UNITY TEMPLE -- FINAL OUTCOMES REPORT

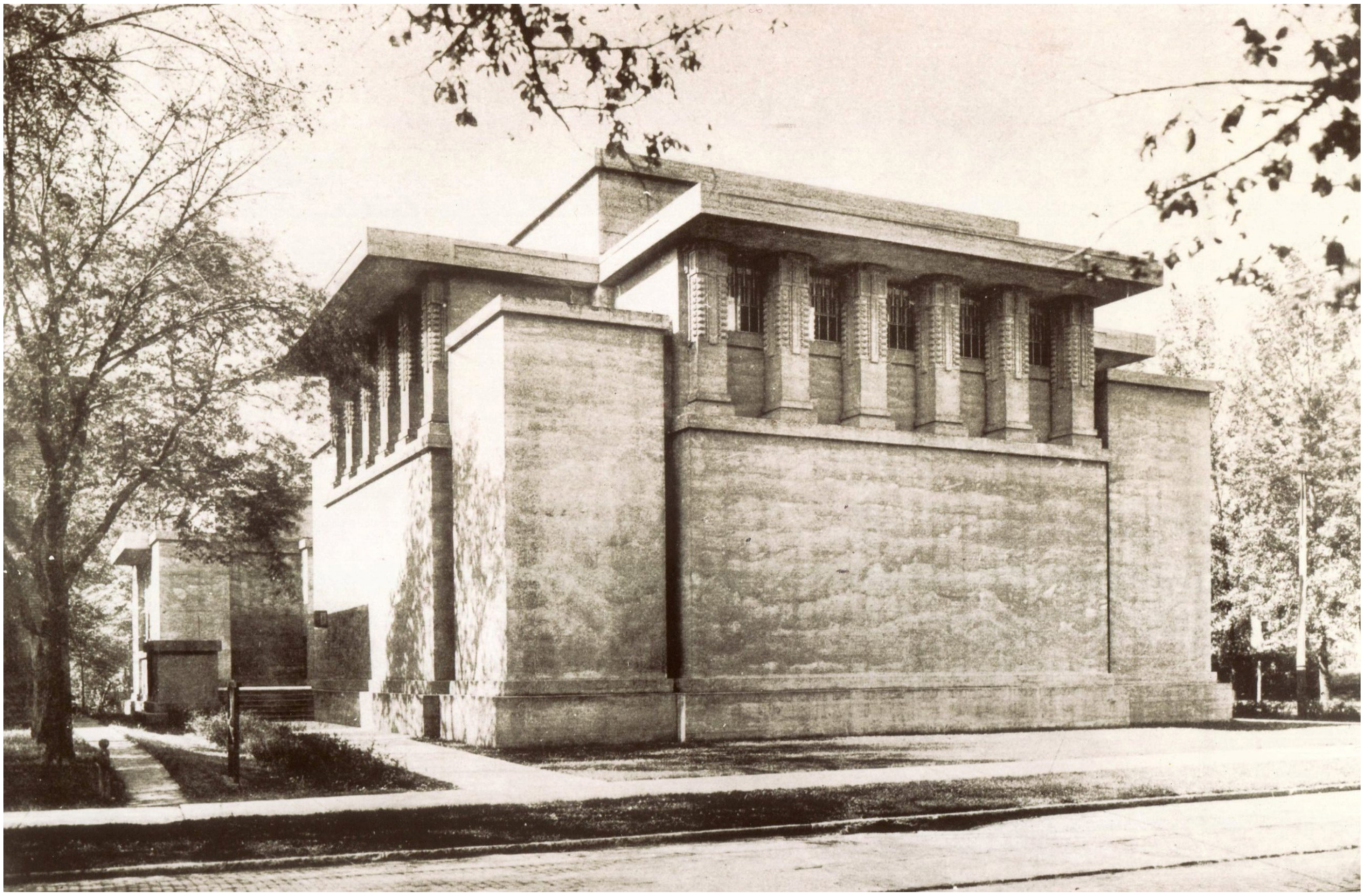

Figure 1. *Circa 1910 photo of Unity Temple's north elevation. (Public Domain)*

Designed by Frank Lloyd Wright and completed in 1908, Unity Temple is one of Wright's greatest works and a National Historic Landmark. It is included as one of the ten sites nominated to the World Heritage list as the *Key Works of Modern Architecture by Frank Lloyd Wright*. Wright's concept for the building was to create a space for both the sacred and secular. This concept evolved into two separate masses that respectively hold the Temple, or sacred space, and Unity House, a space for assembly and classrooms. These two general masses constitute the major spaces of the building and are connected in the middle by the foyer. The result was a bold and innovative design conceptually rooted within the Prairie School period but yet foretelling of the Modern architecture movement then germinating in Europe.

Project Location:	Oak Park, Illinois
Work Completed:	Restoration Master Plan, testing for new geothermal heating system, art glass window study, south roof repairs. Full $25 restoration project including complete exterior, interior and all building systems.
Date Completed:	Master Plan: 2006; South Roof Repairs: 2010; Million Restoration project: 2015-2017.
Client:	Unity Temple Restoration Foundation
Client Contact:	Mr. Brad White Associate Director Alphawood Foundation PO Box 146340

Project Summary

In 2015 Unity Temple was awarded a generous implementation grant of $200,000 from The Getty Foundation *Keeping It Modern Initiative* to fund the entire cost of restoring and conserving the exterior concrete surfaces on the North Elevation of Unity Temple, the public face of the building. Facing Lake Street, a main thoroughfare in Oak Park, the North Elevation, or Façade, is the most visible elevation of Unity Temple.

Figure 2. *1974 photo of shotcrete application. (UTP LLC)*

The material submitted for the grant provides a detailed description of the building's significance, integrity, construction chronology and the design approach for the concrete restoration. In addition, the *Summary Report on Conditions of the Concrete Structure of Unity Temple*, prepared by the CTL Group in 2014, and made available to the Getty Foundation to share with the public, describes the findings of investigative analysis that was conducted to identify the properties, condition and root causes of deterioration associated with the original concrete and the circa 1973 exterior shotcrete application.

