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MYCONCRETE

THE BULLETIN OF THE AMERICAN CONCRETE INSTITUTE - MALAYSIA CHAPTER
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MyConcrete:
The Bulletin of the American Concrete Institute – Malaysia Chapter

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ARTICLE

Reprint from CI Magazine, Volume 37, No 9, Page 34-35

Drone Companies Set Sights on Construction Industry

Low-level aerial flights provide high-resolution imagery

The use of unmanned air vehicles (UAV) could soon be the status quo for construction companies around the world. Drone company Skymatics is working on two large-scale construction projects in downtown Edmonton, AB, Canada—the Walterdale Bridge and Rogers Place, a $480 million arena that will be the new home for the Edmonton Oilers National Hockey League franchise.

The company filed over 80 pages of paperwork with Transport Canada under the country's Special Flight Operations Certificate to gain permission to use a DJI S1000 octocopter to conduct two flights that took place in September 2014.

"We're the first commercial aerial operator to gain permission to operate in Edmonton's downtown core, a privilege that doesn't come without its challenges both in terms of paper-work and a pilot's skill level," said E.J. Burrows, Operations Manager, Skymatics. The tight quarters of downtown Edmonton are filled with high rises and construction cranes. The project requires skilled piloting, with a lot of weaving maneuvers to avoid obstructions.

Still the effort is proving to be worth it, according to Burrows. Skymatics' clients have been happy with the results, to the point that they have now entered into a contract to have return flights conducted every 2 months on average. This provides the client a chance to gain a new perspective on their progress as well as gather real-time data and marketing footage for the future.

The flights are limited to 100 ft (30 m) away from major roads and a maximum altitude of 400 ft (122 m).

"It offers the client a way to see their sites in a way that is easier, quicker, and more efficient," Burrows said. "And low-level aerials also ensure a much better scale when it comes to creating three-dimensional (3-D) models. Instead of the resolution of feet that typically comes with satellite imagery, unmanned aircraft systems (UAS) allow us to map down to a resolution of centimeters."

Jakub Karas, UAV Manager for Czech Republic company UpVision, agrees that high resolution is one of the biggest benefits of using drones for construction projects.

"Our UAS mapping services offer high image resolution for digital surface models at a precision of one centimeter per pixel, which offers the client much more accuracy in their data collection," he said.

Both Skymatics and UpVision currently divide their time between both fixed wings and multicopters, depending on the size, scale, and scope of the project and the industry they are undertaking. For construction projects in crowded urban settings like Rogers Place, the vertical takeoff systems are by far the product of choice. Larger, more open area sites favor fixed wing aircraft due to the platforms' endurance, capacity, and ability to map larger areas in less time, covering upwards of 200 acres (80 ha) in just under 30 minutes.

"We use both systems, because we are doing comprehensive services with UAS, and while we do use fixed wings for mapping larger areas, there are some added benefits of using multicopters, include offering online, live-view monitoring in dangerous areas, variability in sensors, and the ability to take off and land from almost anywhere," Karas said.

While current applications of drones in construction focus on collecting images and data, Japan is leading the way by looking to UAS as one method of replacing professionals tasked with building a project.

A project known as Smart Construction, developed by Tokyo-based heavy machinery manufacturer Komatsu Ltd.,

This article, authored by Gail Jansen, was originally published in the May 2015 issue (Vol. 5 No. 2) of AUVSI's Unmanned Systems Mission Critical. Reprinted with permission of the Association of Unmanned Vehicle Systems International (AUVSI), www.auvsi.org.

Skymatics used its drone to capture images of the new Walterdale Bridge project in Edmonton, AB, Canada

was started in reaction to a forecasted shortage of construction workers in Japan that could hamper new projects, including the facilities for the 2020 Summer Olympics in Tokyo.

The first of the proposed six-phase process involves using drones to create high-precision surveys of a site to create accurate 3-D models, including the volume of earth that unmanned bulldozers and excavators need to move. Once collected, the data are then uploaded to a cloud-based server that can aid in all aspects of the construction project's process, including mapping out routes for unmanned vehicles and acting as a resource for future maintenance of infrastructure.

