Ultra-high-performance fiber-reinforced precast concrete proves market potential

Gold Bar Wastewater Treatment Plant

Sue McCraven

Over the next few years, North America and Europe are projected to capture over two-thirds of the global water and wastewater market share.[1] This significant growth in water treatment infrastructure underscores the untapped potential for ultra-high-performance (UHP) fiber-reinforced precast concrete, a material used in clarifier troughs in the world's first application of its kind at the Gold Bar Wastewater Treatment Plant in Edmonton, AB, Canada.

This aerial photo shows the location of Edmonton's Gold Bar Wastewater Treatment Plant in Alberta, Canada. The plant treats domestic and industrial wastewater for more than 700,000 residents. The orange and green shading were added to indicate whether the facility's funding source was municipal or federal. Photo courtesy of Tucker Photography. Paul Grigonis designed the illustration.

The Gold Bar Wastewater Treatment Plant in Edmonton, AB, Canada, is credited by Alberta Environment for significant improvements in the water quality of the North Saskatchewan River. Photo courtesy of Tucker Photography.

Lying east of the Rocky Mountains and north of Calgary, Edmonton is the capital of Alberta, operations center for abundant oil and gas resources, and the sixth largest metropolitan area in Canada. Situated among parklands in the North Saskatchewan River Valley, Edmonton's wastewater receives tertiary treatment at the Gold Bar plant, where a recent expansion demonstrates the potential for next-generation technologies initiated in the precast concrete industry.

Gold Bar is situated on 19.5 ha (48 acre) along the shore of the North Saskatchewan River and is bounded by extensive city parks with over 150 km (93 mile) of nature trails. Edmonton's North Saskatchewan River Valley is the largest urban parkland in North America, encompassing 7400 ha (18,300 acre). This location within exceptional urban recreation and park resources makes the plant's tertiary treatment of municipal wastewater of regional importance in maintaining water quality. In providing tertiary treatment, a biological process that reduces or eliminates phosphorous and ammonia-nitrogen, Gold Bar is among the top five plants of its type, Class IV, in treating domestic and industrial wastewater for over 700,000 people.

The City of Edmonton is committed to maintaining high standards of wastewater treatment through state-of-the-art refining technologies, processes, and equipment, including the new UHP fiber-reinforced precast concrete clarifier troughs that are integral to the project's goal of expanding the primary treatment capacity.

Alberta Environment, the Canadian government's counterpart to U.S. state regulatory agencies for natural resources and environmental quality, credits the North Saskatchewan River's significant increases in water quality in the past 10 years to the constant process upgrades and innovations at Edmonton's treatment plant.[2] In addition to being at the forefront of wastewater treatment technology, Gold Bar is the first facility in the world to incorporate clarifier troughs made with Ductal UHP fiber-reinforced precast concrete. Ductal is Lafarge North America's range of patented UHP concretes with ductile characteristics.

Team members

Project architect:

Stantec Architecture Ltd. of Edmonton, AB, Canada

Engineer of record:

Jacobs Canada Inc. of Edmonton

Owner:

The City of Edmonton

General contractor:

Sure-Form Construction Ltd. of Edmonton

Precaster:

Lafarge Canada Inc. of Edmonton

Precast specialty engineer, structure:

RJC of Edmonton

Precast specialty engineer, troughs:

Kassian Dyck and Associates of Calgary, AB, Canada

UHP fiber-reinforced precast concrete important to wastewater treatment

Amid the natural beauty of this Canadian river valley, the Gold Bar plant processes about 95,000 ML/yr (25,000 million gal./yr) of wastewater, including flows from both the sanitary and combined sewer (sanitary and storm) systems. The plant expansion allowed Gold Bar to increase its primary treatment capacity from 920 ML/d (240 million gal./d) to 1600 ML/d (420 million gal./d). With this critical added capacity, a much larger volume of wet-weather discharge from the city's older, combined sewer system now receives treatment, thereby increasing the quality of water entering the Saskatchewan River.

The clarifier troughs are shown in operation at the Gold Bar Wastewater Treatment Plant in Edmonton, AB, Canada. Photo courtesy of Tucker Photography.

To better appreciate the role of the world's first use of UHP fiber-reinforced precast concrete clarifiers, it is important to understand the basics of wastewater treatment. As in most large cities, Edmonton's municipal wastewater is collected from sanitary and combined sewers.

In primary treatment, sewer effluent goes through a grit removal system to remove inorganic solids; these heavy solids sink to the bottom of the grit tanks. Flow from the grit tanks passes through bar screens to remove large debris that can clog machinery. Solids from the grit tank are removed, washed, and deposited in a sanitary landfill. Wastewater is further processed in

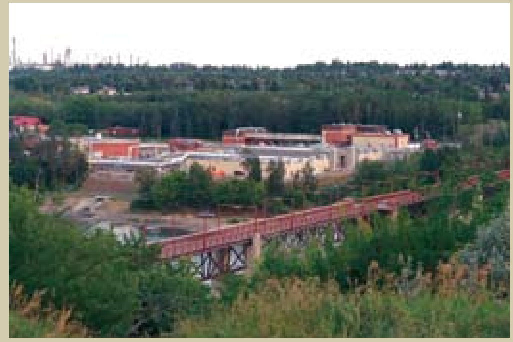
The plan drawing for the Gold Bar Wastewater Treatment Plant shows the process flow diagram and the position of the clarifier troughs. Figure courtesy of Stantec Architecture Ltd.