The North Façade Project was a part of the overall building restoration project. It focused on the restoration of the 1973-74 applied shotcrete finish, which closely matched the original concrete in color and aggregates, but has become severely deteriorated in many locations. The deterioration includes areas of cracking, delamination and spalls that allowed water infiltration into the concrete walls, which, in turn, led to further damage through freeze thaw expansion as well as some corrosion of reinforcing steel.

Figure 3. *CTL Group conducting a condition assessment of the existing shotcrete.*

The concrete restoration work included:

- Cleaning
- Selective replacement of delaminated shotcrete
- Repair of cracks in sound shotcrete

This summary report describes the challenges that arose during implementation of the concrete restoration treatments and the methods that were investigated and implemented to overcome these challenges to achieve a successful project.

Existing Conditions Survey

At the beginning of the project, all of the exterior shotcrete was surveyed with hands-on techniques via scaffolding. Sounding with a hammer identified spalled and delaminated concrete areas. These were marked on the façade with crayon and documented on drawings. During the repairs, areas were resounded to confirm that all damaged areas were included in the repairs. Cracked concrete that was sound and stable was also marked on the façade and documented on drawings.

Figure 4. *Halos around repaired shotcrete were resolved with modification in the facade cleaning treatment. (Harboe Architects)*

Shotcrete Restoration – Cleaning

The approved cleaning of the existing shotcrete facades was carried out using abrasive cleaning with a fine crushed slag. Prior to the implementation, various cleaning mock-ups were conducted utilizing different methods to identify the gentlest means for cleaning the existing shotcrete. It was discovered that if the shotcrete was not cleaned in a similar method to the original finishing, a contrasting halo was created around the repair areas due to the finishing of the new shotcrete. The cleaning was completed without any unforeseen challenges. The decision to use a cleaning method that matched the surface treatment of the original shotcrete finishing allowed the new repair work, which was finished with the same treatment, to visually blend in with the adjacent existing shotcrete material.

