REDISCOVER CONCRETE

ESSENTIAL SOLUTIONS FOR SUSTAINABLE BUILDING AND INFRASTRUCTURE

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CONCRETE COUNCIL OF CANADA | rediscover CONCRETE

Dear Reader,

Many in our industry think of concrete as the unsung hero of the shift to a more sustainable built environment. From climate resilient critical infrastructure to some of the highest performing buildings in the world, concrete provides solutions to a host of pressing sustainability challenges – and continues to push the boundaries of performance.

By weight, more concrete is used than all other construction materials combined – more in fact than any other material except water. And yet, even to our most important stakeholders, concrete can be more or less invisible – an essential material that some take for granted simply because it is so common in their day to day lives.

We are at a critical juncture when it comes to the way we think about our built environment. Sustainability, and in particular the pressing need to mitigate and adapt to the changes in our climate, demands of us more holistic, integrated and innovative models and tools for planning, designing, building and managing buildings and infrastructure. What role will the world's most ancient building material play in this new paradigm? What is the role of concrete in building a sustainable society?

The Concrete Council of Canada (CCC) was formed to take on these questions. Formed in 2013, the CCC is comprised of 14 industry associations representing the full spectrum of the cement and concrete value chain and the diversity of concrete producers and product manufacturers in Canada (concrete masonry, concrete pipe, precast concrete, cast-in-place concrete, interlocking concrete pavement, and cement manufacturers) as well as stakeholder representatives from the environmental, architecture, engineering, construction, insurance and academic communities. Its mission is to "promote and enhance the social, environmental and economic value of concrete, concrete products and concrete systems in Canada."

Collaboration is a key value of the Council. Sustainability is by its very nature a collective challenge that requires diverse solutions. In the pages that follow, we hope to engage you in a discussion about what sustainability means for our built environment. We encourage you to "re-discover" concrete as the sustainable material of choice for your building and infrastructure projects. Finally, we invite you to partner with our industry and with other stakeholders to support the ongoing evolution of critical sustainability evaluation tools – such as life cycle assessment – that will help decision makers optimize the sustainability of our homes, communities and cities.

Robert Burak, P.Eng
Chair, Concrete Council of Canada
rediscoverconcrete.ca

COVER: LILLE MÉTROPOLE MUSÉE D'ART MODERNE, D'ART CONTEMPORAIN ET D'ART BRUT (EXTENSION), FRANCE: Concrete is an ideal material for creating shapes, voids and solids, angularity, and curvature. Architect: Manuelle Gautrand. Photo: Max Lerouge.

BACKGROUND: SHERBOURNE COMMON, TORONTO (ARCHITECTURAL LANDSCAPE). Architect: Phillips Farevaag Smallenberg

RIGHT: LEED GOLD ATRIUM BUILDING, VICTORIA: The seven-storey form is clad in precast concrete panels, zinc, and glass. Architect: Murdoch de Greeff Inc. Photo: Lotus Johnson.

PUTTING LIFECYCLE PERFORMANCE AT THE CENTRE OF SUSTAINABLE COMMUNITIES

Our built environment is at the heart of sustainability – the source of, and potential solution to virtually every sustainability challenge we face. How we design and build our communities and the buildings they contain has vast implications for energy use, transportation, water and wastewater management, food supply and distribution, our social and economic prosperity and health, as well as our safety, security and resilience in the face of natural and human-made disasters.

It's no surprise, and indeed in many ways a great comfort, that cities – their planners, architects, engineers, asset managers, politicians and others – are at the forefront of sustainable innovation. Through initiatives such as Architecture 2030 and, of course, LEED v4, new perspectives and new tools are reshaping the conversation about built infrastructure and the role that it can play in realizing a sustainable and resilient future.

Perhaps one of the most important tools to benefit from this attention on the sustainability of our built environment is Life Cycle Assessment (LCA). LCA recognizes the complexity hidden behind sometimes deceptively simple questions about the sustainability of a product or service by examining all stages of its life, from "cradle-to-cradle" – i.e. raw material extraction through materials processing, manufacturing, distribution, use, repair and maintenance, and end of life (repurposing, reusing, recycling or disposal). LCAs are underpinning greater transparency in the marketplace through, for example, facilitating the development of Environmental and Health Product Declarations (EPDs and HPDs), now recognized in LEED v4. They add rigor and credibility to the claims of product manufacturers about the impacts of their products and services.

At the same time, LCAs are not without limitations, particularly when attempting to assemble a picture of sustainability for complex systems like buildings. In the same way that the whole isn't always the sum of its parts, LCAs for individual products cannot be aggregated to give you a simple measure of a building's overall sustainability. Taking greenhouse gas emissions as one example, buildings are responsible for up to half of all emissions in Canada and the U.S. and, depending on the location and service life, well over 90% of these emissions come from operational energy use. Optimizing building performance is clearly a critical piece of solving the climate change challenge, which makes it all the more critical that we deploy LCAs at the systems level to give us an integrated picture of how all the components of a building – design, materials, technologies etc. – work together to optimize performance.

The Canadian concrete industry has taken this kind of approach, working with experts from MIT, the Athena Sustainable Materials Institute, the University of British Columbia, the University of Toronto, the University of Waterloo and other Canadian institution, to identify and measure what concrete contributes to the life cycle sustainability performance of buildings, roads, and other infrastructure projects. In virtually all cases, and especially for buildings, LCAs demonstrate how architects and other infrastructure professionals can leverage tremendous sustainability performance improvements through integrative approaches to materials and design.

For example, multiple academic studies illustrate that the passive energy efficiency benefits of concrete and masonry's thermal mass – gains of up to 8% over other materials – typically more than make up for the embodied impacts of the cement and concrete manufacturing process. More importantly, integrating thermal mass as a design strategy and pairing it with passive and/or active radiant heating and cooling systems can magnify efficiency benefits by a factor of ten while offering "side benefits" for indoor air quality and occupant health, safety, comfort and productivity.

As we think to the future of green building, a key indicator of progress will surely be the extent to which the transparency offered by LCAs and other predictive measurement tools is translated at the project level to leverage synergies between design, materials and technology and enhance the lifecycle sustainability performance of our buildings and communities.

LEFT: THE PANTHEON, ROME, ITALY. The largest concrete dome in the world, the Pantheon, constructed in 126 AD, endures as an architectural symbol of sustainability, durability and possibility.

BACKGROUND: LAVAL LINE 2 METRO, MONTREAL.

A "BIG PICTURE" APPROACH TO BUILDING PERFORMANCE

Équiterre's Maison du développement durable, Montreal

When Quebec's prominent environmental organization, Équiterre, set out to design and build "the most energy efficient and least energy intensive building in Canada" in collaboration with seven other socially and environmentally minded organizations in Montreal, they embarked on an unprecedented journey to understand the "big-picture" implications of various design and material choices.

Their multidisciplinary design team, consisting of architects, engineers, designers as well as a sustainable development officer, pushed for concrete as the best solution to meet Équiterre's needs. After conducting a macro analysis of the cost and environmental impact of various designs and material choices over the lifecycle of the proposed structure, they found that using concrete as the structural material gave them huge advantages across a range of criteria.

The savings on fire mitigation alone were estimated at $2 million, valuable capital that could be reallocated to energy efficiency investments. Concrete also allowed for a smaller building envelope, minimizing material needs, reducing operational heat loss, and maximizing interior floor space and potential rental income. Équiterre was also attracted to the local nature of concrete, which could be sourced, including the cement, within 50km of the project compared to almost 1000km for alternative materials.

