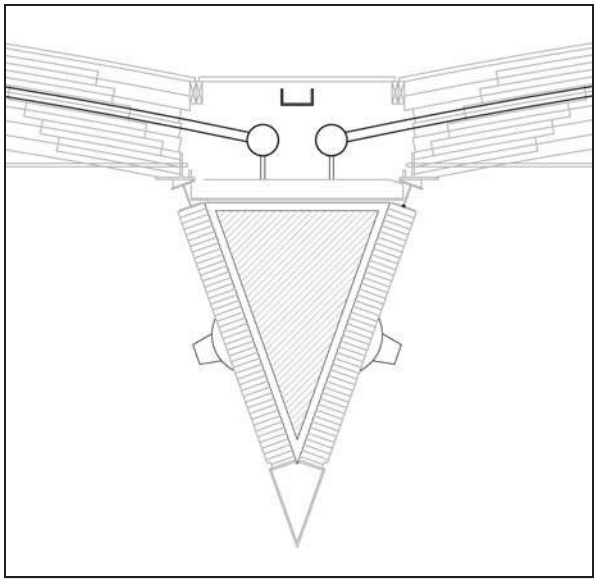
Spanning between these arches is a novel prefabricated WoodWave Structural Panel© system fabricated by StructureCraft Builders Inc. of Delta, BC. (Note 1)

The panel system employs conventional light frame lumber commonly used in wood frame construction throughout North America.

The WoodWave roof uses standard materials including one million board feet (2,400 M3) of SPF (Spruce, Pine, Fir) construction grade dimension


A composite twin glulam beam arch section cavity complete with services


WoodWave panel bolted in place to a pair of glulam arches


Glulam arch and roof integration section

lumber and 19,000 sheets of exterior grade Douglas fir plywood supplied from British Columbia mills.

The 26 inch (660 mm) deep zigzag section and semi-open pattern of the 2x4 dimension lumber elements not only creates efficient structure, but improves the acoustical characteristics of the enormous hall, while at the same time concealing building services. The main arches support a total of 450 WoodWave panels each comprising of three hollow triangular truss-like sections (Vees) made up of 2x4 (38x89 mm) SPF lumber and sheathed with two layers of plywood (5/8 in. and 1/2 in.), the top layer of which is later stitched on site to create a diaphragm.

From the outset of the project, there was a desire on the part of the client to explore the possibility of a wood roof structure, not only as a means to showcase the capabilities of the local wood industry, but also for its warm visual character and sustainable attributes.

Accordingly, throughout the design phase, two roof options were developed in tandem: the innovative, yet unproven, WoodWave system and a more conventional steel option. Both options used primary arches to free span the width of the main hall, infilling between them, on one hand, glulam purlins and steel corrugated decking and, on the other, the arched WoodWave roof panel. Ultimately, the WoodWave system was chosen because of the beneficial properties of wood, architectural beauty, and the system's innovative attributes.

WoodWave panel - tension rods; sprinkler, wood strand pattern and form

Spruce, Pine, Fir (SPF) 2x4 dimension lumber

WoodWave Structural Panel© System

Design Approach

There were few international precedents for wood roofs of this size and span. Those that exist are generally constructed using a system of wood purlins or trusses with steel decking. However significant obstacles would need to be overcome in trying to adapt the steel decking to the two-way curvature inherent in the roof shape, and significant expense would be incurred for gaining superior acoustical performance.

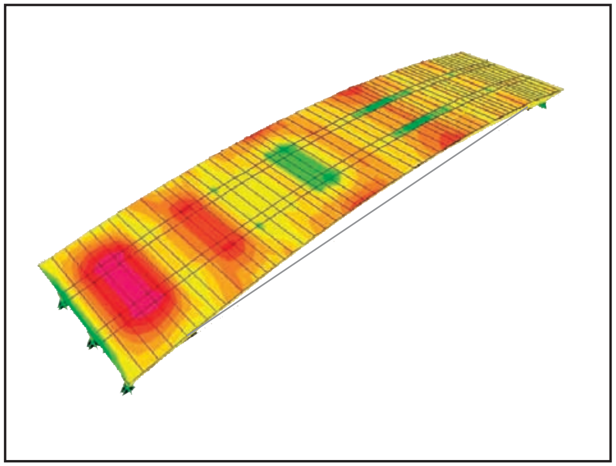
In all aspects, the WoodWave panel is an entirely new product embodying significant technological advancements. It transfers loads in an entirely new way, absorbs sound through regular acoustical openings between splices, and is constructed using simple dimensional lumber in a way that met fire safety requirements.

The uniqueness of the design becomes apparent when looking at the mechanics of the panel under gravity loading. As the dead and snow loads are applied to the upper surface of the panel, the forces are distributed by the plywood skin diagonally through the spliced lumber strands and into the supports located at both ends, where a steel tension rod is attached to each V-shaped arch (Vee) to hold the shape and minimize deflections.

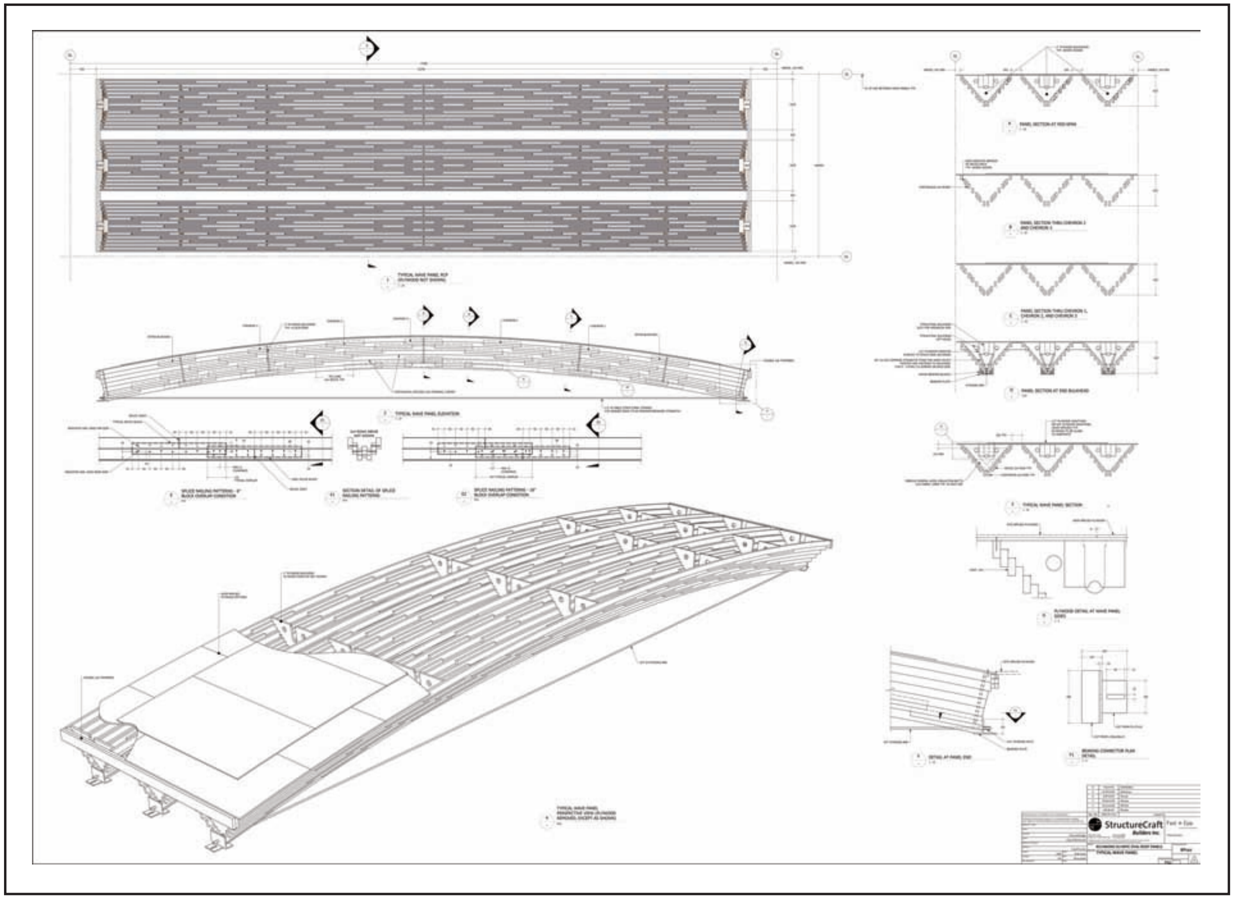
The idea for the WoodWave began in response to the desire for structural efficiency along with acoustical absorption, requiring a panel with some depth, hollow and with perforations. It also needed to be curved. A system of cascading 2x4's joined together with strategically located short 2x4 splice pieces (in some places mechanically reinforced) all curved about their strong axis, was developed and presented to the client, including a full scale mockup.

