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Westmount Recreation Centre

Category: Buildings

2016 CANADIAN CONSULTING ENGINEERING AWARDS

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Photo (cover): Alain Jalbert
Photo (back): Jérôme Langevin

Westmount Recreation Centre

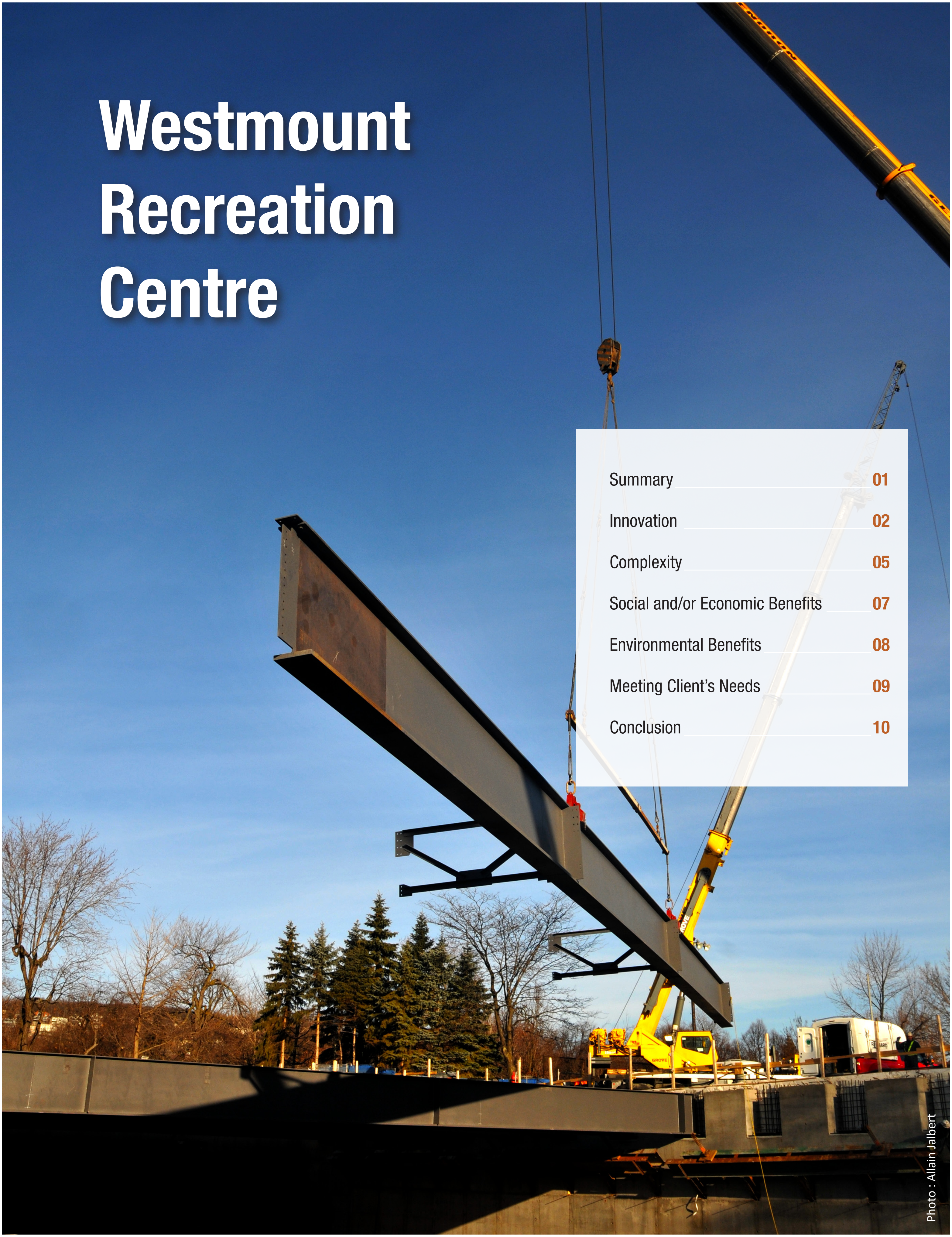
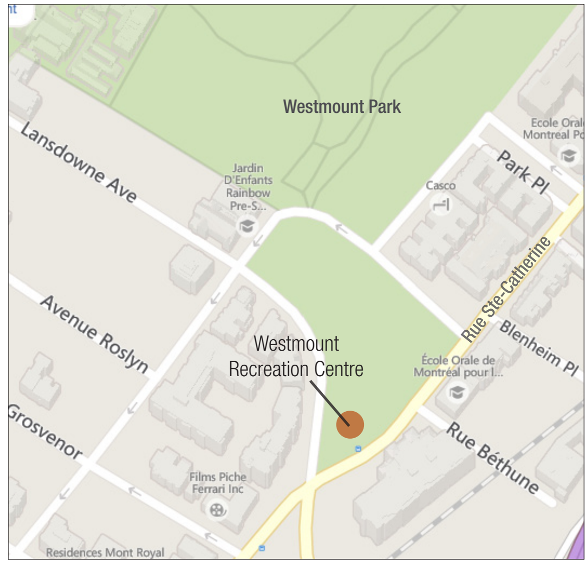