Finally, longevity played a large role, highlighting how one of concrete's key advantages – durability from wind-driven rain, and other forms of environmental degradation – leads to lower maintenance, longer service-life structures that extract the best economic and sustainability value from the cost, energy and materials required to build them.

Modeling the energy efficiency benefits of the concrete's thermal mass was not part of the original study, however, the design of the building takes full advantage of this property; the result is a LEED Platinum building that uses over 40% less energy than an equivalent conventional building. While performance data is still being collected and analysed, preliminary results suggest that per unit of floor area, Équiterre may have realised their goal of becoming the most energy efficient office building in Canada. **For more information on Maison du développement durable, visit www.maisondeveloppementdurable.org.**

LEFT AND BOTTOM: LEED PLATINUM MAISON DU DÉVELOPPEMENT DURABLE, MONTREAL: Using concrete as the structural material for the Centre provided advantages across a wide range of sustainability criteria. Architect: Menkes Shooner Dagenais Letourneaux Architectes. Photo, left: Bernard Fougère. Photo, bottom: Équiterre.

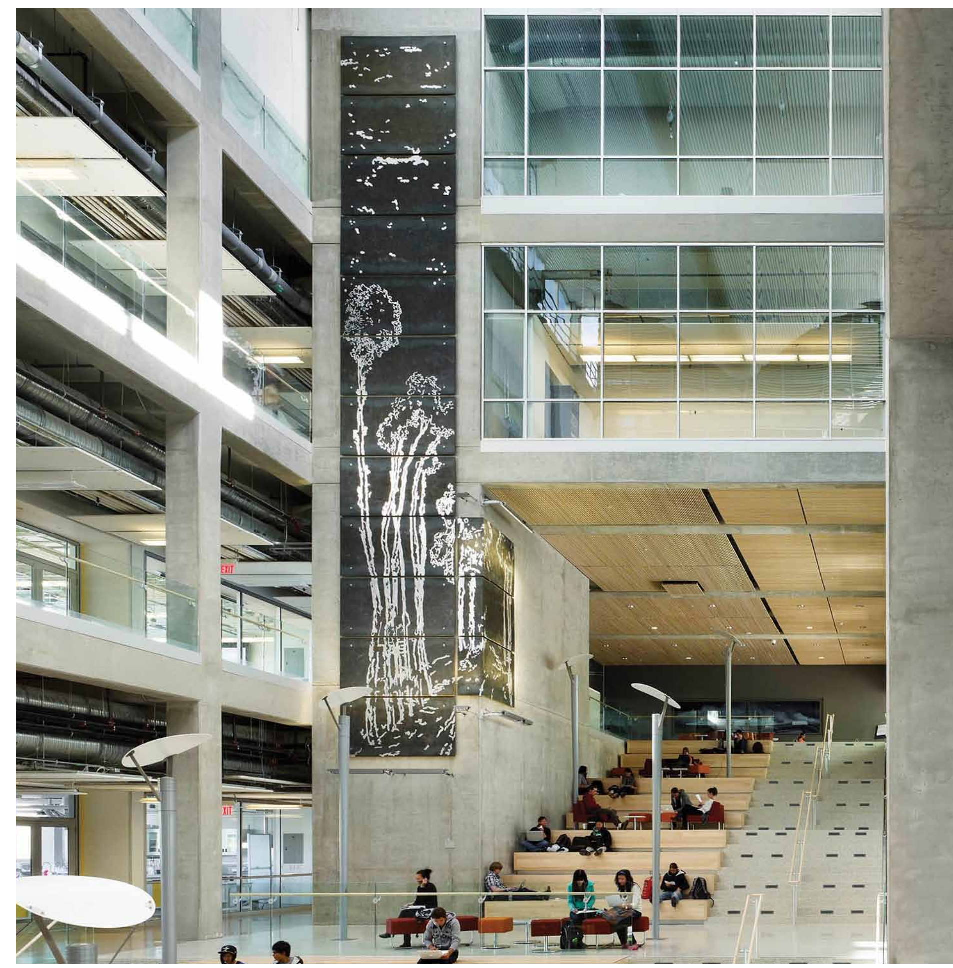
FAR RIGHT: LEED PLATINUM UNIVERSITY OF CALGARY ENERGY ENVIRONMENT EXPERIENTIAL LEARNING CENTER, CALGARY. Architect: Perkins + Will, DIALOG Design. Photo: Tom Arban.

CONCRETE LCAs IN FOCUS

In order to better understand concrete's environmental performance in the context of building construction, use, and end-of-life, the Athena Sustainable Materials Institute (ASMI) and the engineering firm Morrison Hershfield conducted a life cycle assessment (LCA) of a typical commercial building in two Canadian locations – Vancouver (cool climate) and Toronto (cold climate). The LCA compared the performance of three structural framing systems as well as a typical curtain wall design against different concrete building envelopes.

Looking at 60- and 73-year occupancy scenarios (CSA and ISO lifecycles), the best performing buildings in terms of global warming potential (GWP) and total primary energy (TPE), regardless of service life or location, were those with a precast concrete envelope and cast-in-place concrete structure. Energy simulation revealed that the interior thermal mass inherent in cast-in-place concrete and precast concrete floors reduced annual heating energy by 6-15% – and that was without any specific thermal mass based heating strategies since the functional unit was the same for each scenario. As with other studies, the LCA also confirmed that operating energy accounts for the lion's share of a building's energy use (90-97%) and global warming potential (ranging from 54-75% in Vancouver and 90-91% in Toronto) – i.e. the embodied energy and GHGs associated with the materials and construction phase of a building is a fraction of operational impacts. Concrete structures also yielded significant reductions in impacts associated with acidification, respiratory effects, eutrophication, smog, water use, non-renewable energy, and renewable energy (non-biomass) over the full life cycle of the building.

LCA studies carried by MIT found similar results. MIT compared U.S. Department of Energy benchmarked models of three building types (single family, multi-residential and a 12 story commercial building). The residential buildings were modeled for two construction types (wood vs. insulated concrete forms) as was the commercial building (steel vs. concrete). Energy simulations were run for each building type in two locations – Chicago and Phoenix. In all scenarios, the best performing structure from a GWP perspective were the concrete structures, which yielded 8% lower GWP, before considering any additional thermal mass based energy reducing technologies.
For more information on these studies, please see: www.rediscoverconcrete.ca

