AWARD OF EXCELLENCE

HISTORIC CATEGORY

Unity Temple Restoration

OAK PARK, IL

SUBMITTED BY CTL GROUP

Fig. 1: View of front (north) elevation of Unity Temple after restoration

Constructed circa 1908 for approximately $69,000, Unity Temple is a masterpiece rendered inside and out in reinforced cast-in-place concrete. The Unity Temple complex consists of three interconnecting structures: Unity Temple/Sanctuary, Unity House, and Foyer. It is one of Frank Lloyd Wright's earliest designs using reinforced concrete construction, and represents his innovative use of concrete with exposed aggregate finish as both a structural and decorative material. To this day, Unity Temple remains a high point in Wright's Prairie Period and an icon in modern architecture. It remains in use as the home of the Unitarian Universalist congregation for which it was designed and built. A Registered National Historic Landmark building, it is listed on the National Trust for Historic Preservation's 11 most endangered historic places, and Landmarks Illinois' "Most Endangered Historic Places in Illinois."

A restoration master plan was developed in 2000 to 2006 to address the building's exterior and interior deterioration. The master plan was implemented in 2015 with a $25 million restoration project that was completed in May 2017 (Fig. 1). This project will focus on the concrete restoration component.

INVESTIGATION AND RESTORATION PROGRAM

After 100 years of service, the building exhibited widespread concrete deterioration and considerable water damage (Fig. 2 and 3). In 2008, concrete pieces fell from the Sanctuary ceiling. Due to the advanced state of deterioration and associated life safety concerns, a comprehensive survey and evaluation was performed to define existing condition of the concrete structure, evaluate causes of concrete deterioration, and provide an appropriate restoration plan to ensure long-term building performance for review and approval by Unity Temple Restoration Foundation and Landmarks Illinois.

Inspection and Evaluation Methods

The investigation consisted of the following components:

1. Reviewing historical documents, archival photographs, and Wright's drawings to understand Wright's design intent, types of concrete specified, and construction details.
2. Conducting a condition survey to document the condition of exterior and interior concrete elements, utilizing NDT methods and localized exploratory openings.
3. Removing core samples from exterior walls and roof slabs for laboratory examination and testing.
4. Performing a structural analysis of cantilevered roof slabs to evaluate structural capacity and determine if strengthening was necessary.

Findings

Wright's original specifications included different types of concrete, and their use was confirmed in the core samples: Portland Cement Facing Mortar

(PCFM), Stone Concrete, Structural Cinder Concrete, and Structural Concrete.

In 1973, deteriorated areas of Wright's PCFM on exterior walls were replaced with shotcrete. Condition surveys from 1999 to 2015 revealed considerable cracking, delaminations, and spalling of this shotcrete layer on exterior walls, parapet walls, chimney, cantilevered roof slabs, and ornamental planters. Potential falling hazards from loose shotcrete posed a threat to public safety (Fig. 2).

In 2002, the cantilevered roof slab fascias and soffits were restored. The 2015 survey indicated that the 2002 repairs were performing well; however, shrinkage cracks developed along the fascia perimeter of roof slabs (Fig. 2). Structural analysis indicated that roof slabs were structurally adequate and strengthening was unnecessary.

Observed concrete delamination and water damage at interior concrete structural elements were generally localized (Fig. 3) and due to water infiltration through roofs. Several terrace panels exhibited spalling, creating potential tripping hazards; this was attributable to shrinkage cracking, soil settlement, and cyclic freeze-thaw of panels with moisture saturation from poor drainage.

REPAIR SYSTEM SELECTION

At parapet and chimney walls, 100% shotcrete replacement was performed due to extensive deterioration. At other exterior walls and ornamental planters, localized shotcrete repairs were performed to blend with the surrounding wall. Innovative crack repairs were also performed to blend with the surrounding wall. A penetrating silane sealer was applied to mitigate future moisture intrusion.

At the cantilevered roof slab, localized concrete repairs were performed using the form-and-pour method, utilizing supplementary reinforcement and discrete galvanic anodes. Wright incorporated inverted U-shaped transfer beams spanning between corner columns in the Sanctuary to support a skylight structure, parapet walls and cantilevered roof slabs. The Owner opted for a new skylight structure spanning over the original skylight. To support the new skylight structure, the transfer beams were strengthened.

Localized concrete repairs of interior concrete beams were performed and 100% of foyer terrace panels replaced using air-entrained concrete for freeze-thaw durability and installed with positive drainage slope.

FIELD MOCKUPS

Extraordinary measures were taken in designing trial mixes and constructing field mockups (Fig. 4) as matching the exterior wall surfaces was of paramount importance on this landmark project. Exterior wall areas were cleaned to provide basis for comparison of color and texture.