Global demand for water and wastewater treatment increases

A majority of the wastewater treatment plants built in the United States in the past three decades are in need of total replacement or expensive renovation and expansion work to comply with the Clean Water Act (originally the Federal Water Pollution Control Act of 1972) .

The market for precast concrete enclosures, as well as for ultra-high-performance fiber-reinforced precast concrete process vessels, for wastewater treatment facilities can be estimated based on the anticipated future expenditure on secondary water-treatment facilities. According to the American Society of Civil Engineers' 2005 Report Card for America's Infrastructure, "Aging wastewater management systems discharge billions of gallons of untreated sewage into U.S. surface waters each year. The EPA estimates that the nation must invest $390 billion over the next 20 years to replace existing systems and build new ones to meet increasing demands."

The infrastructure needs of the global water and wastewater treatment markets are even more staggering, calling for $680 billion in new construction. This figure includes equipment and services for both wastewater treatment and drinking water purification.



The City of Edmonton's Gold Bar Wastewater Treatment Plant used new material technology developed in the precast concrete industry for processing equipment in a recent expansion project. Photo courtesy of Tucker Photography.

An aging infrastructure, increasing population growth, rapid urbanization, and a strengthening regulatory environment in the European Union and India will continue to drive new construction for wastewater treatment plants around the world. Advances in materials development and innovative and economic design approaches in the precast concrete industry that transfer into practice, particularly in the wastewater-treatment market, have made an auspicious arrival.

Global water/wastewater market by region, 2010

Market	Size	Market Share, %
North America	247	36.2
Western Europe	227	33.3
Japan	113	16.6
East and Southeast Asia	27	4.0
Latin America	15	2.2
CEE and CIS	15	2.2
China	13	1.9
Australasia	13	1.9
Middle East	7.7	1.1
India	4.7	1.1
TOTAL	682	

Source: Data from *Water and Wastewater Technologies Report*
Note: CCE = Central and Eastern Europe; CIS = Commonwealth of Independent States.

the enhanced primary clarifier equipped with UHP fiber-reinforced precast concrete troughs. In the primary settling tanks, biosolids are removed from the bottoms of the tanks, and fats, oils, and grease rise to the top and are skimmed. Remaining water is then distributed to equalize flow through the remainder of the treatment process.

Secondary and tertiary treatment follows, wherein mechanical mixing and aeration prevent settling of solids as the wastewater is infused with air in aeration tanks for biological processing. Air supplies oxygen to microorganisms responsible for removing pollutants and nutrients from the waste stream through a biological nutrient removal process, leaving a clear liquid that flows into secondary settling tanks. Solid residuals are removed and the cleaned water is processed further.

After the biological processes, the tertiary-treated effluent flows through ultraviolet disinfection to remove disease-causing bacteria. In the Gold Bar plant's tertiary treatment process, 98% of contaminants are removed before the effluent returns to North Saskatchewan River.

Because the UHP fiber-reinforced precast concrete primary clarifiers in the Gold Bar plant receive the initial, untreated wastewater from Edmonton's domestic and industrial sewers, the need for a product with superior durability, strength, and impermeability to contaminants and corrosives becomes clear. Stainless steel has been the traditional material of choice for wastewater-treatment clarifying basins. This first use of state-of-the-art precast concrete material technology in wastewater processing in the Gold Bar expansion project creates new, economical design options for future construction in water treatment facilities worldwide.

The expansion design evolves

Stantec Architecture Ltd. of Edmonton, the City of Edmonton's design and engineering consultants for the owner, recommended the original design for the Gold Bar expansion. Initial plans outlined a steel structure with steel columns, beams, joists, and decking and masonry walls with steel cladding and stainless-steel clarifier troughs. During the design phase, however, market indicators warned of materials shortages and impending cost increases in the steel manufacturing industry. Industry shortfalls for steel would certainly affect the availability of specialty products, particularly the stainless steel for the plant's clarifiers.

As a result of an earlier presentation on UHP fiber-reinforced precast concrete by Lafarge Canada Inc. of Edmonton, the precast concrete material supplier and precaster, and based on Lafarge's extensive technical resources and successful working relationships with Stantec Architects Ltd., the consultants invited Lafarge to submit alternative designs for the Gold Bar plant expansion.

Stantec took a proactive approach in materials selection by researching UHP fiber-reinforced precast concrete's properties to satisfy itself that the material would perform in this application and worked closely with Lafarge during the design and budget-development stages to confirm its redesign decision. It was through this collaborative teamwork among the material supplier, designer, and engineer that a new economic design became a viable option for the owner.

