2012 Outstanding International Project

The Museum of the History of Polish Jews

By Wlodzimierz Czajka

In 2012, SPB TORKRET Ltd completed a unique shotcrete project in Warsaw, Poland—an 85 ft (26 m) high wall with an approximate surface area of 65,000 ft^2 (6000 m^2). The wall was designed by Professor Rainer Mahlamäki. The three-dimensional (3-D), curvilinear wall symbolizes the Red Sea parting for the Hebrews' exodus from Egypt, and it forms the main spatial element for the interior of the Museum of the History of Polish Jews (MHPJ) (refer to Fig. 1 and 2).

Not that long ago, Poland was the center of the Jewish Diaspora and the home of the largest Jewish community in the world. Jewish settlements were established on Polish soil as early as the end of the 10th century. Jews came to call Poland their home. For centuries, Jewish cultural and religious traditions thrived. During the inter-war period, Poland was inhabited by 3 to 3.5 million Jews and had one of the biggest Jewish communities in Europe. In Warsaw alone, Polish Jews comprised almost one-third of the population.

Polish Jews were experiencing what some called another Golden Age. World War II brought tragedy upon the Jews of Poland. The Holocaust left the Polish Jewish community all but destroyed. After the war, remnants of a nearly extinguished Jewish presence in Poland still lingered. A renewal began and continues today. The ongoing rich, thousand-year history of Polish Jews and its impact on Poland today resulted in the decision to create an 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—the MHPJ. This historical event was made possible thanks to the voluntary involvement of many individuals and institutions. Among others, Aleksander Kwasniewski, the former President of Poland, offered his patronage over the Museum and Shimon Peres, the then-Prime Minister of Israel and current President, became the Chairman of the Museum's International Honorary Committee. On June 30, 2005, The Association of the Jewish Historical Institute

Fig. 1: "Waving" of the curvilinear wall

Fig. 2: "Dammed waves" of the walls in the lobby-hall area

Fig. 3: Fire protected wall substructure

of Poland published the results of the international architectural competition for the design of the building for the MHPJ.

This prestigious competition attracted famous architects from all over the world, including Daniel Liebeskind, Peter Eisenman, Zwi Hecker, Kengo Kuma, and David Chipperfield. Finnish architects Rainer Mahlamäki and Ilmar Lahdelma, of a Helsinki-based architectural studio, won the competition. In June 2009, a contract was signed between the owner—the Ministry of Culture and the city of Warsaw—and the main contractor—Polimex-Mostostal SA. Our company was subcontracted by the main contractor responsible for completion of the curvilinear wall.

Originally, the curvilinear walls were planned as resin-cement panels cast ex-situ and then incorporated into the steel curvilinear wall structure with the use of a system of holding elements. This technology of building a curvilinear wall was burdened with various implementation and economic problems. Knowing the possibilities of producing curvilinear surfaces with shotcrete technology, our company prepared three curvilinear wall models. At a meeting with the architect and representatives of the investor and main contractor, which was held at TORKRET's office in September 2010, a presentation of the wall execution method and the prepared models was made. After the visit, a positive opinion was given to the shotcrete application for building the curvilinear wall. Static load and fire resistance tests of the shotcrete model were required. A Poznan University of Technology team led by Professor Józef Jasiczak carried out static calculations and tested the load-bearing capacity of structural elements. The creator of the wall structure design and the detailed working design was Wlodzimierz Czajka.

The envelope of the curvilinear wall is a 2 in. (50 mm) thin-walled, reinforced concrete structure with mesh reinforcement (ø0.177 in. [4.5 mm] stainless steel ribbed bars). The wall is suspended using a system of anchors embedded in a substructure resting on steel columns. The steel columns forming the structure's framework are located in both walls of the hall and run along the entire building's height. Vertical elements are made of ø10.75 in. (273 mm) pipes, composed of sections, bent in one plane, horizontally braced, and formed into a grid by means of pipe profiles. Horizontal elements were made of ø4 in. (100 mm) pipes. The thin-walled, curvilinear dry-mix shotcrete wall is mounted through a system of rigid anchors to the pipes serving as the substructure.

The way stresses were distributed at the point of anchorage and dispersed in the wall surface section was an innovative approach. This distribution of stress was obtained by mounting a strap with radial bars onto the anchor. The solution allowed avoiding possible scratching and cracking of the wall at the points of contact with the substructure. For static calculation model purposes, the wall envelope was considered as multiple point-of-anchorage plates loaded with dead weight. By introducing expansion joints, dimensions of a single plate were limited to approximately 170 to 215 ft^2 (16 to 20 m^2). Each of

Fig. 4: The same element when finished

the wall elements underwent destructive testing, including a cut-out of the finished wall with the anchorage. The test of the wall's fire resistance was also crucial. It must be emphasized that the wall is not merely a decorative element or work of art but also a partition between walking routes for visitors and technical and office premises. The EI30 test was made on test elements in the Fire Testing Laboratory of the Building Research Institute, Warsaw (refer to Fig. 3 and 4).

Another innovative element was specially designed plastic strips embedded both in expansion joints and control joints. The structure of the plastic strips facilitated maintaining a constant shotcrete application layer thickness and delineated the outer surface. This also enabled installation of a membrane, preventing humidity loss and protection against dust when applying onto the adjacent element. The expansion joint strips were removed and replaced by fireproof silicone material. The control joint strips were left in the structure reflecting the so-called wall pattern assumed by the architect (refer to Fig. 5).

