The Restoration of the Baha'i House of Worship

Wilmette, IL

Submitted by The Armbruster Company

The Baha'i House of Worship, designed by architect Louis Bourgeois and listed on the National Register of Historic Places, is one of the nation's finest examples of architectural concrete. The building consists of a structural steel and concrete frame covered with ornamental, exposed aggregate concrete. The ornamental concrete was composed of white and crystal-clear crushed quartz aggregate, quartz sand, and white portland cement formed in elaborate molds.

Twenty years ago, a comprehensive program corrected defective details of the initial construction and restored the temple's concrete to its original, brilliant condition. The concrete repairs have performed flawlessly and continue to look as if they were completed just yesterday.

DAMAGE FROM CYCLIC FREEZING

By the 1980s, deterioration of the concrete in the entrance stairs, clerestory, and clerestory cornice had become noticeable. The Baha'i's project manager created a team with the engineer, contractor, and key craftsmen, and a study was commissioned to investigate problems with the exterior concrete. The investigation consisted of a close-up inspection of the concrete, inspection openings to establish the condition of concealed anchors and examine the space between the ornamental concrete and the structural concrete, water testing to determine the source of water infiltration, laboratory petrographic evaluation of cores to evaluate deterioration, copper-copper sulfate half-cell potential measurements and chloride ion determination to establish the degree of corrosion, and laboratory studies to determine the mixture proportions of the original concrete.

CROWN DETERIORATION

Most of the ornamental concrete in the area along the cornice, soffit, and dentils of the clerestory appeared to be in good condition, with some deterioration. In addition, steel anchors of the ornamental concrete to the structure were fractured as a result of expansion due to water infiltration and freezing.

Twenty years after repairs, the Baha'i House of Worship's exquisite beauty continues to sparkle in the sunlight and dazzle hundreds of thousands of visitors each year

A gap of up to 1 in. (25 mm) was found where the white ornamental concrete had originally been in contact with the underlying structural concrete. Petrographic analysis of the samples showed that the structural concrete was damaged as much as 30 in. (762 mm) below the surface, even where the ornamental concrete appeared sound. The damage did not affect the overall strength of the building's structure, but it weakened the support for the ornamental concrete.

SEARCH FOR MATCHING MATERIALS

The restoration called for matching the original pattern, material composition, color, and texture of the ornamental concrete while improving on original construction details to extend its life. The most effective forming, mixing, casting, and finishing techniques to replicate the original concrete were determined through careful experimentation. Over 50 concrete samples were prepared to develop materials and techniques. The final mixture included crushed quartz aggregate, crushed quartz and silica sand, white cement, water-reducing admixtures, and an air-entraining agent.

STAIR REPLACEMENT

The first stage in the repair program addressed the monumental stairs at the temple's entrance. The existing precast stairs and the cast-in-place upper landing were removed. The water-resistant membrane beneath the stairs was replaced. New precast architectural concrete stairs and a cast-in-place upper landing duplicated the original appearance.

CROWN REPAIR

The restoration of the crown and clerestory consisted of replacing deteriorated concrete and the existing copper gutter at the base of the dome. For ornamentation to be replaced, a rubber impression was taken from the building and a positive model was cast from this mold.

Small jackhammers were used to remove the damaged ornamental concrete at the crown. The deteriorated structural concrete was then removed down to sound concrete, which was 3 ft (1 m) deep in some places.

Each of the crown's nine sides extends 31 ft (9.5 m) wide and 5 ft (1.5 m) high. In each of the sides, the craftsmen drilled and set 240 new 3 ft (0.9 m) long steel anchors in epoxy. Epoxy-coated steel reinforcing rods were carefully fit behind curved forms. Once the substrate was properly prepared, the structural concrete material was then placed into the forms.

The ornamental concrete of the soffit and dentil section was cast in place using white quartz concrete placed into rubber molds. A retarder on the inside surface of the molds facilitated exposure of the quartz aggregate with wire brushes when the molds were removed the next day.