One of the biggest hindrances to using UAS in the con-struction industry is the wide spectrum of legislation that exists for drone usage across borders.

In the Czech Republic, UpVision is currently one of only 10 companies that have permission to fly, and it is the only one with the approval to conduct mapping. The company has expanded its services to other countries, including within the European Union, which is preparing for new legislation in an attempt to address UAS usage across all states.

"These laws have an effect on our company, because for some projects we need special exceptions or specific rules for specific construction sites or we find ourselves needing to split our flight plans to conduct thermal mapping to ensure that we always have line of sight," Karas said. "While the technical possibilities are unlimited, what is limiting is the legislation."

This is a sentiment echoed by Skymatics. While it was the first to get a license to fly UAS in Bermuda, when it came time to expand the company, they looked to western Canada.

"We saw the potential for Calgary as a good central western location that would give us opportunities in a number of industries," Burrows said. "And Canada's regulation systems are far and above everyone else."

Burrows admits that Canada's regulatory system is starting to become overwhelmed with the number of applications to gain permission to conduct flights, and he believes they will soon be heading to a less demanding licensing system.

UpVision uses an octocopter to perform construction surveys in the Czech Republic

Selected for reader interest by the editors.

TECHNICAL REPORT

Reprint from CI Magazine, Volume 37, No 4, Page 42-46

Using Self-Consolidating Concrete for Bridge Repairs

SCC mixtures prove to be effective for substructure repairs

by H. Celik Ozyildirim and Gail M. Moruza

The annual cost of concrete repairs in North America is about $20 billion, and a significant amount of the money is spent on bridge substructure repairs.1 While shotcrete is commonly used for substructure repairs,2 place-ment and testing of shotcrete require specialized operators and methods, proper curing may be difficult to achieve, and the finished product can have a rough finish (Fig. 1(a)). Self-consolidating concrete (SCC) can also be used for substructure repairs. The benefits of SCC have been known since the late 1980s, when initial placements in Japan were made, and it has since been used successfully throughout the world for repair of bridge abutments, pier caps, tunnel sections, parking garages, and retaining walls.3

Placement and testing requirements for SCC are similar to those for conventional concrete, formwork provides initial protection against moisture loss, and the finish can be as smooth as the formwork surface (Fig. 1(b)). Our experience at the Virginia Department of Transportation (VDOT) has shown that properly prepared and placed SCC consistently provides high strength values and good durability.4

SCC Placement

With no external force required for consolidation, SCC fills tight spaces between reinforcement and within formwork. The elimination of large entrapped air voids helps produce SCC with low permeability and high strength. Compared to conventional concrete, SCC requires less labor to place, construction time is reduced, and the noise level at construction sites is lower.5

Mixture properties

An SCC mixture must be highly workable, as demonstrated by the slump flow test (Fig. 2). To ensure good quality, durable SCC repairs, the workability of a mixture should be maintained throughout a placement. Delays can result in decreased workability, so it may be necessary to use a retarding admixture or a workability-retaining admixture to