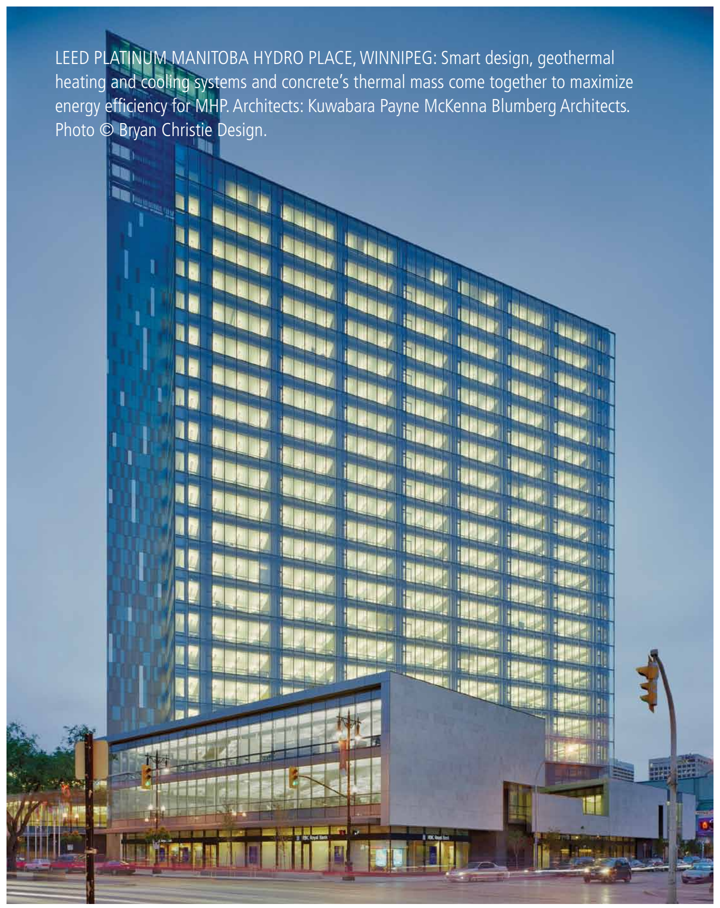


CASE STUDIES IN THERMAL MASS BASED ENERGY SYSTEMS

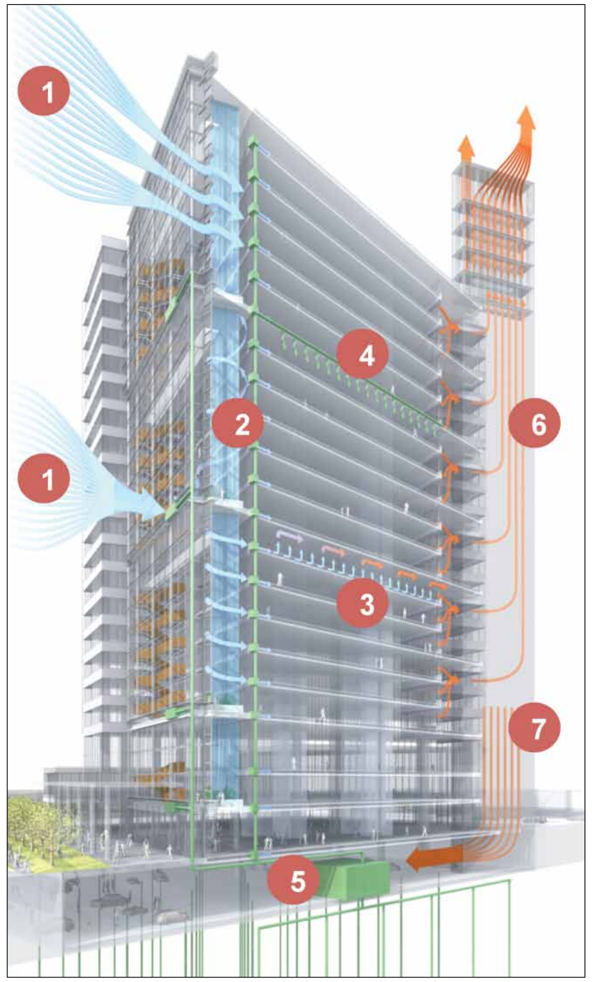
1. Manitoba Hydro Place

Located in the heart of Winnipeg, the LEED Platinum certified Manitoba Hydro Place (MHP) deploys an innovative "solar chimney" design. In combination with geothermal radiant heating and cooling systems to activate the thermal mass of the building's 40,000 m³ of concrete, the design allows the building to coast through outdoor temperature changes, shift peak energy demand and achieve an overall 66% efficiency improvement over the Model National Energy Code for Buildings.

This strategy is saving MHP $500,000 per year in operating expenses while supporting 100% fresh air circulation, 24 hours per day, 365 days per year – even in the depth of Manitoba's winter. It's a model example of a building that takes advantage of the key features of the local weather – cold, sunny winter days, and cool summer nights – using design based solutions to maximize lifecycle sustainability performance. **For more information, see: www.manitobahydroplace.com.**



LEED PLATINUM MANITOBA HYDRO PLACE, WINNIPEG: Smart design, geothermal heating and cooling systems and concrete's thermal mass come together to maximize energy efficiency for MHP. Architects: Kuwabara Payne McKenna Blumberg Architects. Photo © Bryan Christie Design.



1. 3 – 6 storey tall atria act as the building's lungs
2. 24m high waterfall either humidifies or dehumidifies the air depending on the season
3. Air is distributed via the raised floor distribution plenum
4. Exposed ceiling mass uses radiant heating and cooling
5. Geothermal system draws excess heat or cold stored within the soil to condition the building
6. Air flows to the solar chimney and is exhausted upward in the summer
7. Air is drawn down in winter and used to warm the parking garage

2. Riverdale NetZero Energy Duplex

When Habitat for Humanity set out to pioneer a new model for achieving an affordable, net-zero energy, LEED Platinum home in Edmonton, they found an innovative solution in insulated precast concrete panels.

Touted as the first residential development of its kind, the affordable housing residential duplex emerged from an integrative design process aimed at optimizing the social, environmental and economic benefits of the project.

Each two-storey home is 100 square metres above ground with a 50 square metre unfinished basement. The double wythe insulated precast panels used on the homes' roof and exterior walls – 80 in total – provide three times the standard level of insulation (R44 / RSI 7.75 walls and basement slab, R88 / RSI 15.5 roof) to create a high energy efficiency building envelope that also has exceptional fire and sound resistance.

Combined with a geothermal heating and hot water system, in addition to photovoltaic rooftop panels to generate solar electricity, concrete's thermal mass is at the heart of the design strategy for meeting the net-zero energy goals of the project. Concrete will also offer the additional longer-term advantages of being extremely durable with low-maintenance, providing significant life cycle cost savings.

The deserving family will have little to no utility costs (energy performance will be closely monitored by MIT over the next two years). Another key sustainability feature of the project is that precast roof and wall panels were produced using regional and recycled materials in a low-waste production process, and can easily be disassembled and reused at the end of the useful life of the structure.

The result is a model for a highly efficient cradle-to-cradle solution to affordable and sustainable housing. **For more information, see: http://www.lafarge-na.com/wps/portal/na/en/6-Sustainability.**

RIVERDALE NETZERO ENERGY DUPLEX, EDMONTON: Concrete's thermal mass is at the heart of the design strategy for meeting the net-zero energy goals of the project. Architect: Stantec Architecture Ltd.

3. Mundy's Bay Public School

Mundy's Bay Public School, located in Midland, Ontario takes advantage of the ancient principle of thermal energy storage. It uses precast concrete hollow core slabs between the floors and ceilings, coupled with heat recovery ventilation and a ground-source heat pump, to create an innovative "on demand" system for capturing, storing and releasing naturally occurring heating and cooling energy.

In summer, when outdoor temperatures are generally cooler outside than inside at night, a simple ventilation fan draws in the cool air, circulates it through the hollow core slab and "supercharges" the concrete. The concrete behaves like a battery, absorbing and eliminating indoor heat (e.g. occupant body heat, lighting, solar gain) during the day to keep indoor temperatures cool and comfortable while lowering demand peak air conditioning loads. In winter, the same principle works in reverse, drawing heating energy from the ground-source heat pump. Thermal energy storage also facilitates greater circulation of fresh outdoor air to dramatically improve indoor air quality – known as a key driver of student/employee performance and reduced absenteeism – while keeping energy consumption well below the industry average (about 40%-50% less energy than a conventional school).

