

Green Concrete **Goes for the Gold at** **2010 Winter Olympics**

Fly ash use helps reach sustainability goals

BY R. DOUG HOOTON AND ANNE WEIR

From the outset, planners for Vancouver's 2010 Olympic and Paralympic Winter Games focused on maximizing the sustainability of its many developments. Fly ash concrete helped to meet the sustainability and technical performance criteria demanded of both Olympic and British Columbia infrastructure, including concrete used in the Vancouver Olympic Village, the Richmond Olympic Oval, the Vancouver International Broadcast Centre, the Whistler Sliding Centre, and the Golden Ears Bridge.

Canada's *National Master Specification* notes that fly ash and other supplementary cementitious materials "should be considered as partial replacement of cement in concrete in order to reduce GHG [greenhouse gas] emissions, increase the conservation of raw materials, energy, resource recovery and reduce waste."¹ But it's the technical performance fly ash brings to concrete that has made its use standard in the Vancouver area for years, motivating owners and specifiers to opt for the best of both worlds, improving both the life-cycle performance and sustainability of their projects.

While many of the venues are in the Vancouver metropolitan area, the alpine events are located at Whistler, north of Vancouver, up the 100 km (60 mile) Sea-to-Sky Highway. This highway, including 48 bridge structures, had to be rebuilt and widened for the Olympics. In addition, the Skytrain rapid transit system was expanded to link Vancouver International Airport with the downtown core.



Vancouver Olympic Village (Photo courtesy of Lafarge)

VANCOUVER OLYMPIC VILLAGE

Situated on a former industrial area, the Vancouver Olympic Village combines sustainable building and land reclamation practices. The Village comprises eight separate buildings within 7 ha (17.5 acres). Seven buildings will provide 1100 residential units to house up to 2800 athletes and officials. The residences are certified LEED Gold, while the eighth Community Centre building is certified LEED Platinum. Continued development of Southeast False Creek through 2020 will culminate in 5000 residential units, community and interfaith spiritual centers, an elementary school, childcare facilities, and 10 ha (24.7 acres) of park.

Structural engineering firm Glotman Simpson developed performance specifications for the complex, designed to meet a 50-year life span. Approximately 95,000 m³ (125,000 yd³) of concrete was used, with specified strengths ranging from 25 MPa (3600 psi) for the footings and walls to 50 MPa (7250 psi) for the support columns and shear walls. To meet sustainability requirements, a low-cement, high fly ash concrete with high early-age strengths was used. Maximizing recycled content, including using 35 to 50% fly ash replacement of cement in the concrete, was a key strategy to achieve LEED certification. Exposed elements such as basement walls and exterior columns comprise air-entrained concrete, and concrete used in parking areas meets CSA A23.1 exposure Class C-1 requirements for chloride exposure—a minimum of 35 MPa (5000 psi), air entrained, a maximum water-cementitious material ratio (*w/cm*) of 0.40, and a maximum of 1500 coulombs (ASTM C1202) at 56 days.

RICHMOND OLYMPIC OVAL

Immediately south of Vancouver, the Richmond Olympic Oval was conceived as a world-class destination for skating competitions. The city of Richmond targeted LEED Silver certification for the 33,750 m² (363,150 ft²) Oval, a unique goal for a facility of its type. The building, designed to seat up to 8000 spectators, required 335,280 m³ (438,550 yd³) of concrete.

Built with a 100-year minimum design life, compressive strengths of 25 to 50 MPa (3600 to 7250 psi) were specified for various concrete elements. Fly ash was used at replacement levels of 24 to 31% to achieve durability goals, increase recycled content, and reduce material costs. All concrete had to meet the CSA A23.1 optional shrinkage limit of 0.04% at 28 days.

Thirteen massive buttresses along the south and north walls, symbolizing Canada's 13 provinces and territories, redirect rainwater for reuse in venue toilets and irrigation.



Exterior view of the Richmond Olympic Oval (Photo courtesy of Rempel Bros. Concrete Ltd.)

Salmon motifs, sculpted by First Nations (*Musqueam*) artist Susan Point, adorn runnels inset into each buttress, creating the illusion during rainfalls that the fish are swimming upriver. Self-consolidating concrete—with a strength of 50 MPa (7250 psi) and approximately 30% fly ash—was placed against carved yellow cedar formliners to achieve the smooth surfaces necessary to create the desired effect. Mock-ups of buttress and arch exterior walls were constructed to establish acceptable surface finish criteria. From these mock-ups, mixture proportions were fine tuned and concrete placing and consolidation procedures were established.

There were tight construction tolerances for the 35 MPa (5000 psi) slabs for the ice rink, and the 20% fly ash concrete also had to meet a 0.04% 28-day drying shrinkage limit. Flatness and levelness criteria were quite stringent to maintain a constant ice thickness; and tolerances on the refrigeration pipe cover thickness were quite small to minimize variations in temperature of the concrete surface, which would affect the temperature and hardness of the ice surface.

The Institution of Structural Engineers honored the Richmond Olympic Oval with its top award for sports or leisure structures in October 2009.