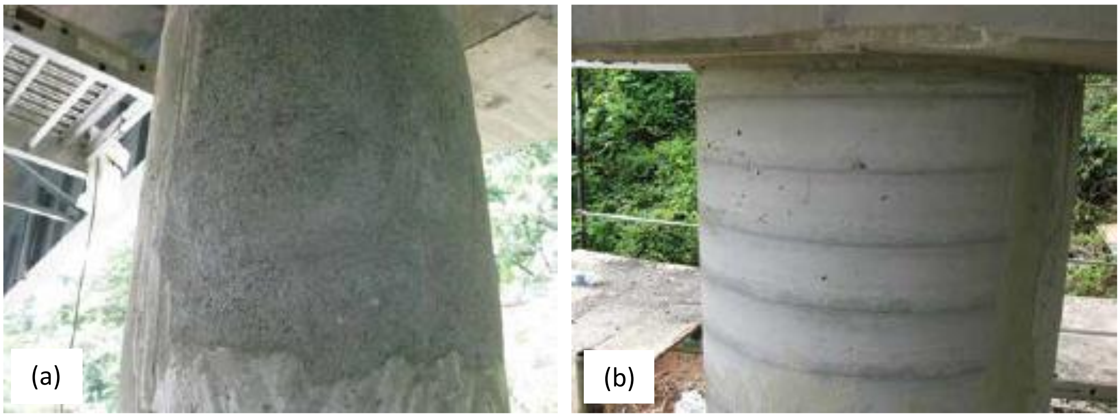

Fig. 1: Typical finishes for substructure repairs using: (a) shotcrete; and (b) SCC

avoid the need to add high-range water-reducing admixtures (HRWRAs) in the field.
The SCC mixture must also exhibit stability, or resistance to segregation. In general, stability requires that a mixture comprises a large amount of fine material and has a low water-cementitious material ratio (w/cm), but it may also require the use of a viscosity-modifying admixture (VMA). Figure 3 shows a cross section of a hardened column specimen made using an SCC mixture with good stability.

Placement means
While VDOT has successfully used bucket placements for repairs, placement with a pump is preferred. When placement is made using a bucket, the geometry of the repair must be relatively simple, the SCC must have a high slump flow, and a funnel can be used to guide the flow and provide a pressure head (Fig. 4).
A small pump is usually sufficient for SCC placements as the objective is to inject the SCC into the formwork without interruption (Fig. 5).

Fig. 1: Typical finishes for substructure repairs using: (a) shotcrete; and (b) SCC

Fig. 4: SCC placed using a funnel and a chute

Fig. 3: The stability (resistance to segregation) of an SCC mixture was evaluated by casting a 4 ft (1.2 m) tall column in a PVC pipe, allowing the SCC to harden, and cutting the column in half using a masonry saw. A uniform distribution of coarse aggregate over the height of the column demonstrates that the mixture is stable

Fig. 5: SCC pumped into formwork

Fig. 6: Backwall repair on Route 699 bridge: (a) SCC was placed using a bucket; and (b) in the background, a sample of the SCC exhibited good stability, as the aggregate and paste in the mixture reached the bottom of the slope simultaneously

The repair formwork should be designed to resist the full hydrostatic head of the concrete placement, and it should be monitored to avoid bulging or failure. If necessary, the concrete can be placed in increments and at a reduced rate. The following discussions provide examples of repairs made with SCC by VDOT.

Route 699 and Route 712 Repairs

VDOT's first applications of SCC for bridge repairs were made in 2010, on Route 699 and Route 712. Figure 6(a) shows the SCC being placed in the backwall at the Route 699 project. This repair required a large placement in an open form, so concrete was placed using a bucket. In the back-ground of Fig. 6(b), a sample of the SCC can be seen flowing down a slope. This material exhibited very good stability, as both the paste and the aggregates reached the bottom of the slope without separating.

At Route 712, the concrete was placed by handheld buckets in some parts of the structure. There was little cover over the steel, so flow around the reinforcement was hindered. Furthermore, due to delays of placement, the concrete stiffened before the placement was completed. Although vibration was then applied, large voids were visible after the forms were removed.

Regardless of the issues encountered during construction of the latter, the repairs on Route 699 and Route 712 turned out well. Figure 7 shows a portion of the final state of the repair on the Route 712 bridge.

The mixture proportions for both Route 699 and Route 712 were the same (Table 1). The cementitious material content was high for workability and stability, a commercially available air-entraining admixture was used for freezing-and-thawing resistance, and an HRWRA was used for improved workability. After the initial early stiffening problems, a workability-retaining admixture was also used successfully to

Fig. 7: Final state of the repair on the Route 712 bridge substructure

Table 1:
Concrete mixture proportions for Route 699 and Route 712 SCC repairs

Ingredient	Quantity, lb/yd3 (kg/m3)
Cement	660 (392)
Fly ash	200 (119)
Coarse aggregate	1323 (785)
Fine aggregate	1220 (724)
Maximum water content	335 (199)
w/cm	0.39

maintain flow of the SCC for extended time during placement. In both locations (Route 699 and Route 712), tests showed that the compressive strength of the concrete exceeded 5000 psi (34.5 MPa), and the charge passed per AASHTO T 277, "Standard Method of Test for Rapid Determination of the Chloride Permeability of Concrete," was below 2000 coulombs.