This teamwork led to a redesign of the entire project. The new design laid out construction of an all-precast-concrete expansion building, including precast concrete beams, columns, and 300-mm-thick (12 in.) hollow-core, with UHP fiber-reinforced precast concrete clarifier troughs for the primary wastewater process area. Considerable design work and attention to

From top **The interior of the Gold Bar Wastewater Treatment Plant in Edmonton, AB, Canada, shows columns, beams, and 300-mm-thick (12 in.) hollow-core.** Photo courtesy of Tucker Photography.

The hollow-core slabs of the Gold Bar Wastewater Treatment Plant support a crane rail system. Photo courtesy of Tucker Photography.

This photo shows the exterior wall elevation of the Gold Bar Wastewater Treatment Plant. Photo courtesy of Tucker Photography.

Gold Bar Wastewater Treatment Plant expansion precast concrete components

Precast, prestressed concrete component	Number	Dimensions
Column	36	306 mm x 305 mm
Structure beam	33	410 mm x 810 mm
Hollow-core	324	305 mm, 7.3 m span
Loadbearing insulated wall panel	202	
Clarifier trough, UHP fiber-reinforced precast concrete	192	

Note: UHP = ultra-high-performance. 1 mm = 0.03937 in.

detail were required to accurately size the elements and connections, as well as to maintain budget pricing for the owner.

The first consideration for the precast concrete redesign was the location and operation of the process equipment. Equipment requirements dictated the positioning of columns, which in turn mandated span requirements. When the project's exterior walls were changed from loadbearing masonry to loadbearing, insulated, precast concrete panels, the originally proposed steel cladding for the enclosure was eliminated. During project re-engineering, the precaster designed and priced UHP fiber-reinforced precast concrete troughs and developed a precast concrete structure to enclose the process area.

Architectural precast concrete suits the park setting

Stantec designed the exterior of the Gold Bar plant with balanced color, form, patterns, and natural vegetation to create a low-profile structure. Edmonton city planners and project designers made every effort to minimize an industrial-plant appearance and to maximize the structure's external harmony with its natural surroundings. The final design incorporates the following aspects to meet these needs:

- Simple forms create an interesting, formal, architectural pattern that considers views from adjacent parks, trails, and the river.
- Areas of color are introduced to offset and complement the large scale of the clarifier building.
- A material palette of precast concrete panels and brick complements the existing facilities.
- Integrated architectural forms allow natural light into the facility and create attractive glowing forms at night.
- Strategically placed areas of low plantings and stands of trees frame desirable views and screen unwanted ones.
- Natural hues are used in the precast concrete insulated sandwich panels.
- Areas of Kalwall (a high-performance, insulated, corrosion-resistant, translucent panel) integrate natural light and the emergency mechanical exhaust systems to produce an illuminated look at night.
- A larger center form breaks up the elevation and provides an opportunity for color contrast and visual interest.

Weight limitations affect the design

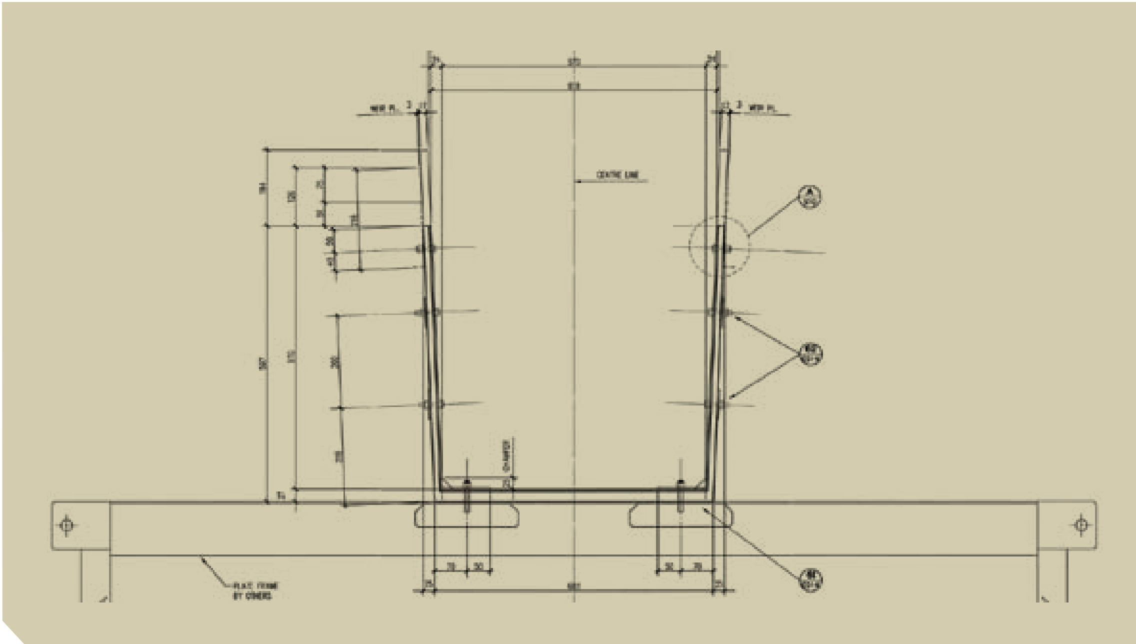
In addition to aesthetic requirements and structural cost considerations, the Stantec design team faced major technical hurdles in its quest to find a replacement material for the process equipment. Specifications for the stainless-steel clarifiers called for both superior durability in service and restrictions on dead weight for the troughs.