To fully understand the behavior of these splice members and how they would act together in the structure, extensive research was undertaken. Attempts were made to model with

sophisticated software the complexity of the structural forces at play within the panel. However, these could not be trusted without physical testing. Such testing was carried out in two ways. First, because it was determined that the connections between the 2x4's needed to be reinforced in high stress areas with screwed steel clip angles, numerous screw/angle combinations were push-tested in shear before full-scale panel testing procedures were finalized. Second, in all, 14 full-span tests measuring load and displacement were used to both optimize design, and prove different loading conditions. The test results were used to calibrate the computer models, which allowed more accurate predictions of panel behavior in the roof assembly.



Computer simulation image of differential loads applied to a panel



WoodWave panel - detailed drawing

Panel Vees - staged prior to assembly

Panel Vee with sprinkler line positioned, lined with fabric and plywood gussets drilled for services

Panel Vee with plywood gusset positioned and glued

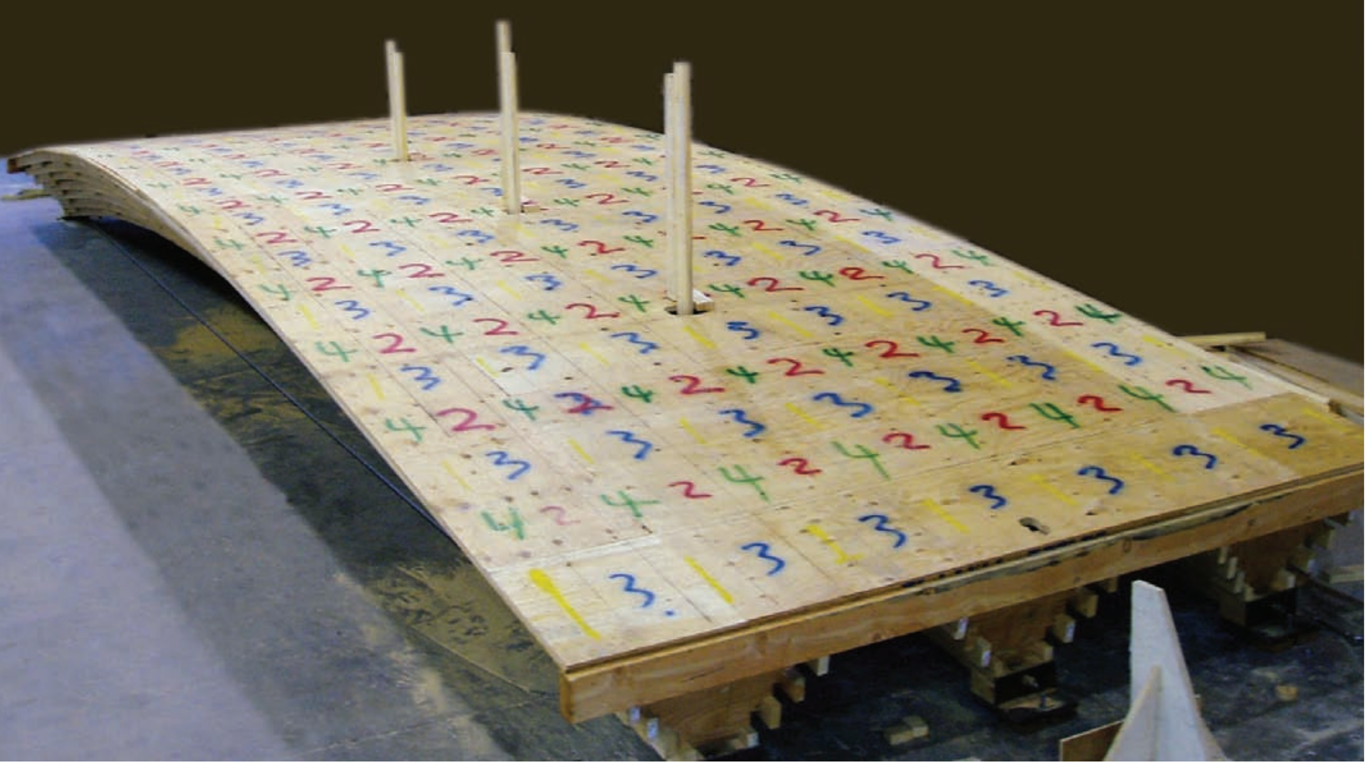
WoodWave Panel Construction

The WoodWave panels are designed to span between the primary glue laminated arches. The saw tooth profile of the soffit and the gentle undulation of the panels minimize reverberation of crowd noise, and amplified sound, while the shadow pattern created by the regular gaps in the panels creates a visual texture rare in a building of this scale.

Each panel comprises three hollow triangular composite sections of stitched together 2x4 (38 x 89 mm) material, typically 41 ft (12.5 m) long, 4 ft (1.2 m) wide and 26 in. (660 mm) deep laid side by side and connected together on top by a 1 1/8 in. (28 mm) dual skin plywood membrane. The two sloping faces of each V-shaped truss splay out from a central bottom chord of 2x4 (38 x 89 mm) members, and are built up from successive strands of the same material laid on edge.

Each strand is vertically offset from the one below it and fastened together for structural composite action. Only every second strand is continuous, with alternating strands comprising short lengths of lumber separated longitudinally by gaps of varying length. The voids thus created lighten the structure and enhance acoustic performance. Internal plywood gussets at intervals along the span give shape and lateral stability to the sections. The incremental longitudinal offset of each successive row of blocks stitched together creates a multipart action, turning short, weak 2x4's into a strong integral structural element.

During fabrication, which involves custom computer numerically controlled (CNC) production; each triangular section is pressed into a curve and tensioned with a steel rod, giving it a camber of 26 in. (660mm) from the ends to the crown. The result is a composite panel whose structural performance is complex, but in which each component performs at optimal efficiency. Factory fabrication of the panels included the installation of sprinkler lines, a black fabric liner and mineral wool insulation to meet fire codes and acoustical requirements.



Test panel prior to loading with differential loads

Panel Vee – metal straps and clips

WoodWave Panel Testing

Before the client and design team could approve the WoodWave panel system for use in the Richmond Olympic Oval roof, a number of technical questions had to be answered.

Full Scale Structural Testing

Significant analysis and testing was carried out on the WoodWave panels during the development and refinement of the design, including testing of metal reinforcing clips which are critical to the strength of the system and numerous full scale loading tests.