Route 340 Repairs

In 2013, VDOT again successfully applied SCC as a repair material for three of the piers supporting a bridge on Route 340. The SCC mixture comprised a high cementitious material content, a commercially available air-entraining admixture, a retarding admixture, and an HRWRA. The retarding admixture was used to maintain SCC workability throughout the placement. The HRWRA was advertised as being capable of providing extended, high workability without segregation, and this was verified by slump flow tests conducted at the start and end of the placements. Due to this high slump flow, no extra consolidation efforts were required. However, the formwork bulged during the initial placement. As a precaution, the formwork was strengthened and the height of each repair stage was limited to 8 ft (2.4 m). A portion of the formwork used for the final repair is shown in Fig. 8, as well as the formwork from the previous placement kept in place for the specified 7-day curing.

Fig. 8: Final stage of the SCC repair on one of the piers of Route 340 bridge. On the right hand side of the pier is the completed repair

Table 2:
Concrete mixture proportions for Route 340 SCC repair

Ingredient	Quantity, lb/yd3 (kg/m3)
Cement	546 (324)
Fly ash	182 (108)
Coarse aggregate	1414 (839)
Fine aggregate	1364 (809)
Maximum water content	292 (173)
w/cm	0.40

Although the SCC mixtures used in previous projects had high cementitious material contents, they did not exhibit wide visible cracks. This can be explained by the large amount of reinforcing steel in the repair zones as well as the relatively small size of the repair areas themselves. Even so, the mixture for the Route 340 bridge repairs was modified by decreasing the water and cementitious material contents as well as increasing the amount of large aggregates. The nominal maximum size aggregate in the repairs was 3/8 in. (10 mm). The mixture proportions for the Route 340 repair project are listed in Table 2. The strengths of the SCC used exceeded 5000 psi (34.5 MPa) and the AASHTO T 277 test values were below 1500 coulombs.

Conclusions

VDOT has been successfully using SCC on bridge sub-structure repair projects for about 5 years. Our experience shows that:

- Retarding admixtures and workability-retaining admixtures can be included in SCC mixtures to maintain workability for the duration of a placement;
- Proper selection and proportioning of ingredients, includ-ing VMAs, ensures that the SCC mixture does not segre-gate and maintains stability;

- Following proper placement procedures and using pumps and other means that provide a head and constant delivery of concrete is crucial for the concrete to be able to consoli-date with no external vibration (placement using handheld buckets should be avoided); and
- Formwork must be designed to handle the pressure of SCC, and it may be necessary to slow the placement rate and limit the height of placement to prevent bulging or failure.

Acknowledgments
The authors thank the FHWA and VDOT for enabling the implemen-tation of SCC in repairs.

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Note: Additional information on the AASHTO standard discussed in this article can be found at www.transportation.org.

Selected for reader interest by the editors.

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CASE STUDY

Reprint from CI Magazine, Volume 37, No 6, Page 31-35

Construction of Undulating Walls Using Dry-Mix Shotcrete

Expansive concrete surface creates the main spatial element inside the Museum of the History of Polish Jews in Warsaw, Poland

by Józef Jasiczak, Włodzimierz Majchrzak, and Włodzimierz Czajka

The impact of the rich, 1000-year history of Polish Jews on today's Poland was the basis of the decision to create the Museum of the History of Polish Jews (MHPJ) in Warsaw, Poland. In January 2005, the City of Warsaw, the Polish Ministry of Culture and National Heritage, and the Association of the Jewish Historical Institute of Poland signed an agreement establishing a joint cultural institution. An international competition for the design of the MHPJ was soon initiated. Hundreds of entries were submitted, including proposals by prestigious designers such as David Chipperfield, Peter Eisenman, Zwi Hecker, Kengo Kuma, and Daniel Liebeskind. On June 30, 2005, the Association of the Jewish Historical Institute of Poland announced that Finnish architects Rainer Mahlamäki and Ilmar Lahdelma were the winners of the competition.