Photo : Allain Jalbert

A "WORLD FIRST" AT A COMMUNITY LEVEL

Constructing a large underground arena complex with a park space on its roof and an outdoor pool is quite a challenge *(photo 2)*. With 40% of the project's total budget dedicated to structure components, CIMA+ played a leading role in building the Westmount Recreation Centre, which redefines the art of blending contemporary institutional architecture into a residential and heritage environment. The structural engineer borrowed from bridge-building methods, creating a green roof fitted with long-span steel girders, so that the vast empty spaces required for the two rinks could withstand the significant lateral and vertical earth pressure. The thermal stability found underground contributed to the LEED Gold certification of this unique energy-efficient building.



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INNOVATION

“What is essential is invisible to the eye.” – Antoine de Saint-Exupéry

Certain engineering feats are so spectacular that they become iconic of the cities where they are located. Such visually stunning projects are emblematic because they transcend their original purpose. A building like the Westmount Recreation Centre that has been largely “buried” can claim no such status. On the contrary, its usefulness transcends its appearance, representing a completely different kind of tour de force!

An “underground bridge” spanning functionality, environment and community

To take full advantage of the underground thermal stability—between 12ºC and 15ºC year-round—and thus enhance the building’s energy performance, it was first necessary to develop a structure that would:

1. Withstand tremendous underground pressure
2. Allow for a 6-metre vertical clearance above the rinks
3. Limit the depth of foundations as much as possible to minimize economic and environmental costs of excavating

Adopting a bridge-building approach to deal with issues such as a weight-bearing roof over the open rinks was the keystone of addressing the project’s structural challenges. This unique bespoke design features 37 long-range metal beams (1.4 m X 32,569 m). The two rinks run parallel to each other and are separated at the ceiling by two central 64-metre header joists resting upon pillars placed on a 0.9-m-high raft foundation. Supporting the beams that span the ice rinks—19 on one side and 18 on the other—are 700 mm sidewalls with elastomeric bearings nested within niches, as would be used for a bridge. The header joists supporting the opposite ends of the I-beams also feature a particular type of reinforcement: their stiffeners each contain 14 slots elongated horizontally by ±30 mm *(photo 7)*. This way, even after being bolted to the stiffeners, some forward and backward movement of the beams on their axis is still possible. This was particularly important for pouring the concrete for the roof and compensating for the beams’ projected loss of camber.

The roof diaphragm or the art of creating a responsive composite material

The roof anchoring system, consisting of studs welded to the girders which bind the metal structure to the concrete apron, forces the roof to react as a monolithic material, reacting somewhat like a living diaphragm that transfers vertical and lateral loads to the foundations.

In summary, the significant interdependence of structural elements required custom designs of:

- Thirty-seven 32.569-metre-long variable-pre-camber-type “bridge” girders with a 1.4-m-web (single and vertical part of I-beam), a 300-mm-by-25-mm top flange and a 400-mm-by-50-mm lower flange (parallel and horizontal portions of I-beam)
- 152-mm-long studs with a 19 mm diameter, pressure-welded to each girder at every rib of the steel deck, activating the composite action between the concrete slab and the steel beams
- Two 64-metre-long header joists (central beams) resting upon pillars placed on the raft foundation and separating the two rinks lengthwise *(photo 5)*
- Two different support systems for the beams—one at the header joists and one on the exterior wall *(photo 3)*—to provide the beams with rotational and absorption capabilities
- 700-mm-thick perimeter walls made of reinforced concrete on a 1-metre thick perimeter foundation *(photo 8)*
- A central slab foundation 0.9 metre thick, 9 metres wide and 64 metres long

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Photo: Allain Jalbert

A more efficient design due to an optimal alignment of the roof beams

The roof structure of the East rink includes one additional beam. This difference stems from a slight difference *(photo 4)* between the two rinks caused by the sloping terrain. By adding this beam, the engineer maximized the alignment of the beams for both rinks, reinforcing the structure as a whole.