The unique shape of the 3D roof geometry required the panel design to fall into two snow loading zones: either 32 psf or 48 psf (1.5 or 2.25 kPa). The tests were performed following a specific load test procedure developed by the engineers. The Vees were tested in a pin/roller condition, where one end of the arch is held in a fixed position by a pin and the other end is allowed to move on a roller support. The loading, which consisted of concrete blocks, was applied in increments and the following deformations determined:

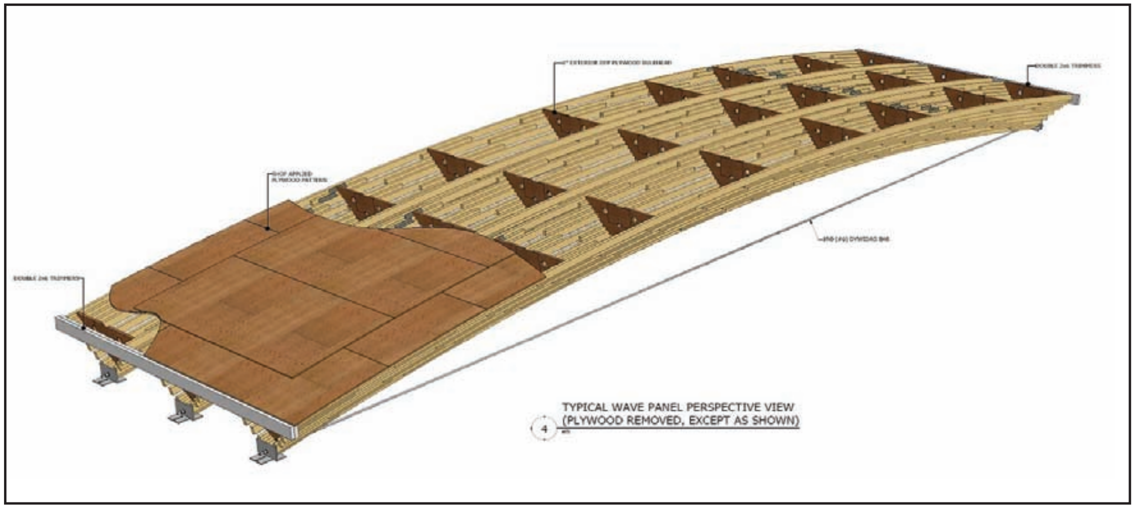
- The vertical deflection at mid-span and quarter span of the Vee
- The horizontal deflection on the roller side at the top and bottom of the Vee
- The relative displacement of the splice/strand/clip angle at the most critical location (splice nearest the support).

When the design load was reached, the panel was left for 24 hours in order to determine creep characteristics , then the panel was unloaded to allow the rebound to be measured. And finally the panel was reloaded until failure.

Panel Vee and concrete blocks prior to test loading

Placing a WoodWave panel

It was interesting to observe that, even after failure under very heavy loading, when the loading was removed, the panels recovered much of their original form, indicating significant resilience. In both loading cases the Vee performed in accordance with the design criteria in terms of strength, stiffness and behavior under full testing load. The test configuration being conservative, it is reasonable to expect even better performance of the WoodWave panels in their final state on the roof.



The main sports hall measures 660 feet x 330 feet (200 m x 100 m)

Acoustic Testing

Most stadium-type buildings with a rigid roof construction employ acoustic metal deck as the primary treatment to attenuate reverberant sound and achieve clarity and intelligibility for speech and music. For the purposes of establishing a performance target for the WoodWave panel system, an acoustic metal deck was considered to be a comparable product, as it also combines structural spanning capability with acoustic performance. Acoustic metal deck generally achieves an overall Noise Reduction Coefficient (NRC) rating of 0.85 to 0.95, so this was agreed to be an appropriate target to be used in the acoustic testing for the WoodWave panels.

The NRC provides an estimate of the sound absorptive property of a material and represents the average of the sound absorption coefficients measured at a range of audible frequencies: 250 Hz, 500 Hz, 1000 Hz, and 2000 Hz, as measured and calculated in accordance with the test method, ASTM C 423 *'Test Method for Sound Absorption and Sound Absorption Coefficients by the Reverberation Room Method'*, which requires rounding of the calculated values to the nearest 0.05.

As a result of small modifications and testing by acoustical consultants, the WoodWave panel evolved to meet design objectives.

Panel Vees loaded with fibrous insulation

Panel Vees – underside

Initial sound tests of the WoodWave panel were found to meet objective sound absorption requirements and offer other acoustic benefits, which have resulted in excellent natural acoustic performance and sound quality within the Richmond Olympic Oval.

The Wood Wave Panel's positive acoustical attributes were found to be:

- improved sound diffusion,
- low-pitched sound absorption performance,
- high pitched sound attenuation due to the large volume of the space, and
- beneficial high-pitched sound reflections.

The average sound absorption over the 250 Hz to 2000 Hz center frequencies was calculated to be 1.00. The key acoustic features that contribute to the high sound absorption performance of the WoodWave panel system are:

- The effective surface area of the ceiling is far greater than the roof plan (or Reflected Ceiling Plan) area. This results in greater sound absorption per unit of roof area versus a relatively flat product, such as a metal deck.
- The overall open area of the wood 'lattice' (approximately 24%) and the uniform distribution of the open sections results in an effective method for allowing sound to penetrate into the panels and be absorbed by the fibrous insulation material located inside the hollow triangular sections.
- The end bulkheads are sound absorptive, thereby exposing an additional sound absorbing finish directly to the space below.

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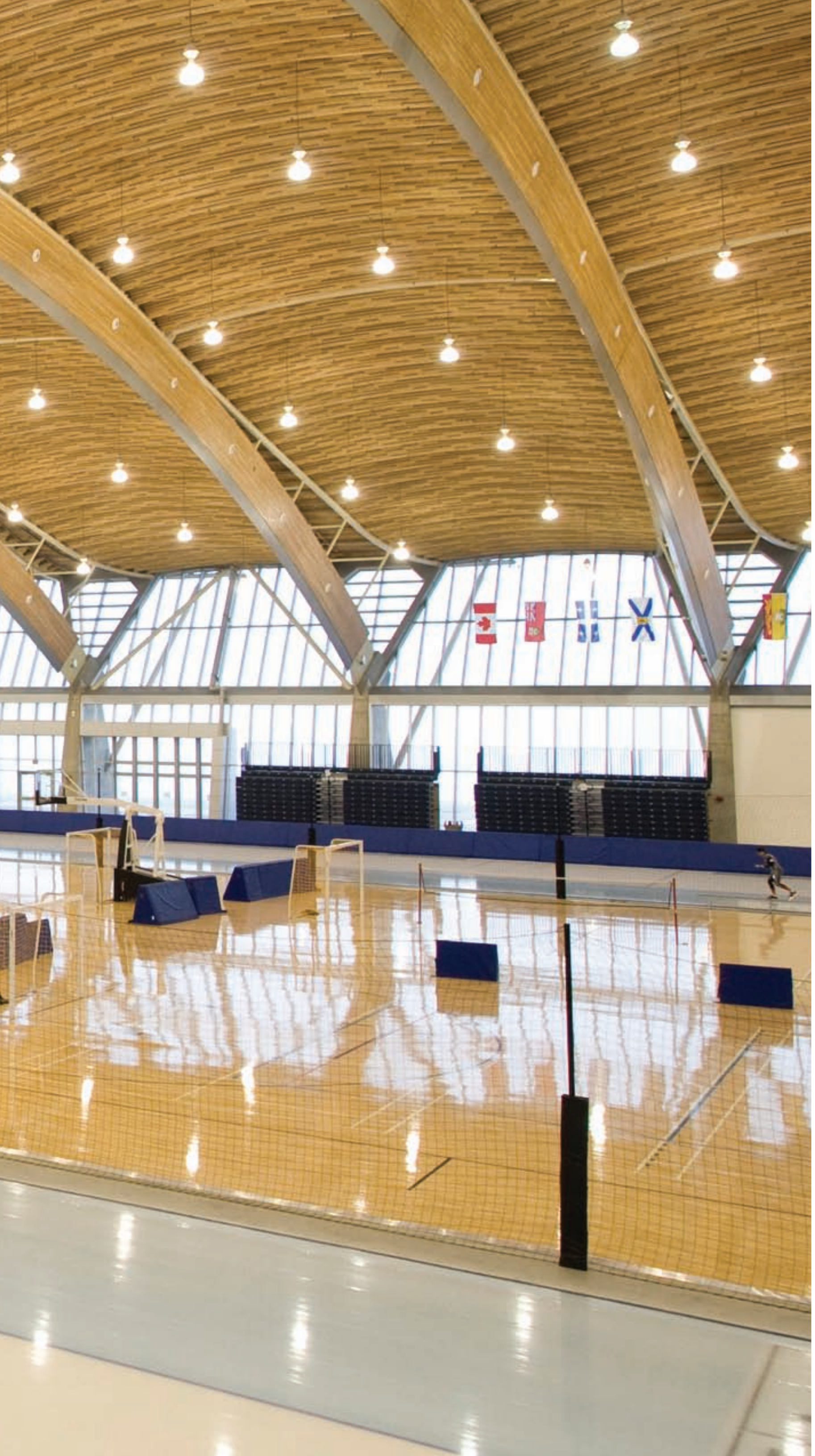
Richmond