Because the clarifier troughs sit on top of filter plate frames, the weight of the troughs is restricted by the limited support capacity of the frames. In addition, during the life of the plant, the troughs need to be removable to allow the underlying plate packs to be serviced. Conventional concrete, at about 2400 kg/m^3 (150 lb/ft^3), is too heavy to be practical in this application.

Design engineers were able to take advantage of UHP fiber-reinforced precast concrete's remarkable material properties to effectively replace the original, 6.5-mm-thick (0.25 in.), U-shaped, stainless-steel clarifier troughs with UHP fiber-reinforced precast concrete clarifier troughs with a thickness of 17 mm (0.7 in.) and a cross section of 0.6 m × 0.6 m (2 ft × 2 ft). A UHP fiber-reinforced precast concrete trough weighs about 50 kg/m^2 (10 lb/ft^2). A 4.6-m-long (15 ft) trough weighs 380 kg (840 lb), which was slightly less than the originally planned stainless-steel troughs. Altogether, about 1000 linear m (3300 ft) of UHP fiber-reinforced precast concrete clarifier troughs was installed in the Gold Bar plant expansion.

The precast concrete redesign met the dead-weight limitation for the troughs because of the high strength and durability achieved in UHP fiber-reinforced precast concrete elements with relatively thin cross sections compared with conventional concrete. Stainless steel was significantly more expensive than any of the other material options, and the owner decided to use precast concrete for economic reasons more than equipment weight restrictions.

The elevation drawing illustrates the low profile of the process and chemical storage buildings at the Gold Bar Wastewater Treatment Plant in Edmonton, AB, Canada. Figure courtesy of Stantec Architecture.



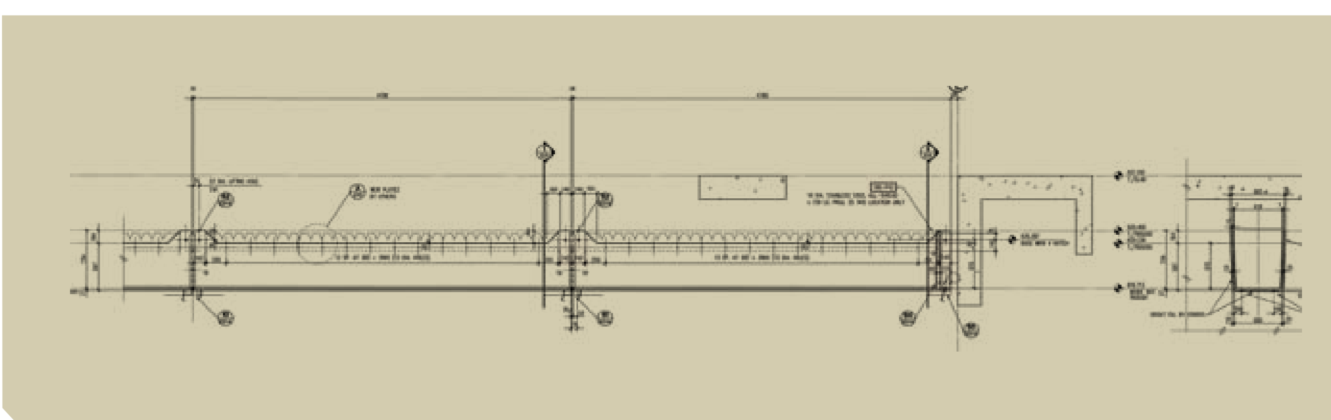
The drawing of a trough cross section shows the remarkable thinness that can be acheived with ultra-high-performance fiber-reinforced precast concrete. Note: All dimensions are in mm. 1 in. = 25.4 mm. Figure courtesy of Lafarge Canada Inc.

A crack in a steel trough, however, can be repaired with welding, whereas a crack in a precast concrete element would necessitate replacement. Thus, the importance of the high strength, ductility, and impact resistance that is afforded by UHP fiber-reinforced precast concrete is apparent. Because of the concrete's lower cost, Lafarge Canada Inc. was allowed to make the alternative bid for the project and UHP fiber-reinforced precast concrete became the base bid for the expansion's new clarifier troughs. Structural and stainless steel remained the initial bid for the project.