Rust Stain Removal

Rust stains existed on the 1970's shotcrete. They were due to the corrosion of pyrite aggregates (typically less than ¼ inch in diameter and containing iron or other ferrous minerals) present in the 1970's shotcrete layer, and not connected with corrosion of the walls' embedded reinforcing bars. The offending pyrite aggregates were removed, followed by chemical rust remover to clean the stains.

Shotcrete Repairs

The selective replacement of delaminated shotcrete proved to be very challenging. The existing 1973 shotcrete exhibited several different colors of concrete paste, likely due to variances in the original cement color from batch to batch. In addition, the exposure and color mixture of aggregate had a wide range of variation. These variations in paste and aggregate color as well as aggregate exposure often resulted in the shotcrete having a different appearance on each surface of corners, as well as across large wall surfaces, such as the north façade. These variations in appearance created a challenge to matching the new shotcrete repairs to the adjacent existing material when the repair areas crossed multiple zones of finish appearance. Many repair areas were at corners, requiring the new shotcrete material to be placed on both wall surfaces for the same repair area. A mix design that provided a good visual match to one of the corner wall surfaces would have a contrasting visual appearance with the existing shotcrete when the repair turned the corner. Also in the large flat surface of the north façade a large repair area crossed four different appearances of existing shotcrete. These variations were likely due to the 1970s work having been applied in several vertical "lifts". They were not really noticeable until new repair shotcrete was placed, cured and finished.

Challenges

In order to address the challenge of multiple colors of existing shotcrete being adjacent to a single repair area we considered the following modifications to our originally conceived treatment approach:

- *Cold joints at corners to match original shotcrete placement* – This approach would likely have provided a visually successful treatment, allowing for different colors of shotcrete at each face of a repair at corner conditions. This approach was not utilized due to concerns about increasing the area of cold joints at corners that have been particularly susceptible to delamination in the past. It was decided that limiting the potential for water infiltration at cold joints was more important to the long-term preservation of the concrete than the improved visual match of the repair material that could be achieved with this approach.

- *Using multiple mix designs within a patch area with a wet-applied joint* – This approach was proposed by the design team as a means to address repair areas that crossed multiple colors of existing shotcrete without adding additional cold joints in the repair material. The craftspeople applying the shotcrete were very reluctant to utilize this approach due to the difficulty of setting up for multiple repair mix designs being applied simultaneously. This

Figure 5. *Selecting custom shotcrete mixes for repairs. (Harboe Architects)*

Figure 6. *Shotcrete at corner with two different colors of 1974 shocrete. Our new patch matched the material on the right but not the left. The mix on the right was accepted for local shotcrete repairs. (Harboe Architects)*

Figure 7. *The shotcrete patch was cut-out and re-patched with a mix design that worked for both colors of existing shotcrete. (Harboe Architects)*

method was identified as a back-up approach that would be attempted if other approaches were not successful. As it turned out, other approaches provided acceptable results and this approach was not attempted. In future projects this approach may still merit consideration and mock-up trials to determine if it could be successfully executed.

Figure 8. *The shotcrete aggregate was exposed utilizing abrasive blasting. (Harboe Architects)*

- *Varying the level of aggregate exposure across repair areas* – The appearance of the repair shotcrete can vary depending on the amount of aggregate that is exposed while finishing the shotcrete. Several of the repair areas required using different levels of aggregate exposure across the new repair shotcrete to achieve acceptable visual matches to the adjacent existing shotcrete. This repair approach was successfully executed by slowly increasing the aggregate exposure a little at a time until the optimal appearance was achieved. Great care was required to ensure that the aggregate exposure was not too aggressive compared to the adjacent existing shotcrete, since once the finishing becomes too aggressive it cannot be reversed.