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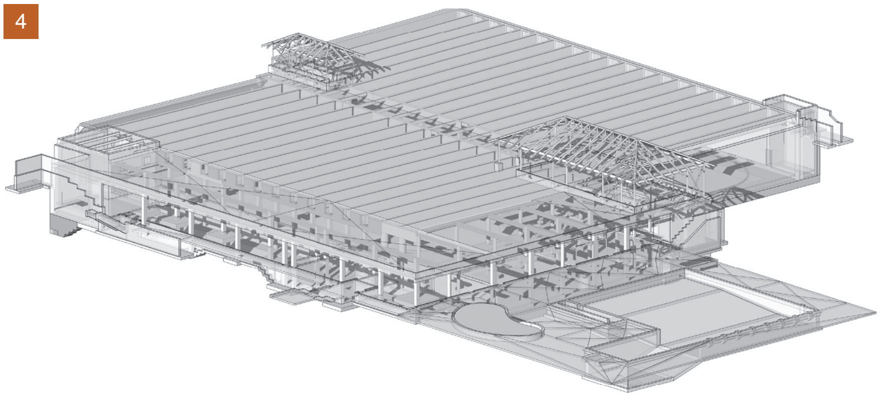

3D-view of the Westmount Recreation Centre using the Revit software.

Landscaping with artificial hills for a more natural appearance

The project included all of the areas related to the rinks (reception, lobby, locker rooms, community halls, youth centre), as well as the outdoor pool, and water management systems for the entire site. The landscape design for the building's green roof presented yet another element of complexity. To achieve the desired effect of a natural-looking landscape with a minimum load on the roof, expanded polystyrene blocks (100% recyclable) were used to create slight hills. These were assembled, much like a 3D-puzzle, before a thin layer of topsoil was added.

Innovation is not possible without highly motivated and skilled employees

The head engineer, responsible for ensuring successful completion of the project, had 55 years of experience. Aware of his role as a mentor, he assembled an interdisciplinary team consisting of two structural buildings engineers, each with 5 to 8 years of experience, and one LEED AP BD+C CBCP® CMVP® engineer with over 10 years' experience who had supervised other LEED Gold and Silver projects. In order to confirm his intuition that the building's roof had all the attributes of a bridge, he also included a bridge engineer on the team. This engineer was supervised by a senior department engineer, and both men had a PhD in Structural Engineering.

Taking advantage of every available experience and technique

The team also added two senior technicians, one an expert in the Revit software and the Building Information Modelling (BIM) approach, the other a specialist in bridge techniques. Having previously worked as a draftsman for a steel manufacturer, the latter technician's input was critical to the project. His in-depth knowledge of the challenges of steel construction was greatly appreciated by the other engineers, who, with his help, established a specific sequencing for this innovative hybrid structure that adapted bridge-building techniques to the construction industry.

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Photo: Allain Jalbert

Installation conditions and specific sequencing for certain structural work

In order for the structure to be progressively assembled properly, the first beam is attached to one end of the building without bracing. Two of three braces are then fastened to the following beam to be installed so that the crane can rotate it and place it, unhindered, on its abutment *(photo 6)*. Before the crane releases the beam, it is attached to the header joist. The free end of its two braces is fastened to the previously installed beam, and then bolted to the bracing adjacent to the exterior wall.

Another specific feature of the sequencing was that the upper walls at the ends of two rinks (parallel to the beams) were cast after the other walls and after the slab, because the weight involved in this procedure affects the beam camber. The beams must be allowed to settle freely while the concrete cures. This process works for the abutments on the outer walls and for the central header joist, but would not have worked if the roof had been immediately fastened to the walls located at the end of the rinks.