In its application at the treatment plant, the UHP fiber-reinforced precast concrete uses steel fibers for reinforcement, which permits the creation of remarkably thin products with strengths comparable to steel-bar-reinforced concrete and stainless steel. The high-carbon metallic fibers in the mixture are extremely small, 0.2 mm (8 mil) in diameter and 13 mm (0.5 in.) long, and can easily puncture human skin. Polyvinyl alcohol (PVA) fibers are typically used in applications in which significant human contact with the material is expected. Ductal mixtures incorporate a third-generation, high-range water-reducing admixture.

The main enclosure for the facility expansion measures 92.4 m × 40.8 m (303 ft × 134 ft) for a total area of 3810 m^2 (41,000 ft^2), and the height of the building is 7.73 m (22.1 ft). Total project cost was US$60 million, and the project timeline was two years, from January 2005 to December 2006.

This view shows the cross section through the length of the clarifier trough. Note: All dimensions are in mm. 1 in. = 25.4 mm. Figure courtesy of Lafarge Canada Inc.



Tolerances in production are exacting

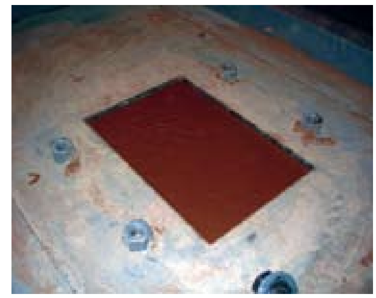
Much tighter production tolerances are required when casting thin sections of UHP fiber-reinforced precast concrete with a wall thickness of 17 mm (0.7 in.). Application of typical precast concrete manufacturing tolerances, commonly specified as -3.0 mm (-0.125 in.) and +6.5 mm (+0.25 in.), would represent about 15% to 30% of the trough wall thickness—tolerances that are unacceptably large for fabrication of the thin-walled troughs. For trough production, precast specialty engineers Kassian Dyck and Associates of Calgary, AB, Canada, specified a wall thickness tolerance of ±0.100 mm (4 mil).

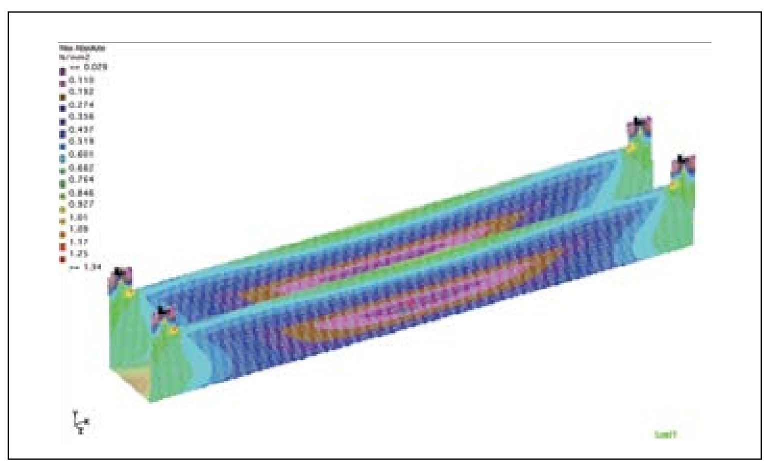
UHP fiber-reinforced concrete casting must be allowed to shrink unrestrained as the concrete transitions from a fresh to a hardened state. Essentially, this means that the form must support the precast concrete product while allowing shrinkage to occur. Therefore, the precast concrete contractor for the clarifier troughs elected to cast the product orientation opposite that of the installed product by using a form designed with a mechanism that allows complete rotation.

The trough mold was initially filled as an upside-down U shape, and a top, or cover, was installed to close the mold. The form's cover contained windows through which the mold was topped off with fresh UHP fiber-reinforced concrete. When the form was filled and before it was rotated to a right-side-up orientation, a slight positive hydrostatic pressure was introduced and maintained on the fresh UHP fiber-reinforced concrete until initial set was achieved. The inner form was then removed to allow for shrinkage while the outer form remained in place to support the product.

Precast concrete trough elements were tightly covered with plastic to prevent warping within the slender sections. Warping could result from differential rates of evaporation between the exposed inner faces of the trough and the form-covered outer surfaces during production. When the product reached release strength, a specially designed lifting device engaged the holes that would be used to connect the steel weir plates. This design eliminated the need to cast lift hooks or inserts for transport and erection.

Hydrostatic pressure on a UHP fiber-reinforced precast concrete form during the casting operation is higher than that for regular concrete. This means that





From top **Workers at Lafarge begin the initial trough fill using a U-shaped form in a position that is inverted from the final in-place orientation in the plant.** Photo courtesy of Lafarge Canada Inc.

This picture shows the window in the top of the form. Photo courtesy of Lafarge Canada Inc.

The trough casting is covered with polyethylene after the removal of the interior form. Photo courtesy of Lafarge Canada Inc.

The trough schematic shows finite element analysis for one perspective of loaded condition. Figure courtesy of Lafarge Canada Inc.