In June 2009, a contract was signed between the main contractor, Polimex-Mostostal SA, and the Polish Ministry of Culture and the City of Warsaw. Eventually, SPB TORKRET Ltd., Poznań, Poland, was selected as a subcontractor, responsible for completion of a three-dimensional (3-D), curvilinear wall designed as the main spatial element of the entryway of the museum. TORKRET completed this unique shotcrete project—26 m (85 ft) high walls with almost 6000 m2 (65,000 ft2) of surface area—in 2011 and 2012.1

Building Construction

The museum building consists of two parts with an expansion joint between them. The first part (Fig. 1) is the main building with plan dimensions of 67.3 x 67.3 m (220 x 220 ft) and a total height of 26 m (85 ft). The main building has four aboveground floors and one underground level, and it was designed as a reinforced concrete structure with monolithic external walls. The façade was designed to comprise slanted narrow vertical glass panes, fixed to the reinforced concrete structure with a light steel structure made of galvanized steel square tubes. The second part of the building, visible in Fig. 2, is the services compound, which consists of a single underground floor with plan dimensions of 67.3 x 41.7 m (220 x 136 ft).

Fig. 1: The Museum of the History of Polish Jews in Warsaw, Poland. The museum stands in what was once the heart of Jewish Warsaw—an area which the Nazis turned into the Warsaw Ghetto during World War II. The building's simple form is split by a wide fracture directly opposite the nearby Monument to the Ghetto Heroes

Fig. 2: The connecting tunnel from the second part of the building, the services compound, which consists of a single underground floor

Undulating Walls

The Initial Design Concept

In the main hall of the building, two undulating walls are the most important elements shaping the interior aesthetics as well as serving as the structural support of the entry hall ceiling (Fig. 3). Both walls start from the ground floor and cover the entire height of the building from the foundation to the roof. The walls were originally designed as precast glass fiber-reinforced concrete (GFRC) shells attached to H-section rolled steel profiles using a system of adjustable fasteners. The H-section profiles were to be connected to a substructure comprising steel tubes rolled from EN 10210 Grade S355J2H steel (similar to ASTM A500 Grade C or CSA G40.21 Grade 50W).

Vertical elements in the substructure were 273 mm (10.75 in.) diameter tubes with wall thicknesses varying from 16 to 20 mm (0.62 to 0.79 in.). These vertical tubes were bent in one plane and braced with horizontal, 193.7 mm (7.63 in.) diameter tubes with 12 mm (0.47 in.) wall thickness. The substructure at the ceiling comprised 244.5 mm (9.62 in.) diameter steel tubes with 16 mm (0.62 in.) wall thickness connected to the concrete roof using rigid inserts.

The GFRC panels, which were to form the finishing layer of the curvilinear walls, were designed to be 15 mm (0.6 in.) thick. The panels were to be diamond-shaped with areas of several square meters, with four fasteners located at the corners for mounting onto the substructure. The panels had to have double curvature to comply with a digital model developed by the architect (Fig. 3), and they had to meet the following conditions:

- Color ”Stained concrete with a shade similar to pale yellow limestone, approved by the Architect on the basis of samples, and resistant to UV staining. The color was inspired by the color of the Western Wall in Jerusalem. Panels impregnated with anti-graffiti protection;
- Geometry ”15 mm (0.6 in.) thick panels with edges thickened to 40 mm (1.6 in.) to strengthen the joints and deepen the gap between panels; and
- Functional condition and in-use performance ”The contractor was obligated to develop the details of the fastening system with the provision that the system must provide load-bearing capacity and stability, meet the requirements of fire regulations, and enable the installation of the panels on both sides of the hall.

Due to a number of difficulties, an alternative finish system shotcrete applied directly at the jobsite—was investigated.