In 2011, Mundy's Bay Public School was named the most energy efficient school in North America in an assessment of the energy performance of over 500 schools. Mundy's Bay, which opened in 2008, has a total energy consumption of only $0.53 per square foot or 32 KBTU per square foot per year. It achieved LEED Gold certification in 2009 and was one of the first sustainable education projects in Canada. **For more information see: http://www.grnland.com.**

LEED GOLD MUNDY'S BAY PUBLIC SCHOOL, MIDLAND, ONTARIO: Precast hollow core slabs between floors and ceilings play a key role in creating an "on demand" system for energy use management. Architect: Ted Handy & Associates. Photo: Janet Hammel.

PRODUCT TRANSPARENCY THROUGH ENVIRONMENTAL AND HEALTH PRODUCT DECLARATIONS

LEED GOLD PLACE DE L'ESCARPEMENT, QUEBEC CITY. Architect: Pierre Martin Architecte.

EPDs and HPDs measure a wide range of environmental and health impacts (e.g. greenhouse gas emissions, toxic substances, habitat destruction, water impacts, ozone depletion, etc.) at every step of a product's life cycle – from raw material extraction and processing, to manufacturing, to distribution and disposal or recycling at end of life. It's a standardized methodology for product manufacturers, much like a nutrition label.

For builders, product declarations offer an internationally consistent, science-based methodology for understanding the full life-cycle performance of building products, from construction materials to interior finishes. It's also a significant tool for manufacturers, who can use information from product declarations to discover opportunities for improving environmental and health performance throughout their value chain.

While product declarations provide a standardized platform for comparing a variety of metrics, they do not, in-and-of-themselves, account for how different materials can influence a building's overall performance. For example, in the case of concrete, EPDs should be accompanied by an assessment of the effect of thermal mass on the total sustainability performance of the finished structure. Nonetheless, EPDs provide important opportunities to compare like-products from different manufacturers or to compare different formulations of the same product (e.g. fly ash vs. non-fly ash concrete or concrete made from Portland Limestone Cement – branded Contempra in Canada – vs. traditional general use cements).

The recent introduction of the LEED v4 Rating System and growing popularity of Architecture 2030 are major drivers for EPD and HPD adoption in North America. A number of Product Category Rules (the precursor to product declarations) have been developed and tailored for the North American cement and concrete industry and several concrete EPDs have been produced. In Canada, major players in the precast products, masonry and ready mix markets are actively pursuing EPDs for their products.

As product declaration methodologies and use mature, they have the potential to transform fundamentally the way we plan and measure the sustainability of buildings by supporting a better understanding of how materials and design work together for a more sustainable built environment.

DEVELOPER FEATURE: WINDMILL DEVELOPMENT GROUP

By Rodney Wilts, JD, LEED AP, Partner,
Windmill Development Group, Ltd.

Windmill is a real estate company dedicated to transforming the built environment – we believe in a different model of development, one that sees each project as an opportunity to achieve exemplary economic, environmental and social returns for the communities where we build.

While all of our projects are uniquely customized to complement the community they are in, there are common themes associated with all Windmill buildings. One of these themes is a commitment to using Life Cycle Assessment (LCA) to optimize materials selection and align design and construction strategies with our sustainability performance objectives. Our projects prioritize energy efficiency, human health, low carbon footprint as well as durability and resilience.

IMAGE ABOVE: DOMTAR LANDS REDEVELOPMENT, GATINEAU, QUEBEC.
Architect: Windmill Development Group / Perkins + Will.

Concrete has figured prominently in our portfolio of LEED Platinum buildings. LCA has helped us consider both the sustainability of concrete as a material as well as the role that concrete plays in meeting the sustainability performance objectives of our projects. For example, we were one of the first across the country to incorporate supplementary cementitious materials in multi-unit residential buildings. We also design with ecological systems in mind (such as passive solar and integrated renewal energy systems) and concrete's thermal mass has facilitated this approach in many of our developments.

The market for green buildings and green building materials is expanding exponentially and, in the wake of this expansion, it's essential that the building community remain diligent in its focus on integrated, long-term assessments of what makes a given project sustainable. In this vein, Windmill is looking to the One Planet Community Framework for inspiration on our latest project, a 37 acre redevelopment of the Domtar lands on the Ottawa River less than a kilometre upstream from Canada's Parliament Buildings. The reason we have chosen this framework is the emphasis on ecological footprinting as the basis for the program, and because rather than being a snapshot of the development at time of application, it is an ongoing partnership that promotes the long-term sustainability of the development well into occupancy.

Dockside Green

Dockside Green in Victoria, BC is one of a handful of projects from around the world that was recognized by the Clinton Climate Initiative as being climate positive. Cement and concrete-based strategies used at Dockside Green include:

• Thermal mass based energy efficiency strategies.
• Durable solid concrete floor slabs, columns, shear walls and roofs for structural strength, noise reduction, durability and adaptability (durability results in longer lasting structures, reducing waste and maintenance costs over the life of the structure).
• Concrete with 35–40% fly ash to reduce CO_2 and increase strength. The onsite sewage treatment plant also uses fly ash to promote crack resistance and water tightness, reducing the need for chemical additives and saving approximately $40,000.
• Cement-based soil stabilization to avoid more expensive site improvements that would otherwise be required, such as floating raft-slabs, piles or caissons.
• A cement-based solidification/stabilization process to treat 10 tonnes of lead contaminated soil (a strategy that is now being promoted across Canada).
• Insulated concrete forms and floor system.
• Recycling of waste concrete into concrete blocks.
• Reuse of abandoned slabs buried on the site for the road base and other building purposes.
• Concrete panels with recycled glass are being used for elevator lobbies.
• Concrete also contributed to indoor health (e.g. does not promote mould growth and can be easily cleaned). **Adapted from: http://www.solaripedia.com/files/572.pdf**

DOCKSIDE GREEN, VICTORIA. Architect: Windmill Development Group / Perkins + Will.

THE CONFEDERATION BRIDGE, PEI: One of Canada's top engineering achievements of the 20th century, the Confederation Bridge is a spectacular example of the important role concrete plays in the country's infrastructure. Photo: Shaun Lowe.

INFRASTRUCTURE THAT LASTS

CANADIAN MUSEUM OF HISTORY, GATINEAU: The fluid, curvilinear forms of Douglas Cardinal's groundbreaking vision for the Canadian Museum of History were beautifully realized in concrete, with Tyndall limestone matching the curve of the building. Architect: Douglas Cardinal and Tétreault, Parent, Languedoc et Associés Inc.

Durability and Resilience in an Uncertain World

Durability, longevity and resilience are central, but often overlooked, aspects of sustainability. A highly energy efficient concrete building with a long design service will ultimately deliver the most value from the embodied energy in the materials and construction process and reduce the need to extract new resources. Likewise, a building that can be repurposed at the end of its originally intended service life will avoid the economic, social and environmental costs associated with demolition and rebuilding. A concrete building is unique in its ability to deliver on these metrics, which can be further optimized with proper foresight in the design process.

A key aspect of resilience is the ability of structures to withstand extreme events such as fire, earthquakes and violent weather. Codes and standards require that structures meet minimum safety requirements, and are focused on the preservation of human life. Concrete structures, by their nature, meet and exceed these code requirements and offer a level of serviceability over other materials that ultimately reduces the cost and environmental impact of replacing (or bringing structures back into use) after a fire or other disruption.

Climate change is adding a whole new dimension to the concept of resilience for buildings and, indeed, the entire network of infrastructure that underpins our quality of life. Resilient infrastructure is a first line of defense – a crucial component of broader strategies to minimize the risk to our communities from the impacts of extreme weather.

Yet, according to the Federation of Canadian Municipalities, Canadian cities have an existing infrastructure deficit of $171.8 billion with urgent upgrades needed for roads and bridges ($91.1 billion), waste management systems ($39 billion) and wastewater and stormwater systems ($15.8 billion).