The Richmond Olympic Oval

The Post Games Facility will accommodate

- two 80 ft x 160 ft (24.4 m x 48.8 m) ice rinks
- six basketball courts, and
- a 660 ft (200 m) running track

other areas include

- an indoor paddling centre
- movement studios
- athlete training facilities, and
- sport medicine center

Continued from page 17

In addition to the NRC measure of acoustic performance, the WoodWave panel system contributes to an enhanced acoustic environment by virtue of its performance in the following areas:

Sound diffusion: Diffusion of sound is an important acoustical quality within a space where large groups of people gather. A diffuse sound field is the condition when sound arrives at a listener from many directions at once, rather than from only one or a few directions. For two products with comparable sound absorption coefficients, the material offering greater sound diffusion generally will produce a better, more pleasing sound as heard by listeners. The WoodWave panel system diffuses mid- and high-pitched sound very effectively. While not specifically measured, the sound diffusion coefficient of the WoodWave panel appears to be significantly higher than that generally achieved with an acoustic metal deck.

Low-pitched Sound Absorption: The WoodWave panel is very effective at absorbing low-pitched sound. The low-pitched sound absorption performance is much greater than an acoustic metal deck. This beneficial acoustic attribute is not represented within the NRC metric, but sound absorption measurements indicate that significant low-pitched sound absorption occurs, even at 63 Hz and 80 Hz center frequencies. The benefit of this low-pitched sound absorption performance is that music, even non-performance background music or music to support athletic events will sound much better due to the lack of low-pitch sound buildup typical within arenas and other assembly spaces.

High-pitched Sound Absorption due to Air: The overall enclosed volume of the Richmond Olympic Oval is significant, at approximately 350,000 cubic meters, and the sheer volume of the space serves to help attenuate high-pitched sound. The larger a space, the further sound has to travel before it is reflected, and as the complexity of the reflection pattern increases, the intensity of the sound decreases due to distance. Sounds at 2000 Hz and above is absorbed by air due to the long distance the sound must travel from the original sound sources to the space boundaries and back to the listeners. This acoustic spatial phenomenon is complementary to the physical sound absorptive performance of the WoodWave panel, with its absorption of low-pitched sound being complemented by the absorption of high-pitched sound within air, which occurs naturally in such a large space.

The Richmond Olympic Oval is a space for assembly and, as such, serves as the host facility for live events. The range of characteristics associated with the design of spaces hosting live events could be described as either tangible or intangible. Tangibles include proper sightlines and good speech clarity; intangibles are special qualities of excitement that are felt emotionally and require your physical presence at the event, versus viewing via a broadcast. Proper acoustic design can accommodate the live event. Excellent acoustic design goes beyond the tangible requirements and results in an environment that enhances subtle aspects of attending a live event, thereby making the event special and memorable.

The lattice design of the WoodWave panel will offer acoustic qualities that are not readily apparent from the NRC metric. The moderate high-pitched sound reflections, which will occur off the wood lattice surfaces, combined with the excellent sound diffusion qualities of the surface will tend to enhance applause, laughter, and other audience sounds, thereby adding a level of excitement that would be lost with the use of other materials.

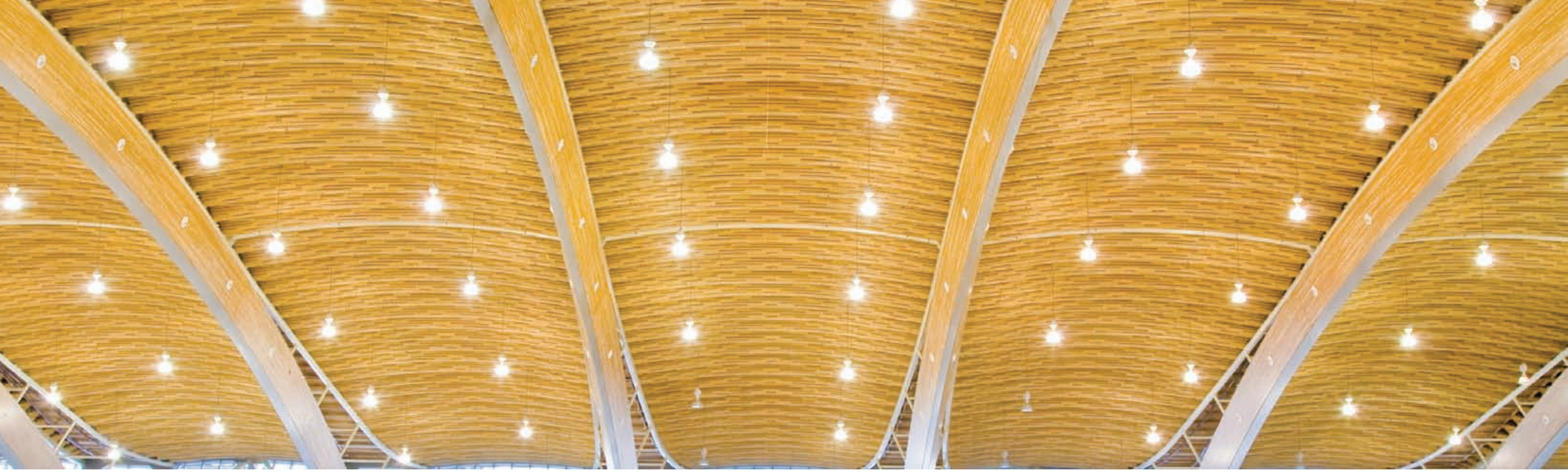
Final acoustic test results are pending, however initial tests have shown great acoustic potential for the complete system.

Building Code Analysis

The design process for the Richmond Olympic Oval was begun under the 1998 version of the British Columbia Building Code (BCBC), but the approach to fire protection engineering anticipated the broader opportunities for objective-based design that were known to be part of the incoming 2005 edition of the BCBC. Analyses by fire code consultants also took into consideration the planned change of use of the building, from speed skating arena to multipurpose sports, recreation and cultural venue - and assumptions were therefore based on the stricter requirements of its post-Games configuration and multi-function assembly use.

According to the BCBC, the expected use of the post-Games structure is classified as a Group A, Division 3 Assembly occupancy – a classification that covers the possibility of the building being used as a venue for exhibitions, concerts and other similar events. With a 2-storey plus mezzanine building height configuration, the building's roof assembly and its supports were permitted to be of 'heavy timber construction', and there were no limits to the building area, so long as the building was protected by automatic sprinklers. This set of basic code-provisions provided the base line for the evaluation of any wood option considered for the building.