Ultra-high-performance fiber-reinforced precast concrete troughs are ready for transport at the Lafarge precasting facility. Photo courtesy of Lafarge Canada Inc.

form deflection considerations govern design and finite element analysis was used for trough form design. Trough gravity loads were calculated based on simple bearing on the supporting-plate pack frame.

The toughest challenge in designing the UHP fiber-reinforced precast concrete troughs was calculating the most efficient way to dissipate the point loads created by buoyancy forces at the tie-down locations. The stiffness of the stainless-steel anchor plates served to distribute the point loads as well as compensate for any localized thickening of the UHP fiber-reinforced precast concrete.

Because the UHP fiber-reinforced precast concrete is self-consolidating, form vibration was not required.

Precast concrete design has construction advantages

The design team elected to use precast, prestressed concrete hollow-core as the main span members to provide a smooth, flat surface that would be ready to receive the roofing system. The interior surface of the hollow-core also provided an attractive, smooth finish that could easily be left as-is or coated. Precast concrete columns and beams were chosen to support the hollow-core roof, allowing U.S. Filter, Siemens Water Technologies Corp., of Ames, Iowa, essential access for installation of the inclined plate settlers before construction of the building's enclosure.

This view shows construction of the exterior walls. Photo courtesy of Lafarge Canada Inc.

Another logistical advantage in choosing precast concrete elements was that the general contractor, Sure-Form Construction Ltd. of Edmonton, did not need to install and remove formwork in the process area, labor-intensive work that would have been difficult to complete with equipment in place. Building walls were constructed with precast, prestressed concrete insulated sandwich panels, providing an efficient, durable wall system that functions as the building's envelope. After erection of the precast concrete structure, all exterior and interior precast concrete surfaces were finished with a colored stain.

Crane access was limited to the west side of the existing treatment facility. With no available laydown area for materials, the contractor needed to pay careful attention to scheduling crane operations that would orchestrate efficiently with material deliveries and the heavy-lifting needs of all of the trades working on the site. Site access restrictions meant that the precast concrete pieces were hoisted from the transport truck and immediately positioned within the structure using a 230 tonne (250 ton) crane. Plate packs were installed first in the crane sequencing, followed by the troughs and the structural elements. Identical sequencing was followed for the north and south clarifier installations in two separate mobilizations.

Treatment plant has aggressive environment

An aggressive environment, both internally and externally, exists at Edmonton's wastewater treatment facilities. Alberta's winter temperatures can drop as low as –40 °C (–40 °F), with an average high of –3 °C (27 °F) and an extreme average low temperature of –15 °C (5 °F). Internally, the building encloses large areas of open water with constant ambient conditions of high humidity and interior temperatures near the frost point. The expansion buildings that enclose the process areas were initially conceived as steel structures with exterior concrete masonry walls, and the building architect and structural consultant quickly realized that the steel framing solution would face environmental challenges, including high humidity conditions.

The site's combination of high humidity and low temperatures creates the potential for generating condensation on exposed interior building surfaces. In this aggressive environment, steel requires special coatings and frequent maintenance to prevent corrosion.

Project designers established that concrete would provide a better solution for the City of Edmonton because concrete has no adverse reaction to moisture and, in fact, exhibits optimal curing conditions in the presence of moisture. Corrosion protection, however, was an important concern in the design. A trough made of precast concrete reinforced with steel bars requires significant clear cover over the reinforcing steel in an aggressive environment, adding to the weight and cost of the structure. The UHP fiber-reinforced precast concrete design with steel fibers eliminated this concern. Cast-in-place concrete was used for the foundations, trenches, and process holding tanks. The forming/general contractor constructed this portion of the project.

Material characteristics of ultra-high-performance fiber-reinforced precast concrete

Material characteristics	Range
Compressive strength	180 MPa–225 MPa
Modulus of elasticity	55 GPa–58.5 GPa
Chloride ion diffusion	1.9×10^{-14} m^2/s
Flexural strength	40 MPa–50 MPa
Carbonation penetration depth	<0.5 mm
Salt-scaling resistance	<0.012 kg/m^2
Freezing and thawing resistance, RDEM	100%
Entrapped air content	2%–4%
Post-cure shrinkage, microstrain	0
Creep coefficient	0.2–0.5
Density	2440 kg/m^3–2550 kg/m^3
Steel-fiber length and diameter	12.7 mm and 0.2 mm

Source: Data from Lafarge North America

Note: RDEM = relative dynamic elastic modulus. 1 mm = 0.03937 in.; 1 MPa = 145 psi; 1 GPa = 145 ksi; 1 kg/m^2 = 0.205 lb/ft^2; 1 kg/m^3 = 1.69 lb/cy; 1 m^2/s = 1550 in.^{2}/s.