The ornamental face of the crown was replaced with precast architectural panels of white quartz concrete. The panels were produced in the temple's shop using intricate fiberglass molds coated with a retarder to allow easy exposure of the quartz material. After 3 weeks of moist curing, the panels were attached to the repaired structural concrete using adjustable stainless steel angles and expansion anchors. A new copper gutter and new drains were installed at the base of the dome. Cracks and spalls in the clerestory were repaired with the white quartz concrete mixture using similar techniques.

CUSTOM HOISTS DESIGNED

Customized hoisting and access systems were designed for the building. All of the hoisting systems were anchored onto the building with stainless steel anchors that remain permanently in place so that the hoists can be used again in the future.

Intricate multi-piece fiberglass and rubber molds provided for accurate and efficient repair of the highly sculpted ornamental concrete components

CLEANING PROGRAM

EXTERIOR CLEANING

Another part of the concrete restoration was a meticulous cleaning completed over a 3-year period. The first cleaning of the structure was in 1969. Technicians used a chemical cleaner that was very effective at removing the general atmospheric staining on the temple but did little to remove the black crusts that formed under window ledges and column capitals.

These black crusts were formed when sulfur dioxide gas came in contact with the moist concrete surface containing calcite compounds. The chemical reaction created gypsum crystals that formed

To repair the crown or clerestory cornice, technicians removed deteriorated architectural concrete and structural concrete. The finished repair matched the original

around other pollutants. Although the crusts were extremely hard, they were slightly water soluble. They were removed in 1989 by dissolving them with a fine mist of water sprayed from modular manifolds custom built to fit each unique architectural feature. The water supply was controlled by timers programmed to spray in cycles of 5 minutes on and 20 minutes off. This not only saved water, but also reduced the risk of water penetrating the walls, where it might have damaged the interior.

Efflorescence, visible on the temple as white crusts and stalactites, were removed with a water mist and gentle brushing. The black scabs and white stalactites covered only a small portion of the building, however. The largest task was removing the staining caused by atmospheric pollution. The quartz stones were covered with blackish stains and there were also organic growths rooted in the cement and sand matrix between the large aggregate. After numerous tests and laboratory analyses, a specially formulated restoration cleaning solution was selected to pre-soften the stains and kill the organic growths.

The Baha'i House of Worship's preservation program includes regular cleaning. The exterior of the House of Worship was cleaned again in 2006.

INTERIOR CLEANING

The 140 ft (42.7 m) tall interior space of the House of Worship is finished with precast polychrome mosaic concrete panels of exposed aggregate. Water leaking through the skylight had generated rust on the steel trusses supporting the interior's precast panels and the rusty water had stained the mosaic concrete in 75 rust locations high above the floor. Crews applied multiple cycles of poultices to each of the rust stains to remove them.

SURVEY OF ORNAMENTATION

During the restoration, the entire exterior and interior surface of the temple was surveyed with modern instruments and computers so that any point on the concrete could be located in three dimensions within 0.125 in. (3 mm).

Control targets were placed over all areas of the building and then precisely measured with the most sophisticated surveying theodolites in the world. The targets were included in photogrammetry, using stereo pairs of photographs taken with a calibrated metric camera. The resulting film images could be used to plot any point on the surface. Through computers, this data could automatically control a milling machine to produce an accurate model for the mold-makers when the concrete weathers and needs replacement in the centuries ahead.

The completed repairs are a faithful reproduction of the original ornamental concrete. The 7-year restoration effort recreated the original appearance of this magnificent structure while combining the finest craftsmanship with advanced technology and refined materials to improve future performance. After 20 years of exposure to the harsh, Midwestern weather on the shore of Lake Michigan, the concrete repairs are in outstanding condition.

Special hoisting and access systems were designed for the concrete repairs

Before the cleaning began in 1989, the temple was covered with black crusts of gypsum crystals, organic growths, and extensive stains of atmospheric pollution

The Baha'i House of Worship

OWNER
Baha'i National Center
Wilmette, IL

PROJECT ENGINEER/DESIGNER
Wiss, Janney, Elstner Associates, Inc.
Northbrook, IL

REPAIR CONTRACTOR
Quality Restorations
Northbrook, IL

MATERIAL SUPPLIER/MANUFACTURER
BASF Building Systems
Downers Grove, IL