Note: The American commercial and institutional designs, technology and regulatory requirements are very similar to Canada's. When it comes to addressing wood design and construction, there are several commonalities between the US and Canadian codes. Such commonalities could possibly permit the use of the WoodWave panel concept in the US and in overseas market.



Under the high-level objective of 'Safety', the 'Fire Safety' objective of the BCBC concerns itself with the fire performance of a building as it relates to limiting the probability of unacceptable risk of injury, which includes sub-objectives related to fires, explosions, structural integrity, fire safety systems and movement of persons. The BCBC also contains requirements relevant to the objective, 'Fire Protection of the Building', which includes sub-objectives related to fire, explosions, structural integrity and fire safety systems.

For large buildings, it is now common practice for fire growth and smoke behaviour modelling to be carried out, even in cases where the building meets the provisions of the building code outright. In this regard, the Richmond Olympic Oval had two important considerations in its favour: the roof elements, even at the lowest point, would be a considerable distance from any likely source of fire (the main glulam arches spring from 10 ft (3 m) high concrete stanchions); and the buildings large volume would delay any build up of smoke in the occupied areas of the structure.

The code consultant carries out its fire and smoke modelling using Fire Dynamic Simulation (FDS) software, which uses the principles of fluid dynamics to predict the behaviour of fires of different types within a virtual model of the building. This 3-D model is constructed to accurately represent the volumetric configuration of the subject building, with each building element given attributes corresponding to its thickness and construction type.

Based on their own experience and accumulated data from real fires, the code consultant engineers chose fires of different sizes with different points of origin in the building according to the risks associated with the building type in question. This type of analysis enables the engineers to compare the effects of different building configurations, partitioning systems, automatic sprinkler configurations, surface materials and construction types.

The BCBC defines 'heavy timber construction' as:

> *"a type of combustible construction in which a degree of fire safety is attained by placing limitations on the sizes of wood structural members and on the thickness and composition of wood floors and roofs and by the avoidance of concealed spaces under floors and roofs."*

In the case of heavy timber roof trusses and roof arches, generally, they are required to be composed of members having a minimum width and depth of 3 1/2 in. (89 mm) and 5 1/2 in. (140 mm), respectively. In the case of spaced members used in built-up trusses or arches, the width (thickness) of individual members is allowed to be reduced to 2 1/2 in. (64 mm) where the space(s) between members are blocked or the members protected on their underside by a

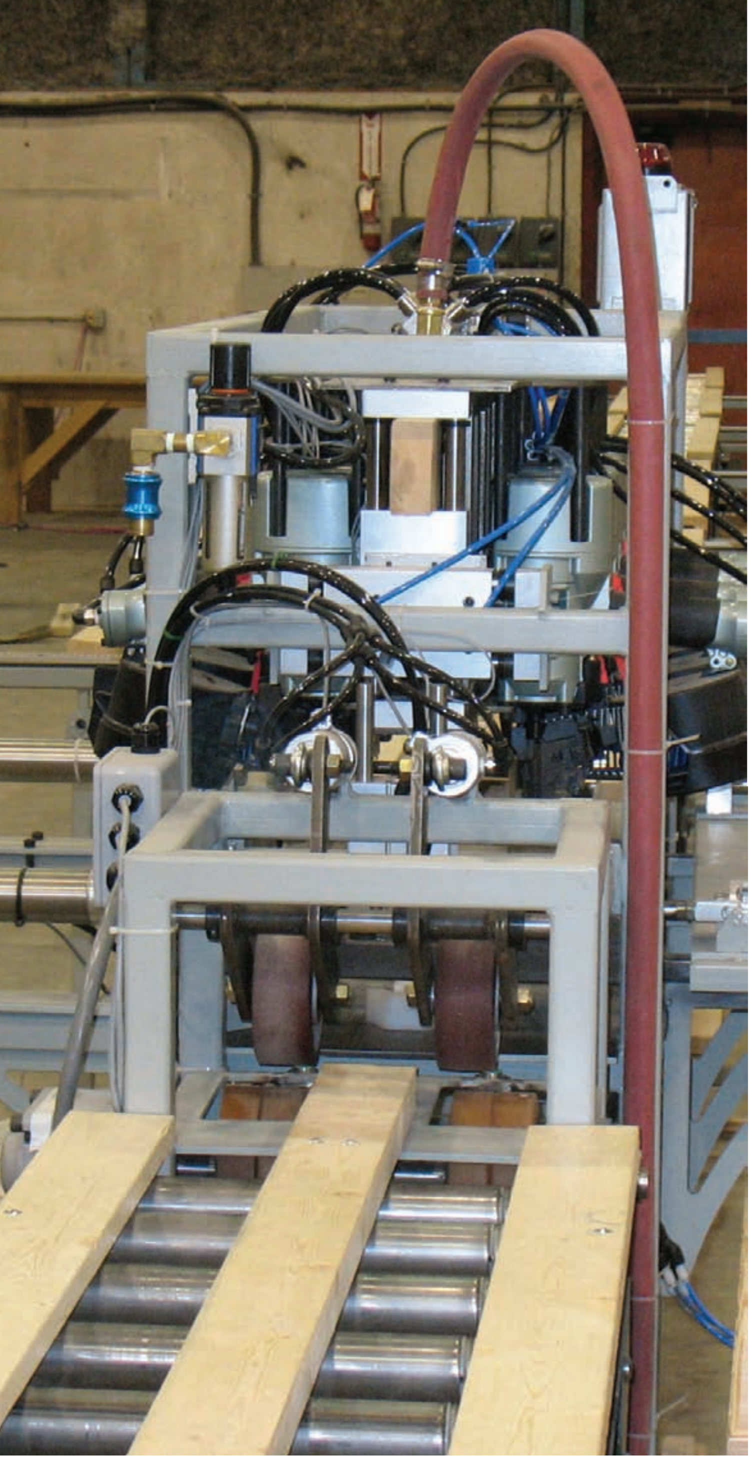
wood cover plate at least 1 1/2 in.(39 mm) thick. If the roof is protected by automatic sprinklers, then the reduced width is allowed to be used without the blocking or wood cover.

In the case of the roof of the Richmond Olympic Oval, the analysis was based on the assumption that a roof of conventional heavy timber construction comprising beams, purlins and solid wood decking was used. As not all of the elements of the WoodWave panel system conform to the prescriptive minimum size requirements of heavy timber construction, it was necessary to create a physical model that incorporated the panel's smaller framing and curved geometry, and to compare its fire performance with that of a model constructed with conventional heavy timber elements.

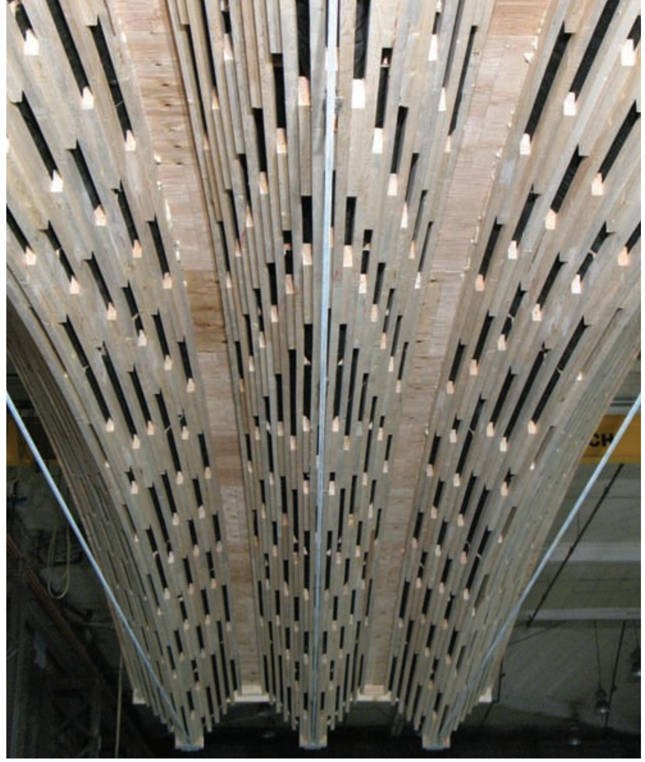
The highest fire hazard scenario for the Richmond Olympic Oval, a 50 megawatt fire, was modelled – roughly equivalent to a portable building being set alight in the main exhibition hall. The modelling results confirmed that the fire performance of the WoodWave option would be similar to that of a conventional heavy timber roof structure over the prescribed test period.