Figure 9. *Rejected shotcrete patches at the north elevation. (Harboe Architects)*

- *Selecting a mix design that minimized the visual contrast with existing adjacent shotcrete* – Careful selection of the mix design for repair areas was critical to achieving a good visual match with the adjacent existing shotcrete. Each area was evaluated to select the closet color match for that specific area. At patches that crossed multiple colors of existing shotcrete a mix color that provided that closest overall appearance was utilized. To be successful, the mix tended to be closer to the lighter color of the existing shotcrete. Once placed the aggregate exposure was tweaked to help the mix blend with the darker colors of existing adjacent shotcrete.

Figure 10. *Rejected shotcrete patches at the north elevation were cut-out and the are re-patched with a revised mix to provide a closer match. (Harboe Architects)*

- *Redoing repairs multiple times until a satisfactory result was achieved* – The selection of appropriate mix designs and the aggregate exposure finishing of the repairs required a high level of artistry by the tradesmen performing the work. In addition, environmental conditions such as temperature and humidity levels during curing had an effect on the finished color and appearance of the repairs. Despite a high level of attention and quality control, some repair areas did not result in a good visual match and detracted from the overall appearance of the exterior concrete. When this occurred it was necessary to cut out the repair shotcrete and redo the repairs with appropriate modifications to the mix design and finishing. In a few instances, including at the north façade, it was necessary to reattempt repairs multiple times before a successful match was achieved. The team's dedication to successful results was essential to achieving good visual matches of concrete repairs in a monolithic finish surface.

Reinforcing and Curing of Shotcrete Repairs

The previous 1970's shotcrete treatment did not include any mesh reinforcement to control shrinkage. During initial repair mock-ups a couple shrinkage issues became apparent.

Figure 11. *Installation of mesh reinforcement to control shrinkage. (Harboe Architects)*

- The new patches shrank away from the edge of the existing adjacent shotcrete. This was resolved by the addition of stainless steel pins at the joint between the existing and new shotcrete.

- Cracks in the original concrete substrate telegraphed through the previous shotcrete repairs as well as the new repair mock-ups. This was resolved with the addition of stainless steel mesh at all new repairs areas which resulted in eliminating the telegraphing of cracks from the substrate through the new repairs.

- Map-cracking developed in the early mock-ups. This is believed to have been caused by a combination of over troweling the repair shotcrete that brought more cement paste to the surface as well as the drying out of the surface material prior to curing fully. This was resolved by reducing the working of the fresh repair shotcrete and the addition of a curing compound applied to its surface.

Figure 12. *Rejected crack repair. (Harboe Architects)*

Crack Repairs

The repair of cracks in existing shotcrete in a way that allowed them to visually disappear proved to be very challenging. Cracks in shotcrete that were sound were ground out and repaired with urethane sealant. Existing shotcrete was crushed and impregnated into the surface of the fresh sealant to help blend the repairs into the adjacent shotcrete. The approach of impregnating urethane sealant with crushed existing shotcrete and aggregate to visually match the appearance of the adjacent shotcrete was difficult to consistently achieve on a large scale. The success of these repairs was dependent on the artistry of the tradesmen doing the work. Repairs that were performed from scaffolding with close-up access often appeared to be good matches, but once the scaffolding was removed and the repairs could be viewed from afar and in different lighting conditions the repairs contrasted with the color of the surrounding existing shotcrete. In addition, some of the successful crack repairs were in close proximity to areas of shotcrete repairs that required additional aggregate exposure once the scaffolding was removed. In these instances, the crack repairs were damaged during the adjacent abrasive aggregate exposure. Much like some shotcrete patches, a number of crack repairs had to be cut out and redone to achieve an acceptable match. In addition, due to the different absorption rate of the shotcrete and the urethane sealant, the appearance of the crack repairs varies with the weather. Repairs that are good matches when the facades are dry become contrasting in visual appearance after a rain storm or in high humidity.