Add to this the anticipated costs of climate change – up to 1% of Gross Domestic Product (GDP), or $5 billion per year, climbing to $43 billion per year by 2050 – and the enormity of the infrastructure challenge becomes clear.

Crisis breeds opportunity, and among the most significant opportunity that climate change presents for designers and managers of infrastructure is to help shake off the "lowest initial cost" model that continues to dominate many infrastructure decisions in an era of fiscal restraint. A holistic, Life Cycle Assessment driven analysis can help establish and promote the return on investment (ROI) for infrastructure decisions that favour durability, longevity, resilience and maximum value for taxpayers.

Building professionals can contribute to the climate resilience of our communities by designing "no regrets" resiliency into their projects. Concrete can play a role in these designs by delivering on a range of economic, social and environmental metrics that add value today while also offering a high degree of longevity and resilience for tomorrow. One example is design that considers the ability of thermal mass to not only deliver efficient and healthy buildings, but also maintain the livability of buildings during extreme temperatures or during the aftermath of power outages. Using concrete wastewater pipe to double as a source of thermal energy to heat buildings is another example of this type of thinking.

Designers can include innovative materials such as ultra-high performance concretes (UHPC) – stronger, longer lasting and efficient concretes that were initially developed for the critical infrastructure sector. UHPC can bring even higher levels of durability and longevity benefits to buildings and structures.

Resilience challenges us all to think in much more integrated ways to ensure what we build today is built right, and built to last. Concrete products and systems offer "win-win" solutions under today's conditions of uncertainty.

RESILIENT INFRASTRUCTURE: WATER IN FOCUS

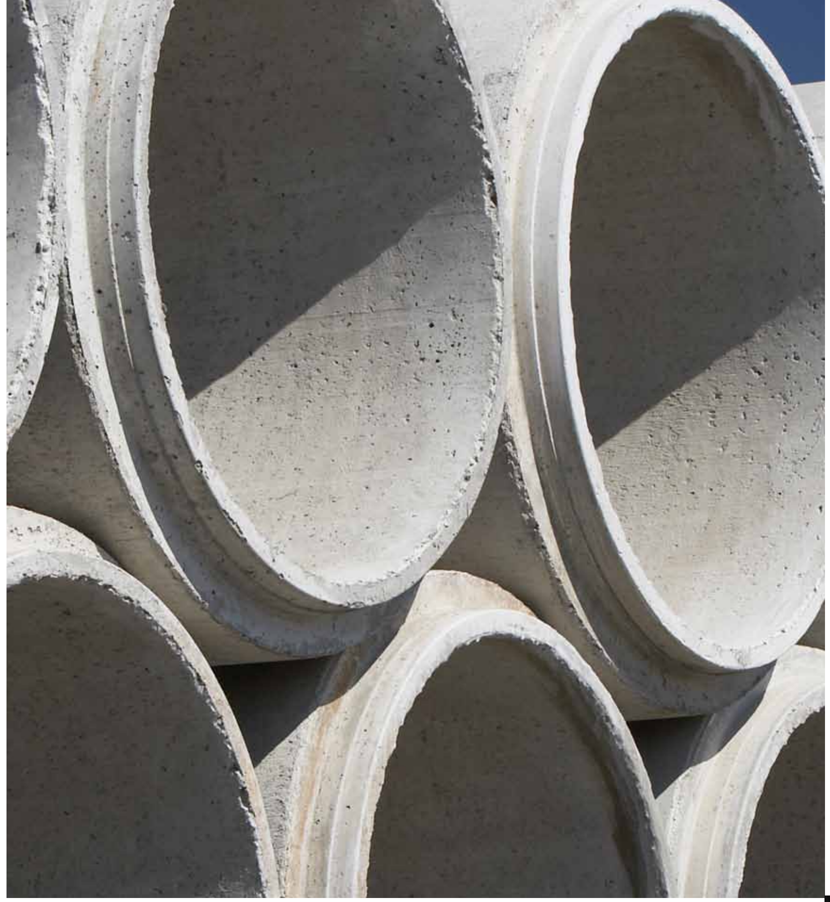
Stormwater Management in the Age of Climate Change

Water is at the heart of climate change's impacts on communities – increased frequency and severity of droughts, floods, storm surges, and sea level rise are already being observed, and mitigating these effects is among the most urgent challenges to make our communities more resilient. A 2014 survey found that a strong majority of water experts in Canada are deeply concerned about the current capacity and condition of water infrastructure across Canada, including water distribution, sewage and stormwater management.

Some of these challenges can be met, in part, with better management of "natural" infrastructure – for example, restoration of wetlands, natural urban riverine systems and forest canopy. However, there is no escaping the critical role that public projects will play in urbanized areas. From infiltration solutions such as pervious and permeable concrete pavements, to bioswales, concrete culverts and concrete pipe infrastructure, the robustness and longevity of our underground infrastructure will play a critical role in protecting our communities and reducing the impacts of climate change.

Concrete products such as precast pipes and boxes are commonly used for sewers, stormwater management and culverts. Some of the concrete infrastructure we continue to rely on today is already decades old if not older yet, demonstrating performance beyond their original expected service life. While traditional below-ground concrete infrastructure continues to show it can play a critical role, new innovations and integrative thinking are demonstrating concrete technologies can provide low cost solutions to multiple sustainability challenges at once.

PERMEABLE INTERLOCKING CONCRETE PAVEMENT, BRYN MAUR ROAD, VICTORIA.
Landscape Architect: Associated Engineering (BC) Ltd. Permeable concrete pavement offers a low impact development solution to stormwater management.



RESISTANT AND DURABLE. Concrete pipes and boxes are commonly used for sewers, stormwater management and culverts.

EXAMPLES

1. Townshend, Vermont Culvert Replacement

When the town of Townshend, Vermont was hit by tropical storm Irene, the storm completely washed out one of the town's main 4.25 meter diameter corrugated metal culverts. Understanding that climate change would increase the frequency and severity of similar storms in the future, the town sought to rebuild the culvert with resilience and life cycle costs in mind. Townshend replaced the destroyed culvert with a new open bottom, concrete arch box culvert that spans the full width of the stream.

The new box culvert is designed to withstand future extreme flooding events, and will maintain equilibrium between the flow of sediment through the culvert and the passage of aquatic organisms. Rebuilding to these higher standards now will save lives and tax dollars in the long term. A similar steel culvert collapse on Highway 174, in Ottawa, Ontario in which a car became trapped, also led city officials to replace the culvert with concrete pipe.

2. False Creek Energy Centre, Vancouver

Precast concrete geothermal sewer pipes are being used to capture heat from wastewater and provide a secure local, inexhaustible and carbon-free supply of heat for district energy systems. One example of this technology can be found at the False Creek Energy Centre in Vancouver.