The most important issue from the wall profile shaping perspective was transferring the 3-D design coordinates to the wall modeling space. This was achieved by continuous layout of the points of crossing of joints or other typical points. Strips were mounted on a special plate serving as a stay-in-place form. The plate had to meet the elasticity (multi-directional bending) and non-flammability conditions. Once the plate with joint-defining strips was formed and fastened, two layers of concrete were applied. An Aliva 246 dry-mix shotcreting machine was used and pumps provided water to the nozzle. Dry-mix shotcrete was prepared internally at Torkret's custom mixing plant with a dedicated production unit designed specifically for the curvilinear wall construction. The first course was shot using a traditional shotcrete mixture based on rounded quartz aggregates and portland cement. The second phase was also made based on a selection of quartz aggregates, but the binding material was white cement with closely matched coloring. According to the designers' wish, the wall color was to reflect the color of rocks in Israel. The color was inspired by the color of the Western Wall in Jerusalem. This shade was obtained by mixing white cement and suitable dyes.

Maintaining a uniform color was one of the biggest challenges. Having experienced with similar applications, Torkret knew that different shades may occur on the resultant surface. Indeed different shades did occur, but they only added to the wall's special features.

Many execution-related issues were faced when building the project. A major part of the wall's surface area was made in the open space of the building. Installation of the roof covering and a glazed window (approximately 6500 ft^2 [600 m^2]) and the entrance structure weren't completed until the end of the project. This forced us to organize our work so that the preliminary stages were prepared during periods of lowered temperature while the application of shotcrete was conducted during advantageous weather conditions. A major execution-related problem was access to individual wall elements. Placement of a frame scaffolding that offered constant

Fig. 5: Mounting of strips–control joints

access would have been the best solution; however, we had to rule it out because wall layout required permanent geodetic survey of the spatial location of the wall. Light and heavy man-lifts and scissor lifts were used. To get access to the highest wall elements, a temporary platform was installed to which a crane track was mounted with a suspended scaffold. This wall access solution made setting-out, control, and verification of the shotcrete surface upon shooting much easier for the client (refer to Fig. 6).

The as-built tests referred to confirming of the assumed concrete class (minimum C30/37 as per PN-EN 14487-1, -2: 2007 Sprayed Concrete). The assumptions made concerning the substructure (rigidity), method of load carrying transfer from wall elements, and joint expansion width of 0.4 in. (10 mm) between the elements proved right. The wall scan made by the wall supervision company was compared to the design assumptions. The comparison proved we had achieved a unique precision of wall execution, expressed in millimeters of deviation (refer to Fig. 7 and 8).

Completion of the curvilinear wall took 13 months, which included basic structural work and several months of finishing work. All the emerging problems (performance-related, technical, and others) were solved on-site with our laboratory and Research & Development Unit during hours of meetings and practical tests. Finally, all wall work was completed in August 2012.

The exemplary cooperation of the architect, Professor Rainer Mahlamäki and his team, in solving the details, not to mention problems and conflicts that emerged, deserves credit.

Politicians from many different countries were interested in the construction of the MHPJ. Implementation of the project coincided with U.S. President Barack Obama's visit to Poland. President Obama paid homage to Jews at the Monument of the Warsaw Ghetto Heroes that is situated adjacent to the museum (refer to Fig. 9).

The unique combination of shotcrete application technology to form the wall's curvature and the selection of materials resulted in exceptional quality of the structure and a durability that exceeds the standard life span of a building.

Fig. 6: Execution of top part of the wall

Fig. 7: Entrance

Fig. 8: A curvilinear wall with glazing (western exposure)

Fig. 9: Museum originators, donors, Polish Minister of Culture, and Mayor of Warsaw with the American President in front of the museum under construction during President Obama's visit

Wall technical parameters:

a) Substructure

- Steel structure made of ø10.75 in. (273 mm) and ø4 in. (100 mm) pipes and reinforced concrete columns

b) Wall structure

- Thin-wall curvilinear double-sided, made of independent elements, separated with joints, of surface area approximately 215 ft^2 (20 m^2), reinforced with stainless steel bars
- Total surface area 65,500 ft^2 (6090 m^2)
- 2 in. (50 mm) thick at an area of 61,000 ft^2 (5700 m^2) and 6.30 in. (160 mm) thick at an area of 4200 ft^2 (390 m^2)
- Fastened to the substructure with ø0.94 in. (24 mm) anchors
- 85 ft (26 m) high
- External surface finished with unidirectional cut, color of light sandstone, approved pattern of joints
- Technology: structural dry-mix shotcrete and architectural through-dyed shotcrete.

Wlodzimierz Czajka *is the Technical Manager and a member of the Board of Directors of SPB TORKRET Ltd. From the beginning of his professional career, he has been interested in the shotcrete method. He gained extensive experience by working 13 years in a large construction company, where he led the Specialized Works Unit. In 1989, together with two partners, Czajka established TORKRET Company, specializing in repairs of reinforced concrete structures. For all these years, he has been a devoted promoter of the shotcrete method to designers and investors and has proactively participated in national and international symposia and conferences. He initiates innovative solutions that allow for implementing the shotcrete method on thin-walled structures in varying applications.*

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Project Name
Museum of the History of Polish Jews

Project Location
Warsaw, Poland

Shotcrete Contractor
SPB Torkret LTD*

General Contractor
Polimex-Mostostal S.A.

Architect/Engineer
Professor Rainer Mahlamaki

Material Supplier/Manufacturer
SPB Torkret LTD*

Project Owner
City of Warsaw & Ministry of Culture and National Heritage

*Corporate Member of the American Shotcrete Association