UHP fiber-reinforced precast concrete benefits Gold Bar

This new material technology provides many benefits in the Gold Bar plant expansion project:

- A lightweight solution for ease of installation and removal during plant maintenance
- Superior strength and self-consolidating moldability in thin-walled clarifier troughs
- Impact resistance for minimizing danger during maintenance and handling
- Superior corrosion resistance and durability in an aggressive wastewater environment
- Ductility for improved local deformation
- Low porosity, permitting almost no carbonation or penetration of chlorides and sulfides from the effluent stream
- Improved resistance to freezing and thawing during the area's harsh winters and abrasion resistance to suspended solids in wastewater
- Superior impermeability against absorption of water-borne contaminants and microbic growth in wastewater
- Elimination of lead times for stainless steel and faster production for locally manufactured troughs
- Significantly lower production costs for UHP fiber-reinforced precast concrete troughs than for the stainless-steel alternative
- An initial tender-price estimate that was sufficient rationale for the design consultant to allow its trial in the project
- A more cost-effective solution for the owner

UHP fiber-reinforced concrete lives up to name in tests

Testing at the Federal Highway Administration laboratory in McLean, Va., on a 24-m-long (80 ft), ultra-high-performance concrete American Association of State Highway and Transportation Officials Type II girder deflecting at 480 mm (19 in.) illustrates the ductility of this material under loading. Photo courtesy of Lafarge Canada Inc.

Ultra-high-performance (UHP) fiber-reinforced concrete has been purported by many in the concrete industry, from researchers to manufacturers, to be a promising material for the next generation of concrete.

With unprecedented strength, durability, and ductility, users wonder what the future holds for UHP fiber-reinforced concrete and whether the industry's expectations for it are realistic.

A 2006 report from the Federal Highway Administration, *Material Property Characterization of Ultra-High Performance Concrete*, supports many UHP fiber-reinforced concrete claims and expectations. More than 1000 specimens were tested to evaluate the material characteristics of UHP concrete for potential use in highway bridge applications.

Full-scale structural use of UHP fiber-reinforced concrete in a wide variety of applications, including building, bridge, and architectural construction, is coming. Numerous outstanding UHP fiber-reinforced concrete projects are already under way or completed.

Clockwise from upper left **The Jumping Trout, a creative and colorful application using colored Ductal on the GE5 highway project, was designed by artists Violet Costello and Bob Thomasson for the City of Calgary in AB, Canada.** Photo courtesy of Tucker Photography.

The 8.0 Chair made of Ductal was designed by architect Omer Arbel. This new-age furniture has a remarkably thin profile geometry. Photo courtesy of Shannon Loewen.

These ultra-thin and lightweight canopies at the Shawnessy Light Rail Train Station in Calgary were designed by Stantec Architects Ltd. The canopies were made possible by recent material advancements in precast concrete technology. Photo courtesy of Tucker Photography.

A combination of design efficiency and art, these bus shelters in Tucson, Ariz., portend the potential of advances in precast concrete material technology in architecture. Line and Space LLC designed the shelters. Photo courtesy of Ed McBain, GPA.

Next generation of concrete materials has potential

In construction, savings are often the result of new engineering solutions to old problems. This project clearly demonstrates UHP fiber-reinforced precast concrete's potential as a replacement for stainless steel due to its superior properties and lower initial cost. The Gold Bar plant application also demonstrates and validates this material's unique combination of superior strength, durability, ductility, and aesthetic design flexibility as an economical and durable replacement for stainless steel in industrial tanks, tubs, viaducts, and other industrial vessels that contain aggressive liquid compounds.

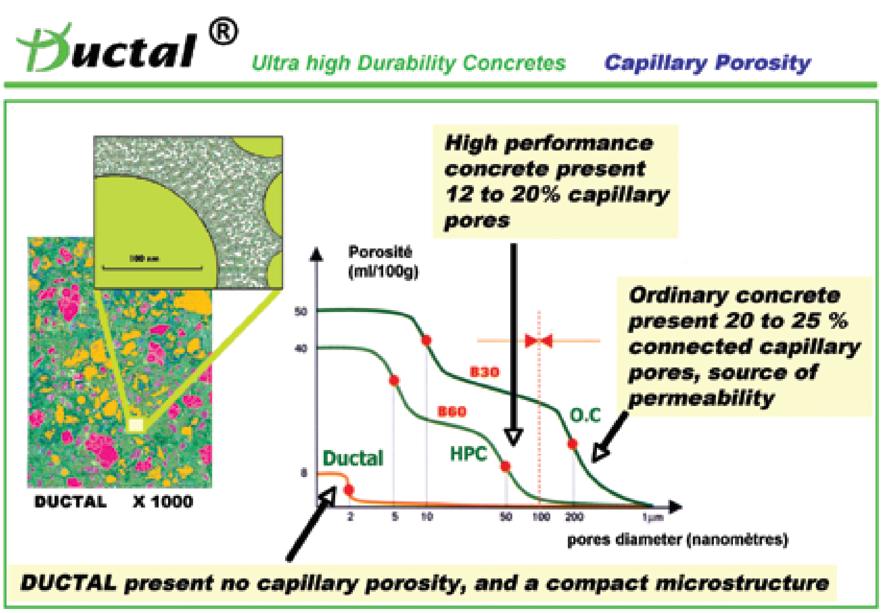
UHP fiber-reinforced precast concrete's material characteristics are verified by extensive testing at the federal level for durable bridges of longer spans and less weight. Every expectation in the industry is that UHP fiber-reinforced precast concrete is the harbinger of not-as-yet-conceived structures and lightweight precast concrete elements of unprecedented thinness, strength, and durability.