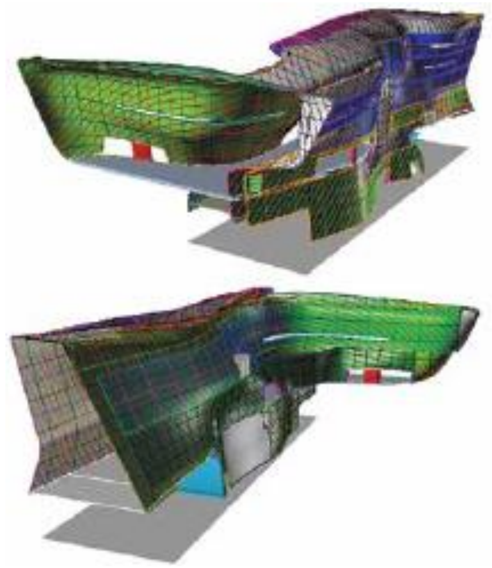

Fig. 3: A 3-D model was generated to set the geometry of the thin-wall shell of the entry hall of the museum, including the locations for the shell's expansion and control joints

Fig. 4: Mockup of curvilinear wall divided into diamond-shaped elements. One of the designers, Rainer Mahlamäki, is on the far right

Proving the Alternative System

Before shotcrete could be used, structural research and calculations were made, taking into account the need to fulfil the color, geometric, functional, and in-use performance requirements defined in the original design concept. Knowing the possibilities of curvilinear surfaces formed using shotcrete technology, TORKRET prepared three mockups of the wall. In September 2010, TORKRET hosted a meeting with the architect and representatives of the investor and main contractor. There, the wall construction method and the mockups were presented (Fig. 4). After the visit, positive feedback was received; however, static and fire resistance tests of the models were required before final approval could be granted.

Samples of the wall elements underwent destructive structural testing as well as tests of fire resistance. It must be emphasized that the wall is not merely a decorative element and a work of art, but also serves as a partition between walking routes for visitors, as well as technical and office premises.

Laboratory studies were carried out at Poznań University of Technology (Fig. 5) on two 2.10 x 0.80 x 0.05 m (83 x 32 x 2 in.) reinforced shotcrete elements. The tests demonstrated that the shotcrete panel system and its mounting on the steel support construction was the right solution. It was determined that the full-scale structure worked as a continuous concrete shell with multiple anchors spaced at 0.8 m (32 in.) in each direction.

The 50 mm (2 in.) thick panels were reinforced with 100 x 100 mm (4 x 4 in.) welded wire reinforcement with 4.5 mm (0.18 in.) diameter deformed bars. The reinforcement was centered at the midplane of the wall section and was designed to secure the structure against complete destruction in the event of exceptional loads (for example, accidental impact or anchor failure).

This role of the welded wire reinforcement was confirmed by laboratory tests. Point loads were applied at anchor points in the test panels suspended between steel beams. The panels deflected 41 and 35 mm (1.61 and 1.37 in.) under applied forces of 4.5 and 5 kN (1010 to 1120 lb), respectively, before the concrete sections were fully cracked. Fire resistance tests were conducted at the Fire Testing Laboratory of the Building Research Institute, Warsaw. These showed that the concrete shell would achieve the required fire resistance.

Shotcrete Implementation

After completion of the basic load-bearing structure of the building (Fig. 6), the implementation of the feature walls began. The dry-mix shotcrete was prepared at TORKRET's mixing plant with a production unit exclusively dedicated to he construction of the curvilinear walls. The first layer of concrete was applied using a traditional shotcrete mixture containing 2 to 4 mm (0.08 to 0.2 in.) rounded quartz aggregates, portland cement (CEM I 42.5R), silica fume, and a non-alkaline accelerating admixture. The second layer was made of quartz aggregates up to 2 mm (0.08 in.) in size, but the binding material was white cement (CEM I 42.5R) with adequately matched dyes including oxide iron yellow and titanium white. Maintaining a uniform color to match that of the Western Wall was one of the biggest challenges. Shotcrete samples (Fig. 7) were used as references.