Figure 13 *The rejected crack repairs were cut-out and the cracks were re-patched to more closely match the approved mock-up sample. (Harboe Architects)*

The North Façade Project presented many challenges to repairing the 1970s shotcrete given variances in the original cement color and aggregate density and exposure from batch to batch. Repair patches had to be carefully customized to blend in with the adjacent shotcrete. The ultimate success of the shotcrete repair work was due to a collaborative team effort and utilization of extensive mock-up trials prior to initiating the actual work. Although time consuming, these trials were essential to maintaining the appearance of one of Frank Lloyd Wright's greatest masterpieces.

Report to

UNITY TEMPLE UNITARIAN UNIVERSALIST CONGREGATION

&

UNITY TEMPLE RESTORATION FOUNDATION

CTLGroup Project No. 231126

Summary Report for the Concrete Structure of Unity Temple

875 Lake Street

Oak Park, IL 60301

January 21, 2015

Submitted by:

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SUMMARY REPORT FOR THE CONCRETE STRUCTURE OF UNITY TEMPLE

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CTLGroup Project No. 231126 January 21, 2015

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SUMMARY REPORT FOR THE CONCRETE STRUCTURE OF UNITY TEMPLE

UNITY TEMPLE
OAK PARK, ILLINOIS

1.0 INTRODUCTION

This report is prepared for Unity Temple Unitarian Universalist Congregation (UTUUC) and Unity Temple Restoration Foundation (UTRF) to provide a summary regarding the condition of the concrete structure at Unity Temple, root causes of the observed deterioration and recommended repairs for the Unity Temple restoration project.

1.1 Background

CTLGroup has provided structural engineering and concrete materials consulting services to UTUUC and UTRF related to the concrete structure of Unity Temple on the following projects and studies:

1. **Comprehensive Condition Survey & Evaluation of Concrete Structure of Unity Temple (1999 - 2000)**
   - Performed document review; detailed field surveys; concrete sample removal; laboratory examination & testing; structural analysis.
   - Developed conceptual repair recommendations to address the areas of observed distress and deterioration.
2. **Unity Temple Restoration Phase 1A: Repairs to Cantilevered Roof Slabs and Supporting Ornamental Columns (2001-2002)**
   - Based on repair recommendations developed by CTLGroup, Phase 1A of a two-phased exterior rehabilitation program (i.e., Phases 1A & 1B) for the exterior concrete structure of Unity Temple was implemented in 2001 and completed in January 2002, which included repairs of the cantilevered roof slabs and ornamental concrete supporting columns. At this time, the remaining Phase 1B has not been performed.
   - Performed design development; contract/bidding document preparation; bidding assistance; field trial mockups; contract administration, field engineering/consulting and field observation services for Phase 1A.

3. **Evaluation of Cantilevered Roof Slabs & Ceilings in the Sanctuary of Unity Temple (2008 – 2009)**

   - Performed condition survey of roof slab sections/ceilings in the Sanctuary following spalling of ceiling plaster and concrete to address UTUUC & UTRF's concern with potential falling hazards at the remaining ceiling areas.
   - Prepared report entitled "Evaluation of Cantilevered Roof Slabs and Ceilings in the Sanctuary of Unity Temple, Oak Park, Illinois," and dated February 20, 2009.

4. **South Roof Slab Repairs (2009-2010)**

   - Performed design development; contract document preparation; bidding assistance; coordination with UTUUC, UTRF & Harboe Architects; and field observations during restoration program.

5. **Field Condition Surveys & Budgetary Cost Estimate Updates for Unity Temple Restoration Phase 1B: Repair to Roof Slabs, Parapet Walls, Chimney, Exterior Walls, Ornamental Planters & Elevated Terraces (2009 & 2013)**

   - In 2009, performed field condition surveys of accessible exposed concrete surfaces (via ladder) of the roof slabs, parapet walls, exterior walls, chimney, flower boxes and terraces. The objective of the condition survey was to assess whether any significant progression of concrete deterioration had occurred since the 1999 comprehensive condition survey by CTLGroup. Prepared report entitled "Status Update Reports on Repair & Restoration Program for the Concrete Structure of Unity Temple," dated February 5, 2010.
   - In 2013, performed visual reviews and prepared updated budgetary cost estimate for repairs. Issued report entitled "Budgetary Cost Estimates Update," and dated May 12, 2013.