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Photo: Allain Jalbert

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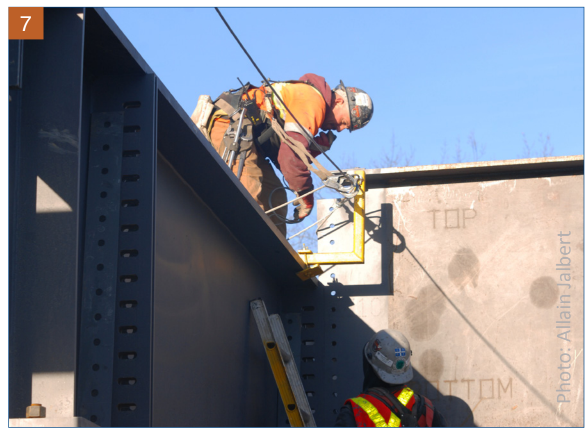

Photo: Allain Jalbert

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COMPLEXITY

The 6-metre-high empty spaces above the rinks posed a real challenge because the structure, unlike that of an underground parking area, needed to withstand the pressure exerted by unequal underground loads without using internal buttresses. Bridge girders were an ideal solution because they require only half the vertical clearance of a lattice steel structure (1.4 m instead of 3 m) and, adding to the complexity, costs associated with deeper excavation grow exponentially: deeper piles and retaining walls; additional amounts of concrete, water, reinforcements and formwork, drainage works…).

Digging a 9-metre hole over approximately 4550 square metres to "embed" the arena meant having to adequately deal with the difficult on-site conditions. As such, it was necessary to:

- Use vertical excavation with retaining walls *(photo 10)*, since the site's confined location made it impossible to use downward slope excavation, which would have been much simpler
- Oversee the decontamination of 142,150 metric tons of soil contaminated over time by its urban setting, excavated and sent to authorized sites
- Draw a new conclusion from divergent studies of two laboratories on the depth of the water table, one commissioned by the City, the other by the contractor
- Straddle an underground river and overburden terrain affecting the site's bearing capacity

In addition to these constraints related to building underground, three other major structural challenges arose, namely how to:

1. Withstand tremendous vertical and horizontal loads (compared to those exerted by wind or snow on an above-ground building), despite an impressive structural emptiness, an elaborate landscape architecture with manufactured hills that added vertical pressure and the need to account for roof drainage, and a service road allowing maintenance and security vehicles to travel on the roof
2. Deal with "unbalanced" loads, that is, asymmetrical horizontal pressure due to the arena having only two sides above ground *(photos 2 & 15)*
3. Adapt the design to the slope of the site despite the complexity of having to offset the two rinks slightly relative to each other.

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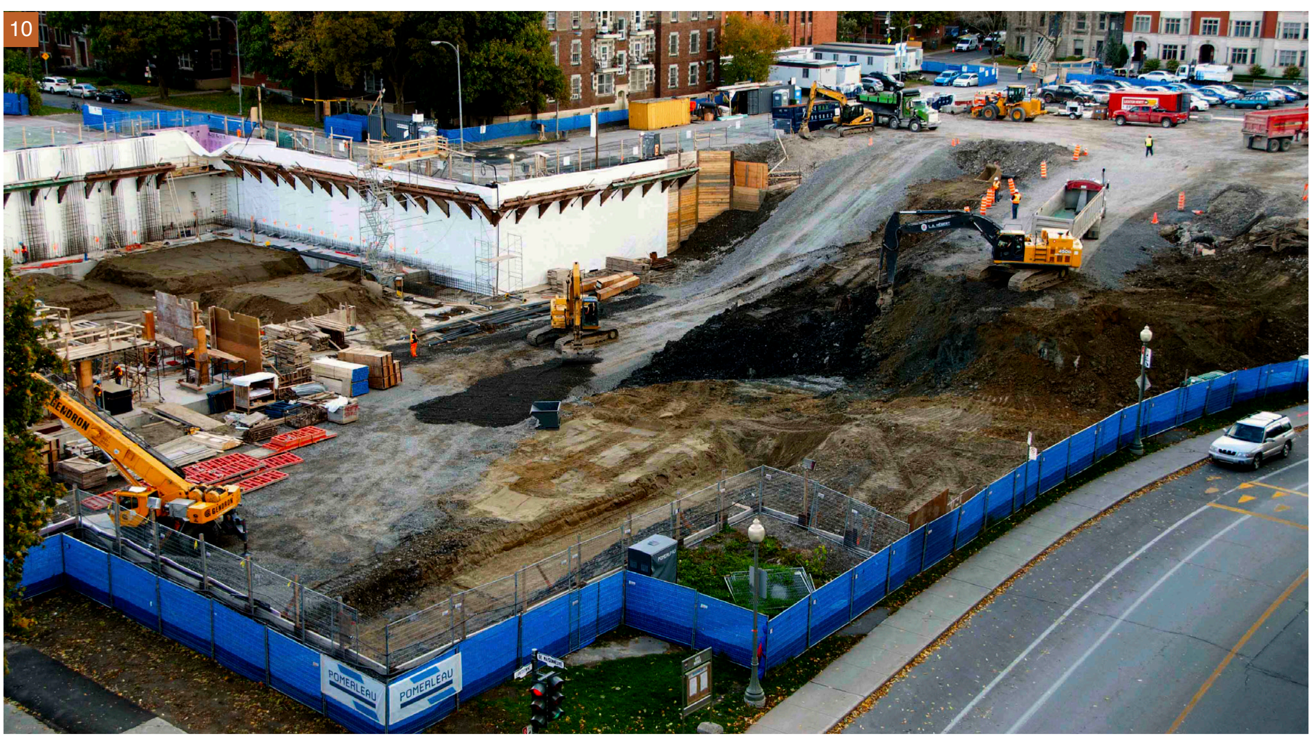