By using UHP fiber-reinforced precast concrete's combination of properties, designers can create thinner sections that are more graceful and innovative in geometry and form while providing improved ductility and impermeability against corrosion, abrasion, and impact. Increased use of UHP fiber-reinforced precast concrete has the potential to reduce costs in global construction, formwork, labor, and maintenance while improving site-construction safety, speed of construction, and service life.

Today, UHP fiber-reinforced precast concrete projects are being implemented around the world and applications include fresh design options for wall, roof, and floor systems; bridges; canopies; furnishings; and art.

One unusual area of exploration involves the use of UHP fiber-reinforced precast concrete for building blast-resistant panels for buildings subject to explosions. The material's high flexural strength and ductility result in a thinner and lighter impact-resistant panel than that of a conventional precast concrete design.

In North America, probably the most innovative and envelope-pushing use of UHP fiber-reinforced precast concrete to date is the construction of ultra-thin canopies for Canada's Shawnessy Light Rail Train Station in Calgary, AB, Canada.[3] The Shawnessy station has won numerous awards, including the Fédération International Du Béton (*fib*) award for outstanding structures.



Left Ultra-high-performance (UHP) fiber-reinforced precast concrete's durability is attributed to the raw material components, which are selected for their relative particle sizing and chemical reactivity. The largest-sized particle in the concrete matrix is the sand, at 0.5 mm (0.05 in.) diameter. UHP fiber-reinforced concrete's matrix has a disconnected pore structure that is 10% denser than ordinary concrete's. The absence of capillary pores prevents water and aggressive agents from penetrating. Figure courtesy of Lafarge Canada Inc.

Right This aerial view shows the completed expansion project at the Gold Bar Wastewater Treatment Plant in Edmonton, AB, Canada. Photo courtesy of Tucker Photography.

Conclusion

Edmonton's Gold Bar Wastewater Treatment Plant project illustrates the benefits of a building constructed with precast concrete and exemplifies the versatility of UHP fiber-reinforced precast concrete, proving its ability to meet the challenges faced by the owner and designers in a special-purpose and first-of-its-kind wastewater treatment application.

Designers chose a state-of-the-art precast concrete material over a stainless-steel option without sacrificing the owner's requirements, particularly the need for a low weight and corrosion resistance.

Clarifier troughs made with UHP fiber-reinforced precast concrete offer numerous advantages compared with conventional materials. Benefits include impact and corrosion resistance, improved impermeability against aggressive compounds, light weight, ease of installation and removal for maintenance, and high cost-effectiveness compared with stainless-steel alternatives.

The Gold Bar expansion project could become the precast concrete industry's marquee illustration of progress made in material design technology that allows precast concrete to compete successfully with steel. This project is an excellent example of UHP fiber-reinforced precast concrete's potential as a stainless-steel replacement in similar applications and serves as compelling motivation for designers to seriously consider innovative precast concrete solutions for their clients.

In awarding the Gold Bar expansion the Harry H. Edwards Industry Advancement Award, the PCI judges appraised the project, stating that "this innovative use of precast concrete takes advantage of the extreme durability offered by ultra-high-performance concrete. This exceptional durability makes the components impermeable to water-borne contaminants and microbic growth. This design offers an example of what can be achieved that can be used by other projects in the future. We believe this concept has great potential."

Acknowledgments

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About the author

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Synopsis

Over the next few years, North America and Europe are projected to capture over two-thirds of the global water and wastewater market share, which is estimated to be $474 billion. This significant growth in water-treatment infrastructure underscores the untapped potential for ultra-high-performance (UHP) fiber-reinforced precast concrete, a material used in clarifier troughs in the world's first application of its kind at Edmonton's Gold Bar Wastewater Treatment Plant in Alberta, Canada. This award-winning project demonstrates UHP fiber-reinforced precast concrete's superior properties of strength, durability, ductility, thinness, and precise moldability. At substantially less cost than that of the original steel design, the project validates UHP fiber-reinforced precast concrete as an excellent solution for similar applications in facilities that process aggressive liquid compounds in harsh environments. In addition to the clarifier troughs, this article discusses the all-precast-concrete expansion at Gold Bar, including precast concrete beams, columns, hollow-core, and the loadbearing, insulated, wall-panel building enclosure. This article explains how inspired designs with a new precast concrete material technology can transfer effectively and economically into practice in a global water-processing market that promises unprecedented growth in the near term.

Keywords

Clarifier, fiber reinforced, high performance, trough, ultra-high-performance fiber-reinforced precast concrete, wastewater treatment plant.

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