Further fire modelling enabled the fire protection engineers to fine tune the locations of the sprinklers for maximum efficacy, ensuring that the downstands (lowest point) of the glulam arches, and the curved soffits of the panels themselves, did not interfere with the distribution of water from the automatic sprinklers.

For economy and ease of installation, the sprinkler branch lines were installed in each WoodWave panel in the prefabrication shop and then simply connected to the main sprinkler risers or supply mains on site when the roof panels were installed.



Strand fabrication machine



Panel Vees – strand orientation and spacing

Panel Vee – inverted plywood gusset and shaping template

Fabrication and Erection

WoodWave Panel Fabrication

The manufacturing process was also studied in great detail. It was clear from the beginning that an automated press would be required to process the near infinite number of unique 2x4 pieces required by the design. Due to the project time constraints, it was decided to create two custom machines, together capable of producing 4 panels, or 12 Vees, per day.

The "strand-builder" machine produces long built-up "strands" of lumber. Each Vee requires thirteen 2 x 4 (38 x 89) strands, 42 ft (12.8 m) in length, spliced together with offset splice blocks. The machine is fed dimensional lumber and blocks at one end, cuts and connects them into the correct length strands, nailing on splices for connecting to the adjacent strand, and ensuring that all connections and splices are in the correct place for its particular location in the Vee. The second custom built machine presses a cassette of strands into an inverted Vee shape for fastening together and attaching the bottom steel tension rod. When pressure is released, the Vees hold their new curvilinear shape.

Top down roof view of an arch prior to sheathing;
sprinkler system main lines, electrical conduits, ventilation system ducting, strut connection detail,
WoodWave panel to arch connection detail, glulam arch steel forming and bracing elements

Sprinkler system connections and pattern

Finally, adjacent Vees are grouped, aligned and tied together with lumber trimmers and a top skin of plywood into a WoodWave Panel consisting of 2 or 3 Vees. The panels are then stored until needed at the site.

The whole process was further complicated by the variety of panels required. In all, 20 different panel forms, with up to 3 variations each, were fabricated.

Integration of Services

In order to accommodate the sprinkler system, shop drawings were coordinated with the mechanical contractor to plan the locations and installation of the branch pipes and automatic sprinklers, e.g. slotting the wood bulkheads to suit the pipe. The mechanical subcontractor prefabricated his piping complete with automatic sprinklers, and the pipes were installed during the panel assembly process.

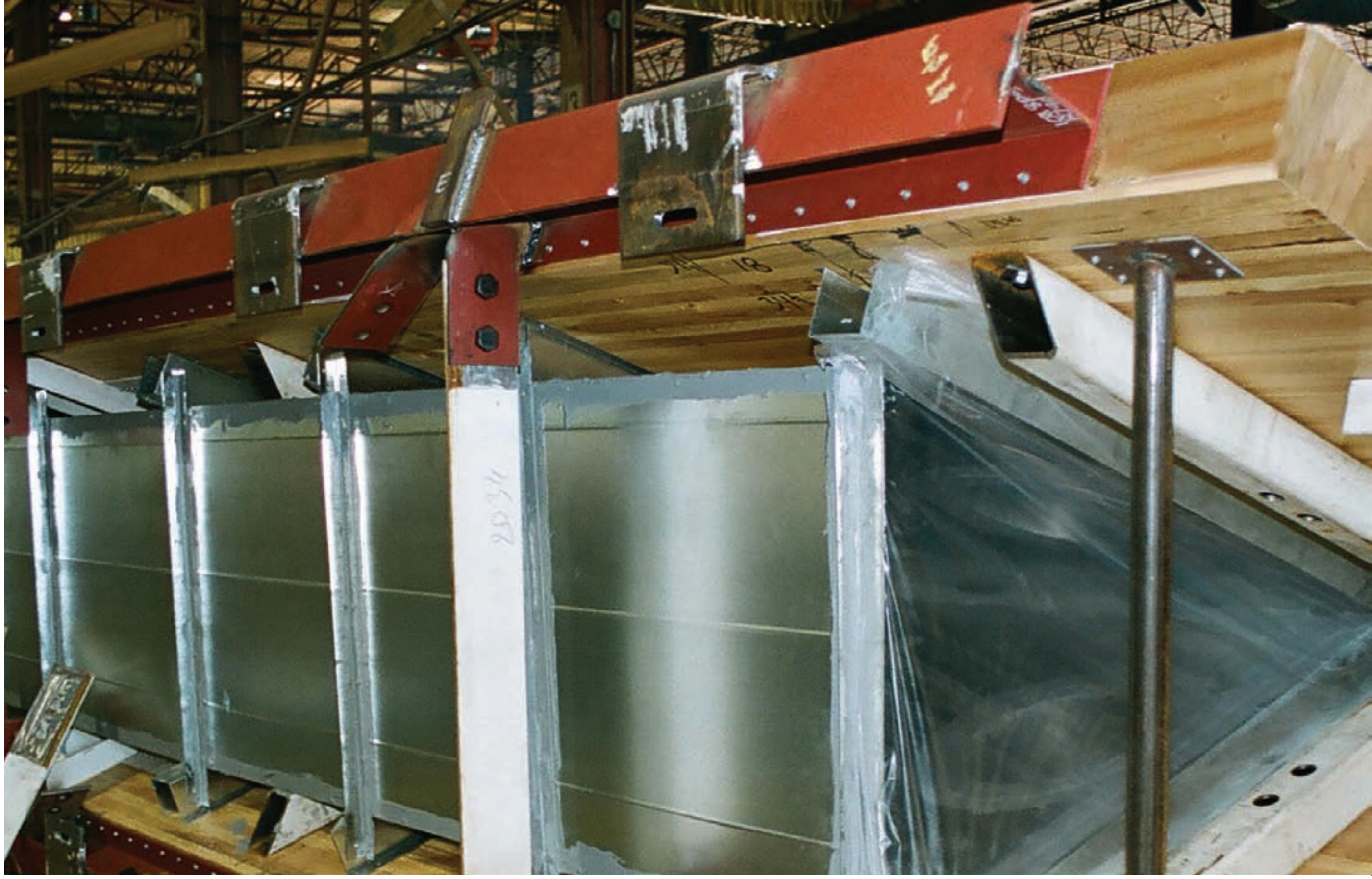
The final appearance of the roof is virtually free of the visual clutter of mechanical and electrical services. Main sprinkler pipes, ventilation ductwork and electrical conduit rise to roof level in the triangular void between the angled glulam arches. From here, the sprinkler pipes connect into the system pre-installed in the WoodWave panels. Automatic sprinklers are almost invisible, being positioned in the gaps left between the wood members in the non-continuous laminations.