Fig. 5: Structural testing of a 2.10 x 0.80 x 0.05 m (83 x 32 x 2 in.) panel cut out from a mockup wall. Anchors were spaced at 0.8 m (32 in.) and load was distributed by the steel channel in the center

Fig. 6: The concrete and steel structure of the museum's entry hall defined the basic form of the undulating interior walls

(a)

(b)

Fig. 7: Shotcrete samples—two-layer concrete with an external pale yellow architectural coat made according to the "cut" technique: (a) cross section; and (b) finished surface

The shotcrete panels are attached to the vertical tubes in the substructure through a system of rigid anchors. Each anchorage point comprises a steel plate with a central hole for a fastener. The concentrated load applied to the anchorage is distributed into the shotcrete section via 4.5 mm (0.18 in.) diameter bars welded in a radial pattern on the plate (Fig. 8(a)). The anchorage forces were therefore distributed to the welded wire reinforcement in the wall. During placement, the welded wire reinforcement was anchored to a profiled substrate made of flexible, water-resistant, and fire-resistant plywood (Fig. 8(b)). This substrate also served as a stay-in-place form for the shotcrete.

Specially designed polymer strips were embedded in the shotcrete at expansion and control joints (Fig. 9). The strips enabled maintaining a uniform thickness of shotcrete and delineated the outer surface. They also enabled installation of plastic sheets to prevent moisture loss as well as provide protection against shotcrete overspray from subsequent placements. The expansion joint strips were later removed and replaced by a fireproof silicone material. The control joint strips were inserted in the shotcrete after placement, in a pattern specified by the architect, and they were left in place in the completed walls.

The most important issue from the wall profile shaping perspective was transferring of the 3-D design coordinates to the wall space. This was achieved by marking the intersections of joints or other typical points. The polymer strips were mounted on stay-in-place plywood formwork panels. Once the joint-defining strips were formed and fastened, two layers of shotcrete were applied. Aliva 246 dry-mix shotcreting machines were used, along with booster pumps that provided water to the nozzle.

The fresh shotcrete was cured using plastic sheets hanging from the top of the finished walls (Fig. 10). Completion of the curvilinear wall took 13 months of substructure preparation and several months of finishing work. The walls were completed in August 2012. The final results are shown in Fig. 11.

Fig. 8: Anchorage/stress distribution elements: (a) individual anchorage plate with radially welded 4.5 mm (0.18 in.) diameter bars; and (b) view of the anchorage plates and welded wire reinforcement anchored to the profiled substrate made of water-resistant plywood

Fig. 9: After plywood panels were installed as stay-in-place formwork defining the wall curvature, anchors and welded wire reinforcement were installed, polymer strips were set to form expan-sion joints and to serve as depth guides, and the first layer of shotcrete was applied

Fig. 10: Shotcreting process. In the lower section of the photo, the finished shotcrete wall is covered with plastic sheets to protect it against contamination by mortar overspray and provide curing to limit drying shrinkage

Fig. 11: Finished curvilinear shotcrete wall before and after installation of the entry hall's glazing system. The large hall divides the building, and its high, undulating, and textured walls create a dramatic space

Construction-Related Issues

Major portions of the surface area of each wall were constructed in the open space of the building. The roofing, about 600 m2 (6500 ft2) of glazing, and the entrance structure were finished at the end of the project. This forced the work to be organized so that preliminary stages could be completed during periods of low temperatures. Shotcrete was then applied during advantageous weather conditions. A major execution-related problem was accessing individual wall elements. While it would have been more convenient to apply shotcrete from scaffolding, that solution was ruled out because of the ongoing need for surveys of the spatial location of the wall surfaces. Hydraulic boom lifts and scissor lifts were thus used instead of scaffolding. To access the highest wall elements, a temporary platform was installed. A crane track with a suspended scaffold was then mounted to the temporary platform. This solution made it much easier for the client to set, control, and verify the shotcrete surface.

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Selected for reader interest by the editors.

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