There was therefore virtually no wiggle room on either on functionality or budget. The engineer also confirmed a hunch when a second analysis of the parameters affecting the vertical and lateral earth pressure against the rinks' lateral walls determined that their size (as well as the amount of concrete required) could be reduced by nearly a third! State-of-the-art modelling also precisely established the size, thickness and precamber needed for the beams.

Even though the manufacturer wanted to use sectioned beams, the consulting engineer was able to demonstrate that even if they were to opt for two sections of different lengths (1/3—2/3), in order for the beam to retain its strength and properties and prevent a weakness at the centre point, the splice (connector plate) would have to be 3 metres long. The engineer's demonstration was enough to convince the manufacturer, thereby avoiding a costly and inelegant solution. The supplier found a way to deliver the beams whole (photo 12), which guaranteed a weld seam quality that could not have been matched on site.

Hybrid stormwater management that prevents stress on the City's main sewer

To ensure optimal management of stormwater, two structures were designed and stacked on vertically. The 600 mm upper structure includes a bioretention basin *(photo 11)* capturing 83% of the annual volume, while the 1500 mm lower structure, containing a "Stormchamber" basin, filters 17%. Together, the structures have an 80% suspended solid (SS) removal rate and filter 100% of the annual runoff volume.

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Photo: Allain Jalbert

SOCIAL AND/OR ECONOMIC BENEFITS

This Public-Private Partnership project is a shining example of co-operation among governments, the City, builder and subcontractors, and the entire community of Westmount, which contributed to a fundraising campaign under Geoff Molson's leadership (adding to the "buzz", from the workers to the investors, and linking the arena project to our national sport). Furthermore, over 30% of materials used in the project was sourced locally, thereby reducing transportation costs and increasing the region's economic intake.

By multiplying services within the site through innovative design and vision *(photo 14)*, stakeholders created a project that generates wealth locally on a daily basis. This alternative type of coexistence attracts new users while benefitting nearby businesses and neighbouring educational institutions. That's why the agreement signed by Selwyn House School for using the rinks is beneficial to both students and to the City.

This ecological and recreational overhaul, which required the full support of residents, has greatly improved the site's appearance and sightlines, eliminating the architectural anachronism of a massive structure *(photo 1)* and its inevitable encroachment on a heritage park and the adjacent Westmount Park United Church—a heritage building.

A versatile approach that contributes to community life

The dimensions of the beams were also established from a thermal stress scale factored at -10ºC to 30ºC. In comparison, the normal magnitude of deformation for metal structures on a bridge is between -45ºC and 25ºC. Given that the underground temperatures are rather constant (15ºC), the engineer took into account the many potential community uses for the rinks, such as concerts, where the temperature is expected to rise!