Erection of the Roof Structure

At the steel fabrication plant, located in Burnaby, BC, the 112 sections of glulam beams were set into the steel truss components to create the Vee form of the twin arch prior to shipping the assemblies to site. Each Vee arch is comprised of 8 individual glulam beam sections. Erection proceeded with the end sections of the first twin

WoodWave panel connection plate, tension rod, nut and wood component detail

Staging of glulam arch sections on the site slab prior to the final connection of the two center span sections



Glulam Arch section - fabrication details

arch lifted into place and connected to the buttresses while the free end was supported on scaffolding. Once aligned and stabilized, the two mid sections were linked together with bolts, welds and epoxy. They were then lifted into place and final connections were made. Drag struts and temporary bracing secured the arches to each other until WoodWave panels were installed.

Installation of the WoodWave roof panels followed the erection of successive pairs of main twin arches and temporary arch bracing. While the first pair of arches was erected and braced, ground personnel ensured the roof panels were properly secured for lifting. A second team, in man lifts, waited to position each panel and bolt it into place at the six connection points. After a number of bays were completed, a third group completed the panel installation by adding and stitching the continuous layer of plywood that creates the diaphragm for the roof.





Exterior Glulam Posts

Where the roof extends beyond the building on the north and south sides, glulam posts are used to support the overhangs. These posts are Computer Numeric Controlled (CNC) milled Yellow Cedar and are oval in cross section, and tapered at their ends, and connect to concrete buttresses using an elegant connection. The 28 posts on the north side are milled from rectangular stock measuring 13 1/4 in. by 18 in (335 x 458 mm) with a finished length of 37 ft 9 in. (11.5 m), while the 6 posts on the south side that support the main entrance canopies are milled from rectangular stock measuring 14 in. by 22 1/2 in. (350 x 570 mm) with a finished length of 27 ft 10 in. (8.5 m).

Building Envelope Design

The roof of the Richmond Olympic Oval is constructed on the 'warm roof' principle. The insulation is placed above the structural plywood deck and beneath the waterproof layer, reducing the risk of condensation.

Above the WoodWave panels are two layers of rigid insulation totaling 4 in. (100 mm) in thickness with an R-value of 25. They are held in place with Z-girts, and covered with a PVC membrane finished in a light colour to reflect heat and minimize thermal stress on the roofing material.

The exterior walls include large areas of glazing which, in some places, extend up to the underside of the WoodWave panels. On the north plaza, the glazing extends upward to meet a horizontal drag strut in the form of a steel tube which connects together the steel columns between the main arches. The drag strut is situated directly below, and runs parallel to the junction between two consecutive WoodWave panels.

A plywood skin extends vertically upward to close off the gap between the horizontal strut and the underside of the panels.

Environmental Aspects, Design Details and Sustainability

General

The size of the building, the site constraints, and above all the requirements to precisely maintain indoor temperature and humidity to provide optimal conditions for speed skating limited the range of possibilities for solar orientation, and made the design of the envelope, especially the large roof, particularly critical. The client not only wanted to create the world's finest speed skating facility, but also wanted the building to be designed for an extended service life. This translated into a concern for durability and for minimizing the cost of maintenance over the life of the building.

The final LEED rating of the building will not be known until the summer of 2009 – although the architects believe it will comfortably achieve the client's goal of LEED Silver certification.

The building is also expected to achieve a rating of a minimum of four (4) out of a possible five (5) Green Globes. The Green Globes system is a building environmental design and management tool that delivers an online assessment protocol, rating system and guidance for green building design, operation and management. The Green Globes rating system provides market recognition of a building's environmental attributes through third-party verification.

Ventilation system main duct fabricated within the glulam arches cavity

Ventilation system directional nozzles embedded in the glulam arches

Building Operation - Systems

The mechanical team developed environmental systems that sought to maximize energy reutilization. These strategies include heat recovery from the ventilation and ice-making systems. The use of a water-based system permits waste heat to be transferred to domestic hot water preheating, and excess ice plant capacity can be diverted to building cooling.

Ventilation air is carried overhead in ducts, which are concealed within the main structural arches, and distributed with directional and adjustable nozzles that will support future reconfiguration of the main space. As a result, no ventilation ducting will be visible in the dramatic ceiling. The air currents that are created by these high velocity overhead air vents will enable different conditions of temperature and humidity to be maintained in immediately adjacent areas of the building, depending on the specific needs of the activity in question.



Wood and Sustainability

Because wood requires little energy to process, and has no toxic by-products, solid sawn lumber is by far the least energy intensive and least polluting of the major construction materials.

The mass of wood in this building sequesters significant volumes of CO2; while at the same time having a positive impact on overall emissions; had alternative structural materials been selected.

Virtually all of the lumber used in the WoodWave panels and roof framing was harvested from certified forests in the interior of British Columbia that have been affected by the Mountain Pine Beetle (MPB).

The BC Ministry of Forests and Range estimates that as of 2008, the cumulative area of provincial Crown forest affected was about 32.5 million acres (13.5 million hectares). Research has indicated that the affected trees can stand for at least five years – and perhaps as many as 15 years – without significant loss of structural properties. Nonetheless, allowable annual harvest rates have been raised, and new markets and applications for MPB pine are being actively sought to maximize utilization of these trees and minimize the negative environmental implications of loss through decay or fire.

To this end, the Richmond Olympic Oval showcases MPB material. By specifying wood, the Oval's roof demonstrates that this solution introduces a new, innovative application in construction. Rather than being underutilized, the affected trees can be turned into buildings and other durable products, locking in their carbon indefinitely. Most of the lumber and all of the structural panels were produced from Canadian Standards Association (CSA) or Sustainable Forestry Initiative (SFI) certified forests in British Columbia. As such, they can be considered as locally sourced under third party green building rating systems such as Green Globes and LEED.

Canada has 40% of the world's certified forests, far more than any other country. Canada is recognized as a global leader in forest management with more than 95% of its' harvestable forests independently certified by either; CSA, SFI or the Forest Stewardship Council (FSC) systems.

Coating Specifications

WoodWave Panels

Interior:
None

Exterior:
CBR Products: Broda Clarity Wood – Stone Acrylic Finish (WS)
Applied over;
CBR Products: Broda Clarity Masonry – Concrete Acrylic Sealer (MC)
Applied over;
PeneTreat Wood preservative

Glulam Beams

Interior:
Target - EMTECH® U9300: Ext. polycarbonate water based urethane top coat

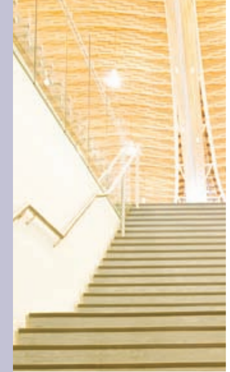
Yellow Cedar Posts

Exterior:
Target - EMTECH® U9300: Exterior polycarbonate water based urethane top coat
Applied over;
Target - EMTECH® 8800 Universal Waterborne Sealer

Architectural Millwork

A number of wood based cabinets, counters, displays and a variety of screening panels have been created through the business and special usage areas of the facility. Wood doors, moldings and trims have also been used to accent the building.

Some of the wood incorporated into the finishing details originated from the trees harvested on the site prior to construction.