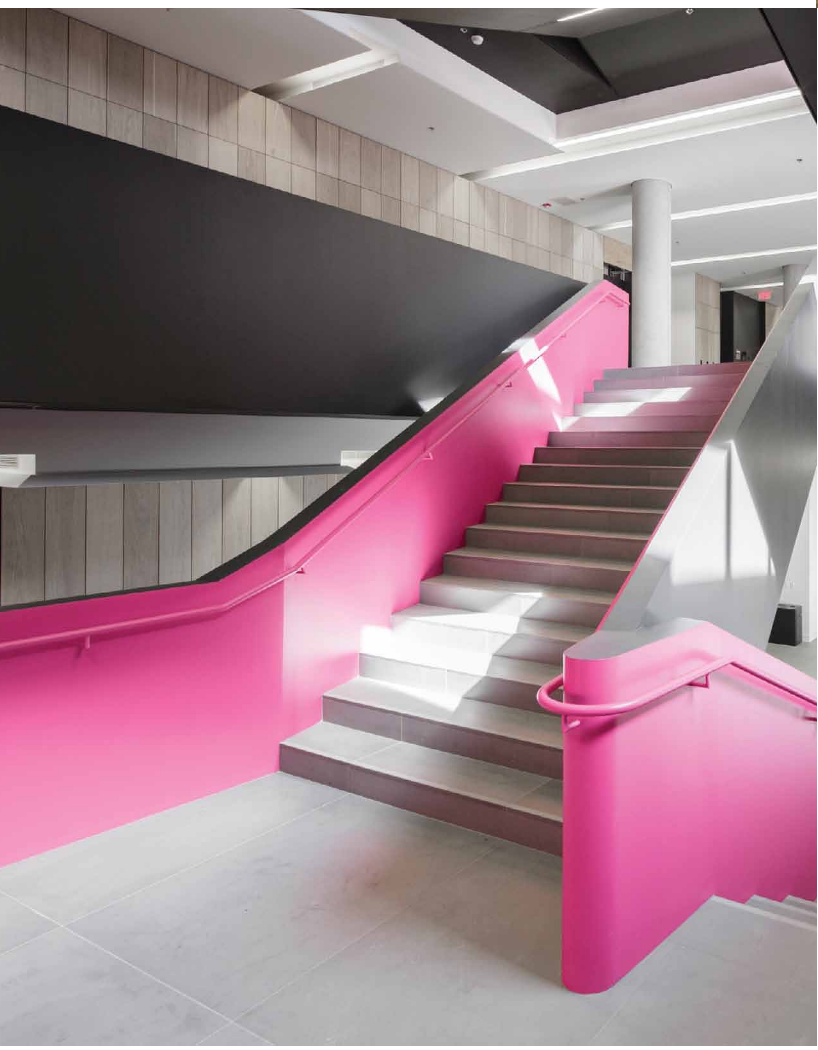
The system supplies 70% of total heating for approximately 250,000 m^2 of space, avoids about 70% of GHGs in comparison to traditional heating, and is self-funded, providing a return on investment for Vancouver taxpayers. More than that, the utility provides a shared infrastructure platform that offers price stability, scalability and adaptability to other sources of renewable low-carbon energy. It's a great example of how to create resilient neighbourhoods and communities that can weather, and quickly recover from, extreme events while offering huge sustainability benefits today. **For more information see: www.greenenergyfutures.ca/blog/waste-heat-how-vancouver-mined-its-sewage-heat-entire-neighbourhood**

FALSE CREEK ENERGY CENTER, VANCOUVER: Precast concrete geothermal sewer pipes contribute to False Creek Energy Center's resilient infrastructure platform. Architect: Walter Francl Architecture Inc. Stacks designed by Pechet and Robb Architecture Ltd.

RESEARCH AND INNOVATION

Research in the Spotlight: MIT Concrete Sustainability Hub

The MIT Concrete Sustainability Hub is an interdisciplinary team of MIT science, engineering and economics researchers focused on three core areas of concrete innovation to achieve more durable and sustainable homes, buildings, and infrastructure in ever more demanding environments.



- ***Materials Science:*** modeling techniques, starting at the atomic level, to predict structures and properties that will improve how cement is designed, reduce CO_2 emissions, and enable US leadership in future cement technologies.

- ***Buildings & Pavements:*** innovative solutions for concrete engineering applications in buildings and pavements. For buildings, research focuses on durability, energy efficiency, and resiliency. For pavements, research focuses on improving structure and design that can result in increased fuel efficiency and lower maintenance costs.

- ***Economics & Environment:*** improved life cycle assessment and life cycle cost analysis techniques to help stakeholders wisely use limited funding for infrastructure projects while considering environmental impacts.

TOP: SIMON FRASER UNIVERSITY – ARTS AND SOCIAL SCIENCE COMPLEX, BURNABY, B.C. Architect: Busby Perkins + Will.

LEFT: ROTMAN SCHOOL OF MANAGEMENT EXPANSION, UNIVERSITY OF TORONTO. Architect: Kuwabara Payne McKenna Blumberg Architects.

PRODUCT INNOVATION IN ACTION

Ultra-High Performance Concrete

Ultra-high-performance concrete (UHPC) is on the leading edge of concrete innovation, permitting the construction of exceptionally light, strong, durable and long service-life structures using less concrete more efficiently. One of the key applications for UHPC is for critical infrastructure, where long-service life in increasingly harsh environments is desired. Reinforced with high-carbon metallic fibers, structural UHPC products can achieve compressive strengths up to 200 MPa and flexural strengths up to 20 MPa. For architectural UHPC applications, Polyvinyl Alcohol (PVA) fibers are used. Architectural UHPC can achieve compressive strengths up to 117 MPa and flexural strengths up to 20 MPa. Due to the material's superior compressive and flexural properties, the need for passive reinforcing can be eliminated or greatly reduced (depending on the application). It is also highly moldable and replicates form materials with extreme precision, allowing for thin, complex shapes, curvatures and customized textures not possible with traditional reinforced concrete. For architects and developers, the advantages of UHPC are numerous and typically include reduced global costs such as formwork, labor, maintenance and speed of construction.

SHAWNESSY LIGHT RAIL TUNNEL STATION, CALGARY: Calgary's Shawnessy's Light Rail Station incorporates ultra-high-performance concrete, which permits the construction of exceptionally light, strong, and durable structures using less concrete. Architect: Stantec Architecture. Photo: Vic Tucker.

BOTTOM: PERVIOUS CONCRETE. Like permeable interlocking concrete pavement, pervious concrete offers a low impact development solution to stormwater management.