The building's contribution to teenagers' sense of belonging is demonstrated through regular use of the rinks by a high school and by the integration of a youth centre, while opportunities for loitering and graffiti (no walls) have been limited. The many bicycle racks encourage active commuting *(photo 13)*. The centre is highly accessible, located near bus stops and a subway/train station. Access to the natural environment is not only physical (1.5 acres of green space adjacent to a major municipal park), but also visual and psychological, greatly improving the lives of many residents!

ENVIRONMENTAL BENEFITS

While the previous arena had created an enormous heat island, the new underground infrastructure creates virtually none! Thanks to its electromechanical systems and its underground installation, the building reaches an energy-efficient performance that is twice that of the standards set by the 1997 MNECB, earning it LEED Gold status!

Moreover, the individual responsible for LEED compliance at CIMA+ scored the project, ensuring that 30% of materials used had a high percentage of recycled content:

- Steel beams (86%)
- Reinforcing steel (90%)
- Steel deck, bracing (62%)
- Metal framework (99%)
- Retention basin structure made of 100% concrete reclaimed from the previous arena and crushed on site

Judicious use of concrete with a reduced portion of less-polluting Portland cement also contributed to the sustainability of the structure. This choice made by the team's LEED expert, however, meant that the engineer had to deal with concrete that would take longer to cure, especially on cold days. Also, 94% of the wood used in the project is FSC certified.

Moreover, keeping recyclables uncontaminated through meticulous sorting allowed 95% of waste materials to be recovered. To this end, the project featured:

- Rigorous identification of the containers
- Efforts to educate employees and staff on special rules pertaining to LEED projects
- A consulting engineer who met nearly every week with subcontractors to prevent any contamination of containers, resulting in only a 5% loss!

The site excavation provided an opportunity to properly dispose of 150,000 tonnes of contaminated soil as well as clean up the urban environment's subsoil.

The 5960 m^2 green roof is a central element, acting as a natural filter that reroutes the already cleaner water into underground drains. The quality of the volumetric management system in place ensures that the post-development amounts and peak flow generated for the entire site (including parking lots) during a rainfall lasting 24 hours at a recurrence of two years are 25% lower than the equivalent pre-development flow and volumes.

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Photo: Nicolas McComber

MEETING CLIENT'S NEEDS

When the City of Westmount defined its citizens' needs based on more present-day values, it opted for an economically and socially responsible project, reducing the creation of heat islands and providing an environment for residents that was healthier and better suited to swimming.

This unprecedented complex was designed and built within 24 months and the project was delivered on time, in October 2013! It took only five weeks to submit a flat-rate proposal and four months to design the final plans. Site supervision was spread over 18 months.

While rigorous cost control and LEED Gold certification reflect the client's overall satisfaction, the engineer still had to meet several specific requirements to reconcile idealism with pragmatism, all within the specified timeline, including:

- Public awareness through information panels (water conservation, intelligent lighting…)
- Judicious placement of rinks at the upper part of the slope to maximize the amount of natural light entering the building *(photos 17 & 19)*
- Modelling the areas where steel beams could be exposed to fire near the bleachers *(photo 16)* to delineate the areas requiring protection by very expensive intumescent paint, saving hundreds of thou-sands of dollars
- 52% energy savings compared to a structure built according to the 1997 MNECB, due not only to the energy recovered by compressors, but also to the thermal stability provided by building underground

Mitigation of the impact of construction (noise, dust) on community life by scheduling special construction work hours that would respect religious services such as weddings in the nearby church.

This underground rink, built according to the highest standards so as to meet LEED Gold requirements, was featured in a video report in the renowned webzine SABMag, ecoHouse Canada (Canadian Green Building Awards), further enhancing the project's reputation for the City of Westmount. By meeting the City's specific needs in such an outstanding fashion, the engineer has led the way for similar achievements of its kind throughout the world, by working with the thermal stability found underground and using it to provide year-round access to the rink or, conversely, to an indoor sports complex in countries where excessive temperatures reduce the time when physical activity is possible.

CONCLUSION

The magic and majesty of engineering

FULLY INTEGRATED! This underground arena is undoubtedly a world first—showcasing a fascinatingly unobtrusive feat of engineering that has charmed people young and old. While visitors may not grasp all the intricacies of the work done, they are definitely in awe of the magic and majesty of it all!

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Photo: Jérôme Langevin

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Photo: Jérôme Langevin

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