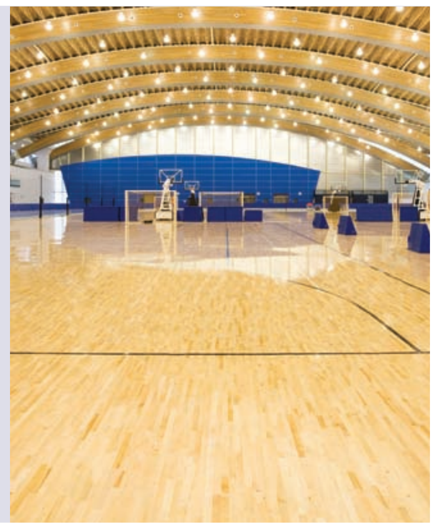


Gymnasium Floor

Surface:
Robbins Bio Channel Classic 31,000 square feet of Maple lumber – 25/32 in. x 1 1/2 in. wide, 2nd and better XL Maple MFMA-FJ

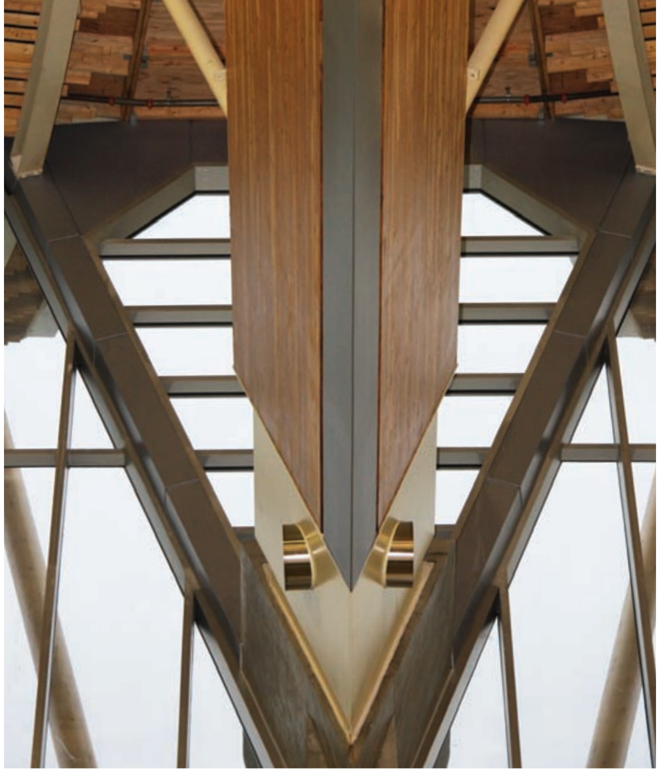
Substrate includes:
997 sheets of 4 ft x 8 ft x 3/4 in. plywood - Exterior grade; Standard D Fir CSP

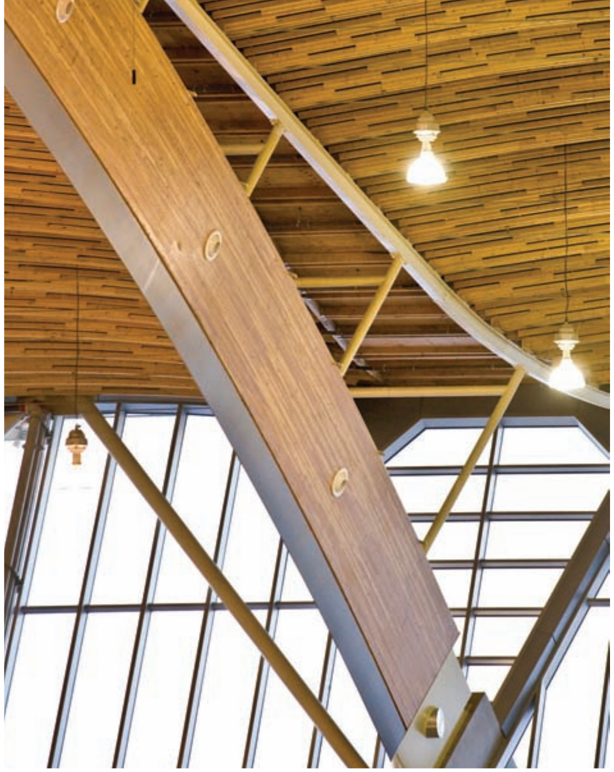
System includes:
Low VOC sealer and finish

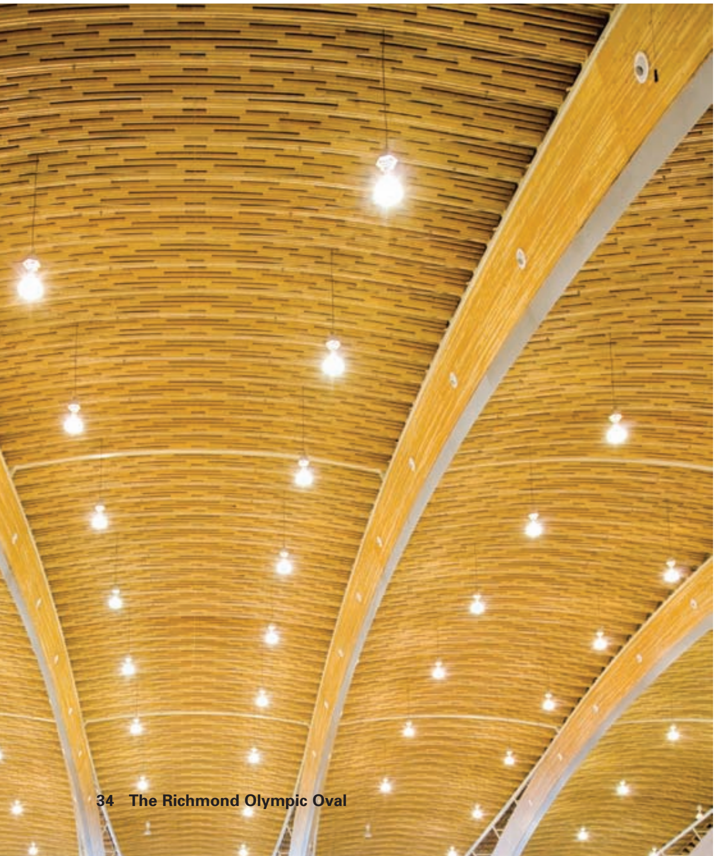


Landscaping

Cuttings were taken from trees that had to be felled on the site to accommodate the project. After being propagated in a City of Richmond nursery, they have been planted along the site's picturesque new Samuel Brighouse Heritage Boulevard; a street named after a circa 1870 pioneer who previously owned the site and who had planted the original trees.







Conclusion

The project vision for the City of Richmond and its design team was to create *"a unique destination that serves as a dynamic international gathering place and an outstanding centre of excellence for sports and wellness at the heart of an exciting urban waterfront".*

The Richmond Olympic Oval has accomplished this, and much, much more.

Through creative design, engineering and the innovative use of regionally available wood products, this unique facility delivers the city an iconic building that connects the culture and history of the site to the economic reality of British Columbia. The extensive structural use of wood, including MPB, in the unique WoodWave solution for the building's roof system clearly captures the design poetic of 'Flight-Flow-Fusion'.

The flexible, safe, innovative and integrated design of the WoodWave panels, working in harmony with other building materials and systems, is a testament to the attributes of wood.

British Columbia's wood design and fabrication industries will be very proud of their accomplishments at the Oval for years to come. The Richmond Olympic Oval is truly a transformative building.

Project Credits

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Project Manager:						
MHPM Project Managers Inc.	2609 Granville Street, Suite 310	Vancouver	BC	V6H 3H3	604 714 0988	www.mhpm.com
Construction Manager:						
Dominion Fairmile Construction Company Inc.	Suite 130 - 2985 Virtual Way	Vancouver	BC	V5M 4X7	604 631 1000	www.dominionco.com
Acknowledgement for technical information:						
StructureCraft Builders Inc.	8279 River Way	Delta	BC	V4G 1G9	604 940 8889	www.structurecraft.com
Structurlam Products Ltd.	2176 Government St.	Penticton	BC	V2A 8B5	250 492 8912	www.structurlam.com
George Third & Sons Ltd. (Corporate Office)	78 Fawcett Road	Coquitlam	BC	V3K 6V5	604 639 8300	www.geothird.com

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