Buttresses supporting wood struts at the Oval

Architectural detail of runnels inset in the Oval's buttresses



(Photos courtesy of Rempel Bros. Concrete Ltd.)



Vancouver Convention Centre, which serves as the International Broadcast Centre for the 2010 Olympic and Paralympic Winter Games (Photo courtesy of Vancouver Convention Centre)

VANCOUVER INTERNATIONAL BROADCAST CENTRE

The Vancouver Convention Centre expansion will be used as the International Broadcast Centre for the Olympics. The structure features a 2.4-ha (5.9 acre) living green roof and a restored marine habitat beneath its extension over the foreshore of Vancouver Harbour. The substructure within the tidal and splash zones was designed for 100-year service life using CSA A23.1 Class C-XL concrete requirements (a minimum of 50 MPa [7250 psi] at 56 days, a maximum w/cm of 0.37, air entrained, and less than 1000 coulombs at 56 days).

The design includes precast “fish skirts” that consist of structures resembling a staircase in the lower tidal zone. Fish prefer to lurk around these skirts along the perimeter of the structure, rather than swim into the dark zone under the structure. The approximately 27,900 m² (300,000 ft²) slab for the main exhibition hall was cast using concrete with an integral hardener made from slag from the Teck Cominco lead/zinc smelter in Trail, BC. Processed to a fine powder, the slag was added to the concrete at 40 kg/m³ (67 lb/yd³). After testing this material, it was concluded that a reasonable hardness could be achieved for this application without the potential problems and risks of using a shake-on hardener.

WHISTLER SLIDING CENTRE

Sustainable practice was considered in every aspect of the Whistler Sliding Centre, from its compact design to the recycling and restoration of original flora to the site. Built on the southeast slope of Blackcomb Mountain, the Sliding Centre is a fascinating structure. Construction of the track’s 1450 m (4757 ft) long, U-shaped structure over rugged, downhill terrain presented an array of challenges, including track wall heights that range from 600 mm (24 in.) on straightaways to nearly 3 m (9.8 ft) on its 16 curves and track floors and walls that include refrigeration pipes



Aerial view of the concrete track at the Whistler Sliding Centre (Photo courtesy of the Vancouver Organizing Committee for the 2010 Olympic and Paralympic Winter Games)



Closeup of the concrete sliding track (Photo courtesy of Stantec)

with two layers of reinforcing steel at each face, all encased within a 150 mm (6 in.) thick concrete shell.

The materials selection, design, spacing, and location of reinforcement were crucial to facilitating concrete placement and meeting stringent International Olympic Committee requirements for concrete density, cover, and finish. Shotcrete, using 15% fly ash, was used for the specialized placement, long-term performance, and improved sustainability required for the track structure.

Prolonged workability was critical to the successful application of the thin shotcrete layer over refrigerant pipes. The increased compressive strength and reduced permeability typical of fly ash concrete provides better corrosion protection for reinforcing steel and refrigerant pipes. Averaging 51 MPa (7400 psi) at 28 days, the exceptionally smooth concrete surface exceeded its 28-day design strength of 35 MPa (5000 psi).

Golden Ears Bridge deck construction over the Fraser River, March 2008



Golden Ears Bridge as seen from the south approach, October 2009
(Photos courtesy of LVM-JEGEL)



GOLDEN EARS BRIDGE

While not directly related to the 2010 Olympic and Paralympic Winter Games, the Golden Ears Bridge opened in June 2009 to improve traffic flow around Vancouver in time for the Olympics. This 1 km (0.6 mile) cable-stayed bridge carries six lanes of traffic over the Fraser River. Part of the Trans-Canada Trail, the Golden Ears Bridge includes 2 m (6.6 ft) wide cycling and pedestrian pathways on either side of vehicle traffic, protected by concrete barriers. A 50 mm (2 in.) deck overlay (over precast panels) on the main bridge used 25% fly ash and 4% silica

fume with a 0.37 w/cm ratio (meeting CSA A23.1 Class C-XL requirements). Values of less than 1000 coulombs were attained by 56 days, and there were no problems with plastic shrinkage cracking. In total, 157,000 m³ (205,350 yd³) of concrete was used on the project.

The project, which began in the summer of 2006, included construction of 17 bridges, ramps, and viaducts. Wherever feasible, bridge components were produced and preassembled off site, then floated into the area by barges on the Fraser River, shortening the construction schedule and reducing disruption to wildlife and recreational and commercial users of the river.

Acknowledgments

The authors sincerely thank the following contributors: A. El-Araj, Glotman Simpson, www.glotmansimpson.com; J. Bush, Lafarge Canada Inc., www.lafarge-na.com; B. Pope, Lehigh Cement Company, www.lehighcement.com; N. Cumming, Levelton Consultants Ltd., www.levelton.com; K. Foster, LVM-JEGEL, www.lvmjegel.com; D. Blender and B. Ball, Rempel Bros. Concrete Ltd., www.rempelbros.com; K.T. Chan, Stantec, www.stantec.com; and the Vancouver Organizing Committee for the 2010 Olympic and Paralympic Winter Games, www.vanoc.com.

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Selected for reader interest by the editors.



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