6. **Predesign Field Mockup Trials for Restoration of Unity Temple (2014)**

   - Assessed suitability of repair materials and techniques as part of the effort to resolve outstanding issues pertaining to the scope of the restoration program related to the concrete structure. Mockups were used to review restoration options with UTUUC, UTRF, Project Management Advisors, Inc. (PMA) and Harboe Architects.

1.2 Current Scope of Work

In response to your recent request, CTLGroup performed the following scope of work:

1. Document Review:
   a. Reviewed CTLGroup reports from the 1999-2000 condition survey and evaluation; 2009 evaluation of the roof slab sections/ceilings in the Sanctuary; and 2010 status update report.
   b. Reviewed results from visual condition surveys from 2009 and 2013.
   c. Reviewed CTLGroup drawings from the 2001-2002 Phase 1A repair program and the 2009-2010 south roof repair program.
2. Report Preparation:
   a. Prepared this report with summary of the condition of the concrete structure at Unity Temple, root causes of the observed deteriorations and recommended repairs for the Unity Temple restoration project.

2.0 CONCRETE ELEMENTS

Our 1999-2000 study resulted in the identification of the following main areas of concern regarding the integrity of the concrete structure of the building.

1. Exterior Architectural Walls
2. Ornamental Columns
3. Structural Roof Slabs
4. Interior Concrete Structural Elements
5. Parapet Walls on Unity Temple & Unity House
6. Ornamental Planter Boxes
7. Chimney on Unity House
8. Concrete Flatwork on the Terraced Area on either side of the Entrances to the Foyer

3.0 EXTERIOR ARCHITECTURAL WALLS

3.1 CONDITION UPDATE

The shotcrete coating (i.e., pneumatically-applied concrete) is nearly 42 years old and was applied to the underlying original parent concrete during the 1973 restoration program. Shotcrete thickness varied from approximately ½-inch to 1 inch. The parent concrete used in walls and columns was designated as “stone concrete” by Wright.

1. Delamination of Shotcrete Repairs from Underlying Concrete

a. Based on condition surveys in 1999, 2009 and 2013, there are new areas where the shotcrete coating has delaminated from the underlying concrete since 1999. In addition, we noted considerable growth in the delaminated areas at virtually all the architectural walls since 1999.

b. Some new shotcrete delaminations occurred along unsealed wall cracks, likely due to water infiltration through these cracks.

c. We noted localized wall areas with corrosion of reinforcing bars embedded in the outer regions of the parent concrete. The corrosion has caused small regions of the parent concrete and the overlying shotcrete coating to crack, delaminate and spall.

d. Several trial repair patches to delaminated sections of the architectural walls were installed in conjunction with the 2001 cantilevered roof slab rehabilitation program to allow monitoring of their appearance with time. One of the repair patches was located on the ledge below the base of the southernmost ornamental column on the east exterior wall of Unity Temple. Other repair patches were installed on the vertical fascias of roof slab at the northeast corner storage room of Unity House. These repair patches are performing well. In addition, natural weathering of these 2001 repair patches has improved the aesthetics of these patches by blending the repairs with adjacent concrete wall areas.

   The temporary repair patch that was installed in 2008 to address a spall at the upper level of the east elevation of the northeast stair tower at Unity Temple also appears to be performing well. This patch was designated as “temporary” since it was performed using an off-the-shelf, non-matching, non-air entrained concrete repair material (at the direction of UTUUC to address a citation from the Village of Oak Park). The same repair material was used to replace several east terrace flatwork panels. The concrete material did not closely match the existing wall areas in terms of color and texture. It is the intention of UTUUC and UTRF to replace this temporary patch repair during the course of the next repair program to the architectural walls.

e. 2014 Field Cleaning & Concrete Repair Mockups:

   Cleaning trials using soda blasting were performed at the east parapet wall of Unity Temple and the south elevation of Unity House in 2014. At the south elevation of Unity House, the field cleaning trials were performed on selected exposed exterior wall sections at or near locations where patch trial repairs will be performed to assess effectiveness of cleaning process, and matching of new concrete against cleaned sections of wall.