Pervious and Permeable Pavements

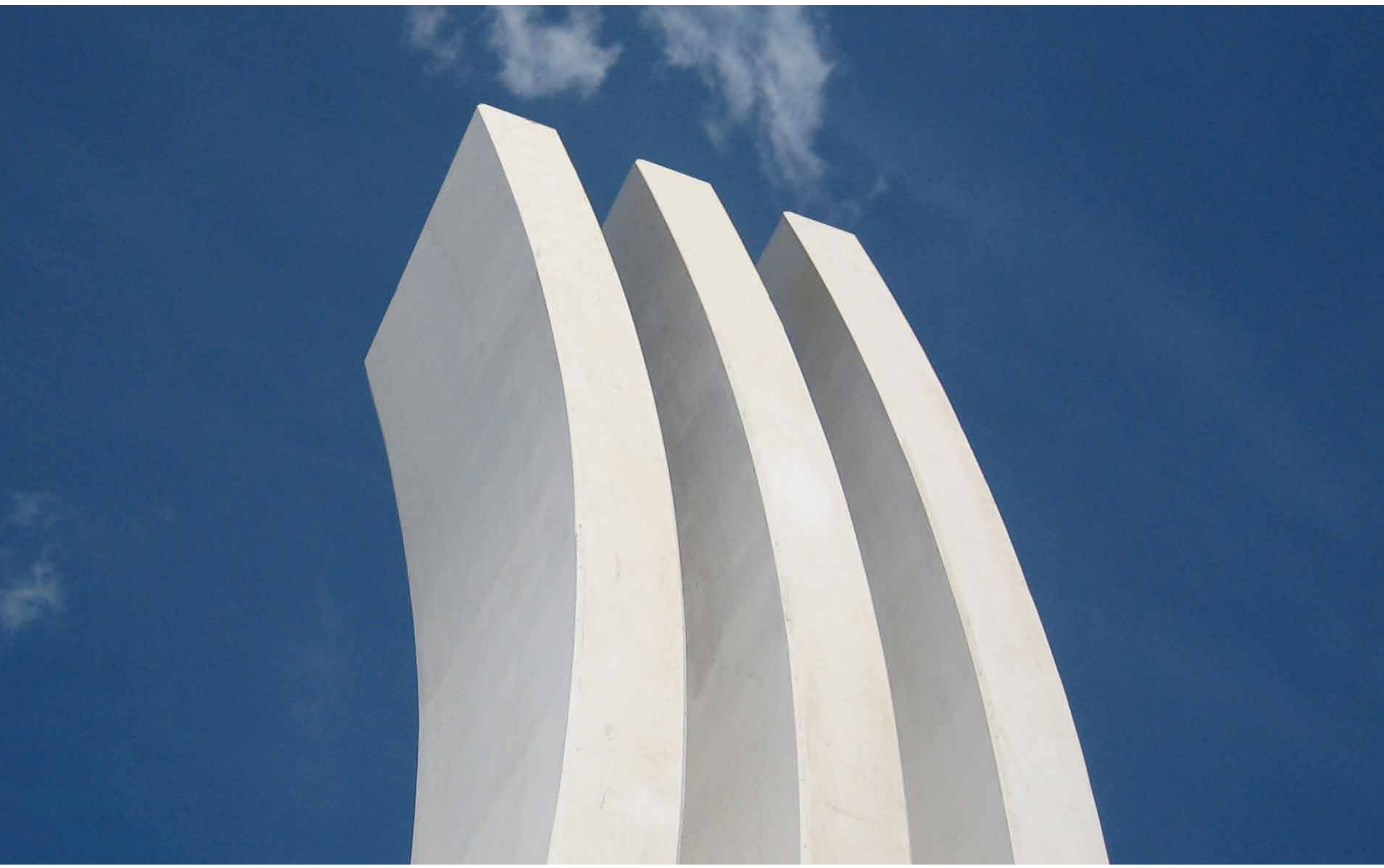
Urban development alters the natural landscape of our communities, creating hardscape surfaces that prevent infiltration of water into soil surfaces and increasing runoff. Stormwater runoff can send as much as 90% of pollutants, such as oil and other hydrocarbon liquids found on the surface of traditional parking lots, directly into rivers and streams. By capturing rainfall and allowing it to percolate into the ground, soil chemistry and biology can treat the polluted water naturally. It can also play an important role in flood mitigation in urban environments. Permeable interlocking concrete paving systems (PICP) and pervious concrete pavements (PCP) both offer a low-impact development (LID) solution to restore the natural ability of an urban site to absorb stormwater.

Photocatalytic Concrete

Today, the sustainable movement has two new words to get acquainted with, words that may be even more important since they affect not just construction but the very quality of life in our communities: depollution and photocatalysis. Photocatalysts keep concrete clean and depollute the air we breathe. Important new concepts often require new words to convey their meanings.

Here is how it works. Strong sunlight or ultraviolet light decomposes many organic materials in a slow, natural process. Photocatalysts accelerate this process and, like other types of catalysts, stimulate a chemical transformation without being consumed or worn out by the reaction. When used on or in a concrete structure, photocatalysts decompose organic materials such as dirt, including; biological organisms, mold, bacteria; airborne pollutants, including volatile organic compounds, and the nitrous oxides [NOx] and sulfuric oxides [SOx] that are significant factors in smog. Plus it's self cleaning (based on particles of titanium dioxide).

THE I-35 GATEWAY MONUMENTS, MINNESOTA. Built using photocatalytic concrete. Designed by Oslund and Associates.



CEMENT MANUFACTURING AND GHGs

Cement is the "glue" that makes up, on average, 10-15% by weight of concrete. As such, it plays an important role in the construction of durable resilient structures worldwide. While cement contributes as little as 3% to a building's total lifecycle greenhouse gas emissions (GHGs), (see the Athena Materials Institute study discussed on page 7), the cement industry recognizes the importance of sustainable stewardship to minimize its environmental impacts, particularly the need to reduce manufacturing GHGs.

The cement industry's commitment to reducing GHGs extends back at least two decades when it made major capital investments in new energy efficiency technologies, such as waste heat recovery through pre-heater towers. Today, the industry's two primary strategies for reducing CO_2 are to a) substitute fossil fuels with low carbon and renewable fuels; and, b) reduce the amount of clinker required in cement and the amount of cement required in concrete. The second strategy is where architects, engineers and planners can play an important role in reducing the embodied CO_2 of their projects by specifying low clinker cement as well as mix designs that maximize cement substitution in accordance with required performance specifications. In fact, cement substitution with by-products of other industrial processes (e.g. fly ash, slag and silica fume) can significantly reduce embodied CO_2 while also diverting waste from landfill. Three years ago, the cement industry introduced to the Canadian market a product called Contempra (referenced in the National Building Code under the name of Portland-limestone cement). Contempra reduces CO_2 emissions by 10% - 12%, while producing concrete with an equivalent level of strength and durability to concrete produced with regular Portland cement.

There are many technologies coming on stream that hold promise for even more dramatic reductions. Carbon capture, reuse and storage technologies are still evolving, but they suggest that carbon neutral cement is both technologically feasible and a likely potential in the future of the industry.

30, RUE VICTORIA, GATINEAU. This was among the first buildings in Eastern Canada to be constructed using Contempra-based concrete.