Following shotcrete mix design acceptance by the Owner, all materials were purchased in quantities sufficient for the entire project to ensure consistency in the concrete mix design throughout the restoration program. A custom concrete mix design was also developed to closely match properties of the original structural cinder concrete for roof slab repairs.

Field trials were performed to assess suitability of sealant materials, variations of aggregate/sand materials applied on sealant, routed

Fig. 2: Concrete cracking and deterioration on exterior walls and cantilevered roof slabs—loose spall at corner of parapet wall (arrow) was removed and covered to address potential falling hazard prior to restoration

Fig. 3: Concrete deterioration of concrete beam (blue arrows) and water damage to plaster finish at interior of Unity Temple Sanctuary—roof slab underside delaminations were removed and covered with plywood (red arrows) to address potential falling hazards prior to restoration

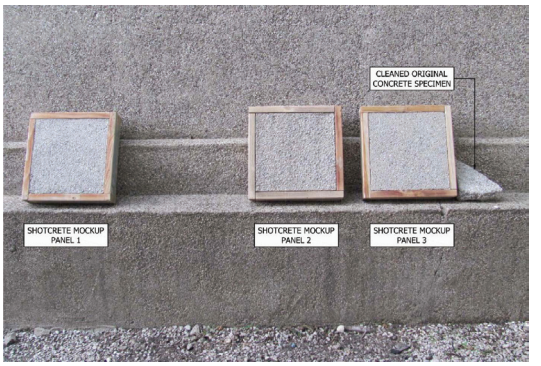

Fig. 4: Field mockup shotcrete panels compared to cleaned original concrete specimen

Fig. 5: Weather enclosure at front (north) elevation of Unity Temple during restoration

groove profiles/widths, sealant tooling techniques, etc. Results from the trials were successful in visually blending mockups with the surrounding wall.

Field trials were also performed to assess the effectiveness of various cleaning methods: soda blasting using common baking soda, grit blasting using fine-grade crushed aggregates, and a proprietary cleaning technique using micro-abrasives. All three methods produced desired results, and the Owner selected grit blasting for economic reasons.

REPAIR CONSTRUCTION LOGISTICS

To meet the project schedule, a weather enclosure was installed over the entire building to allow for continuous construction activities through winter and rain, and to control airborne debris (Fig. 5).

Fig. 6: Localized exterior wall repair using wet-process shotcrete

Fig. 7: Routed and sealed construction joint repair (arrows point to completed joint repair)—crack repair was similar

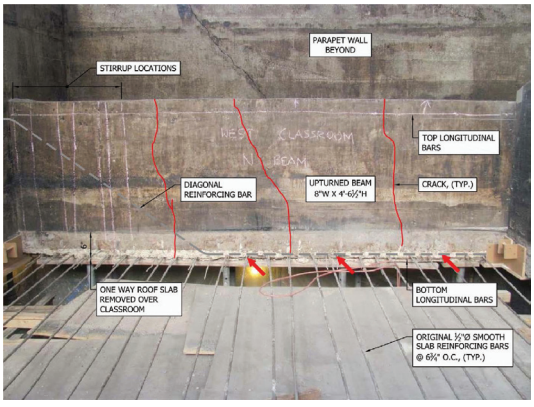

Fig. 8: Unity House classroom after roof slab removal (red arrows point to horizontal splitting above longitudinal bars of upturned beam in zone without stirrups)

Exterior walls were cleaned using fine-grade grit blasting prior to shotcrete repairs to facilitate matching of new localized shotcrete repairs against cleaned wall areas.

Wet-process shotcreting was employed with specific hose air pressure and nozzle distance to work area (Fig. 6). Grit blasting after cure achieved the desired exposed aggregate finish to match the surrounding wall. Wall crack repair included placing select aggregates in the sealant to match the adjacent wall surface (Fig. 7).

Localized cantilevered roof slab soffit repairs were performed using the form-and-pour method. Access holes were cored in roof slabs to facilitate placement of repair concrete from the slab topside.

UNFORESEEN CONDITIONS

Serious structural problems were discovered at roof slabs and supporting upturned beams of Unity House east and west classrooms (Fig. 8). The one-way slabs exhibited extensive deterioration and significant deflection. Structural analysis indicated that slab reinforcement was deficient by 50% of that required to support code-prescribed minimum snow load.

The upturned beams exhibited diagonal shear cracks and horizontal splitting above bottom longitudinal bars at slab-to-beam connections in beam regions without stirrups. Due to continuing deterioration, roof slab collapse appeared imminent if left unaddressed. A new roof system and structural strengthening of upturned beams was designed.

CONCLUSION

The restoration program succeeded in restoring distressed concrete elements of this historic treasure and preserving it for future generations. Besides meeting stringent aesthetic requirements, structural integrity and long-term performance of building elements were enhanced. ■

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