Concrete repair mockups were also performed at the south elevation of Unity House in 2014. Shotcrete trial patch repairs at several representative flat wall sections were performed. In addition, two form-and-pour patch trial repairs were performed at representative wall coping elements at top of walls. The concrete repair mockups were performed to assess the following: whether the shotcrete mix design from the 2001-2002 repair program could be replicated using commercially available materials in 2014; whether the mix design could be varied to address variances in existing surface texture and color of the shotcrete; shotcrete removal techniques (sawcutting patch perimeters and/or detailing/chipping patch perimeters to minimize appearance of sawcut edges); repair cavity reinforcement detailing; shotcrete finishing techniques; curing methods, etc.

Multiple mockups were performed. While further refinements may be performed to enhance aesthetics, results from the later concrete mockups were relatively successful.

2. Wall Cracking

a. In general, there are two main types of wall cracks:

1. Shrinkage cracking of the shotcrete coating.
   These cracks are typically vertically trending, but can be somewhat random and irregular in appearance. The edges of these cracks are generally well rounded. This rounding likely occurred due to the fact that the shotcrete was sandblasted shortly after it was applied to the walls, to achieve an exposed aggregate finish. The sandblasting process abraded the normally sharp, clean edges of the cracks. These cracks are typically quite narrow in appearance. However, the true width of these cracks cannot be visually determined due to the rounding caused by the sandblasting. It is estimated that these cracks likely average less than 0.010 inch in actual width beneath the rounded edges. These cracks may have minimal movement (i.e., opening and closing), if any, in response to ambient thermal changes and changes in moisture content of the concrete. This is because the shotcrete, in which the

shrinkage cracks exist, is in most cases well bonded to the underlying parent concrete.

2. Cracks that reflected through the shotcrete coating due to cracks in the underlying concrete structure.

   This type of crack exhibits clean and sharp edges in the shotcrete coating in most cases, and is generally wider than the shrinkage cracking of the shotcrete coating described above. These cracks likely open and close in response to ambient thermal changes and changes in the moisture content of the concrete.

   We noted that such cracks are typically located at the following locations:

   i. Discontinuities in exterior surfaces of the building. These typically occur at the corners of window and door openings, or at locations where there are sharp breaks in the geometry of the structure. One such location is at the base of the walls below the tall and slender strip of art glass that provide a geometric break between the corner staircase structures and Unity Temple.

   ii. Cold joints (construction joints) in the underlying concrete structure. This problem is particularly evident in the parapet walls above Unity Temple and Unity House where horizontally orientated cracks are present below the scupper openings and above the roofing of the cantilevered roofs. Another example is the horizontally orientated cracks near the top of concrete walls, just below the fascia for the roof slab. These cracks are reflections of construction joints in the walls where they meet the roof slab construction.

   iii. Adjacent to corners of walls. Vertically oriented cracks can occur at the locations that are approximately coincident with the inside face of the intersecting wall at corner locations. For example, this type of cracking is evident at the four corners of Unity Temple that serve as stair towers.

b. In general, the majority of new wall cracks that we documented during our 2009 and 2013 visual reviews were merely extensions of cracks that were documented during our 1999 condition survey. However, cracking of the fascias at roofs over stair towers at Unity Temple and along tops of storage room enclosures at Unity

House appeared more extensive than in our 1999 survey, and some new areas of delaminated concrete were found.

c. There are a number of cracks in the shotcrete coating that were routed-and-sealed prior to our 1999 survey. The majority of these crack repairs had failed. It also appeared that no consideration was taken to match the sealant used with the color and texture of the existing shotcrete layer. As a result, these crack repairs are aesthetically inferior, as can be seen at the west ornamental planter box and screenwall for example.