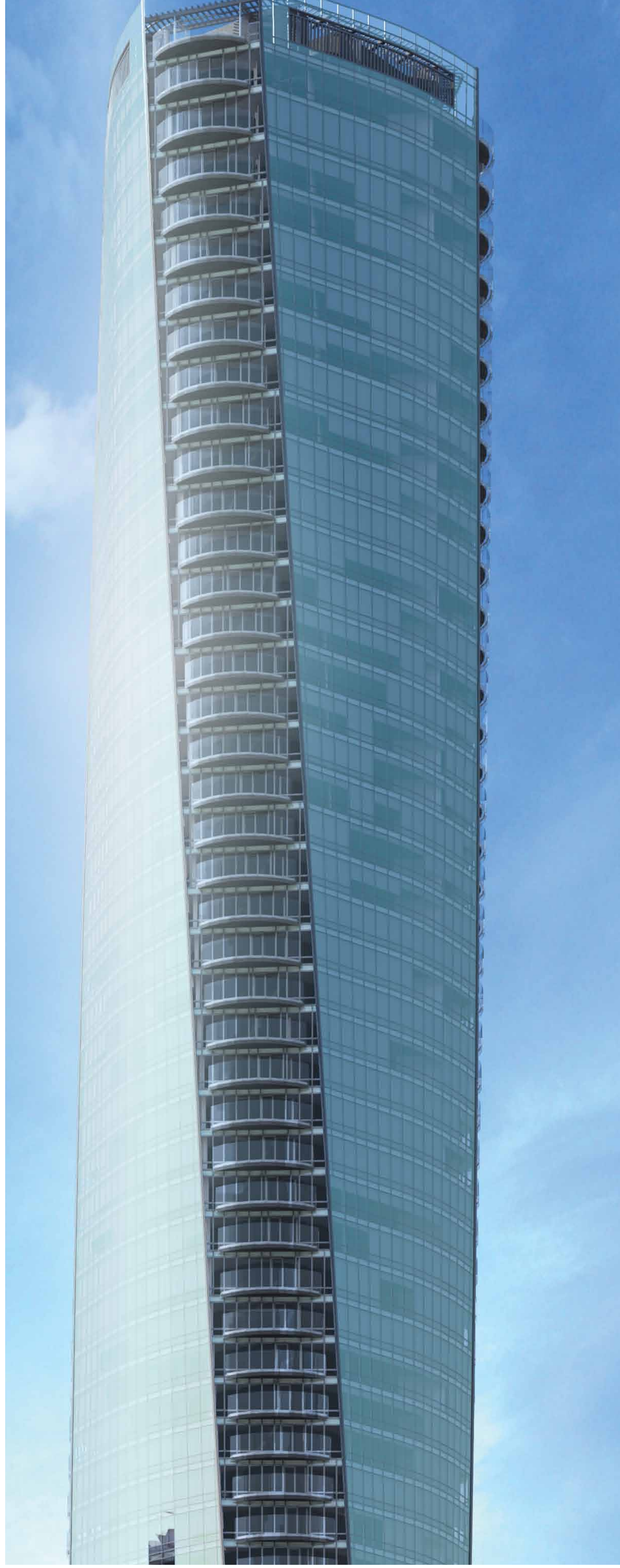
Reducing GHGs with Contempra

In 2011, the Canadian cement industry introduced Contempra™, a new cement that reduces CO_2 emissions by 10% while still producing concrete with the same level of strength and durability as concrete produced with regular Portland cement. This is achieved by intergrinding regular clinker (the main ingredient in cement) with up to 15% limestone, which is 10% more than in regular Portland cement. Reducing the clinker content of cement in this way reduces the amount of emissions associated with its manufacturing.

Today, Contempra is rapidly becoming the preferred standard for the majority of new concrete construction projects in Canada. In British Columbia alone, it accounted for nearly 50% of the domestic cement consumed in the province in 2013. This uptake will accelerate as more and more developers and builders specify the carbon-reduced cement for their projects, leading to potential GHG reductions of up to 900,000 tonnes annually.

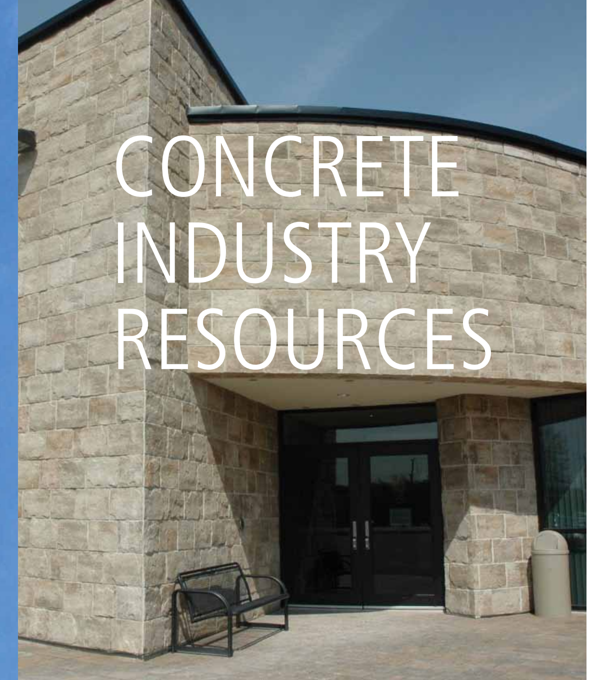
Among the many Contempra projects completed or underway in Canada are the Trump Tower and the Wall Center False Creek Development, both in Vancouver; the Lansdowne Park redevelopment project in Ottawa; the McGill University Health Centre and the Centre hospitalier universitaire Sainte Justine in Montreal; and a multitude of condominium, commercial and institutional projects throughout the country.

Other innovations, such a carbonated concrete (concrete that is cured with CO_2 instead of, or in addition to, water) and the use of novel biogenic fuel sources (e.g. algae grown with flu gas) are quickly evolving and showing tremendous promise for a future of low-carbon concrete. Technologies nearing the commercialization phases today may soon reduce cement CO_2 emissions by up to 70%.



THE TRUMP TOWER, VANCOUVER: Built using lower carbon Contempra-based concrete, the Arthur Erickson-designed twisting Trump tower will stand at 63 storeys in downtown Vancouver. Architect: Arthur Erickson. Photo: Trump International Hotel & Tower, Vancouver.

BACK COVER: ONE KING STREET WEST, TORONTO. The 51-storey tower is the most slender building in the world and the tallest residential building in Canada, framed in concrete and clad in a beautiful light buff precast concrete finish. Architect: Stanford Downey Architect Inc.



CONCRETE INDUSTRY RESOURCES

From the foundation of our homes to our skyscrapers, from our community centers to our bridges, transit ways, and other infrastructure installations – such as dams and water treatment plants – that are essential to our society's ability to function efficiently, we rely on concrete every day.

Whether it is precast concrete, cast-in-place concrete, insulating concrete forms, masonry, concrete pipe, or ready-mixed concrete, we use concrete in so many ways and in so many different types of construction and infrastructure. Each of these applications shares concrete's fundamental sustainability attributes.

Canadian cement companies and a great many independent producers of concrete in its many forms are active in industry associations that aim to advance knowledge of concrete. In 2013, these associations came together to form the Concrete Council of Canada. They can be found on **rediscoverconcrete.ca**, a cement and concrete industry portal that provides comprehensive information on the sustainability of concrete and the activities of the Concrete Council of Canada.

CONESTOGA COLLEGE, ONTARIO: MASONRY TRAINING CENTRE, WATERLOO, ONTARIO. Architect: The Walter Fedy Partnership. Like other concrete products, concrete masonry is energy efficient, durable, resilient and requires very low maintenance.

APPLICATION	INDUSTRY ASSOCIATION	WEBSITE
Cement manufacturing	Cement Association of Canada	www..cement.ca
Architectural and Structural Precast and Prestressed Concrete Components	Canadian Precast Prestressed Concrete Institute	www.cpci.ca
Cast-in-place concrete	Canadian Ready Mixed Concrete Association	www.crmca.ca
	Provincial Ready Mixed Concrete Associations	
	Association Béton Quebec	www.betonabq.org
	Atlantic Concrete Association	www.atlanticconcrete.ca
	Ready Mixed Concrete Association of Ontario	www.rmcao.org
	Manitoba Ready Mix Concrete Association	www.mrmca.com
	Saskatchewan Ready Mixed Concrete Association	www.concreteworksharder.com
	Alberta Ready-Mixed Concrete Association	www.armca.ca
	BC Ready-Mixed Concrete Association	www.bcrmca.ca
Concrete pavements	Canadian Ready Mixed Concrete Association	www.crmca.ca
	Provincial Ready Mixed Concrete Associations	see cast-in-place concrete
	Interlocking Concrete Pavement Institute	www.icpi.org
Concrete pipe	Canadian Concrete Pipe and Precast Association	www.ccpa.com
	Tubécon (Quebec)	tubecon.qc.ca
Insulated Concrete Forms	Canadian Ready Mixed Concrete Association	www.crmca.ca
Interlocking concrete pavement	Interlocking Concrete Pavement Institute	www.icpi.org
Masonry	Canadian Concrete Masonry Producers Association	www.ccmpa.ca
Pervious and permeable concrete pavements	Canadian Ready Mixed Concrete Association	www.crmca.ca
	Provincial Ready Mixed Concrete Associations	see cast-in-place
	Interlocking Concrete Pavement Institute	www.icpi.org

CONCRETE COUNCIL OF CANADA

rediscover CONCRETE