d. 2014 Field Crack Repair Mockups:

   Field trial crack repairs involving use of a two-part polyurethane sealant blended with fine aggregates were installed in 2014 at the east elevation of the roof parapet wall of Unity Temple. This test location was selected since all existing shotcrete on the parapet will need to be removed and replaced at a later date. The field trials were performed to assess suitability of sealant materials, variations of aggregate/sand materials applied on sealant, routed groove profiles/widths, sealant tooling techniques, etc. Results from the crack repair mockups were successful in visually blending the mockups with the wall background material.

3. Rust Stains

a. Rust stains on walls are due to the corrosion of pyrite aggregates (typically less than ¼-inch in diameter and containing iron or other ferrous minerals) present in the shotcrete layer applied during the 1973 restoration, and not connected with corrosion of wall reinforcing bars.

   The 2001 Phase 1A of the exterior rehabilitation program included application of a commercially available chemical to remove rust stains on exterior walls followed by removal of the offending pyrite aggregates. Only areas that were readily accessible from the scaffolding below the cantilevered roofs, roofs of Unity Temple, Foyer and Unity House, and grade were performed in 2001.

b. Our field review in 2009 indicated that stain removal repairs performed in 2001 remained effective. In addition, there were virtually no new rust-stained areas that emerged since 2001 at these accessible wall areas. Therefore, rust stains that are still remaining were present prior to the 2001 rehabilitation program. These remaining rust stains should be addressed using a similar repair approach in the next rehabilitation program involving exterior walls.

3.2. CONCLUSIONS

1. The existing shotcrete layer on the exterior walls has been in place for nearly 42 years (installed during the 1973 restoration program). Shotcrete deterioration in the form of cracking and delaminations was observed on the exterior walls, the fascias along tops of stair towers at Unity Temple, and fascias along tops of storage room enclosure structures at Unity House. Since no comprehensive repairs have been performed in these areas to address observed deterioration, deterioration will continue with time. We noted considerable growth in the delaminated areas at virtually all the architectural walls since our 1999 survey.

2. The majority of observed shotcrete delaminations and spalls are due to debonding of the shotcrete coating from the underlying parent concrete. This deterioration is attributable to thermal and moisture cycles within the concrete over time.

3. There are localized delaminated and/or spalled wall areas with corrosion of reinforcing steel embedded in the outer regions of the parent concrete. The corrosion has caused small regions of the parent concrete and the overlying shotcrete coating to crack, delaminate and spall. Review of archival historic photos from the 1973 restoration program revealed existence of deterioration at these locations prior to 1973. Apparently, the repairs that took place in 1973 to address the corroding reinforcing bars in these locations were not sufficient to permanently correct this problem.

   These localized areas with corrosion damage in the exterior walls are caused by a combination of carbonation of the concrete, lack of adequate depth of concrete cover over the reinforcing bars embedded in the parent concrete, and exposure to sufficient amounts of moisture and oxygen.

   Carbonation of the concrete is the reaction of the various components of the cement paste with carbon dioxide in the air. Carbonation reduces the natural protective alkalinity of the concrete and makes the embedded steel susceptible to corrosion in the presence of sufficient amounts of moisture and oxygen. Carbonation also increases shrinkage of concrete elements, thus promoting crack development.

   If the depth of carbonation reaches the embedded steel in a concrete structure, then corrosion of that steel may take place, if oxygen and sufficient amounts of moisture are present. Typically, an internal relative humidity of 50 to 60 percent is required to feed the corrosion reaction in carbonated concrete. Unfortunately, the average ambient relative humidity in the Oak Park area is above this level. Therefore, the normally available atmospheric moisture (i.e., without precipitation) is a source of moisture feeding the corrosion of the reinforcing bars in the facade elements.

Since carbonation occurs at exposed surfaces of concrete and propagates deeper with time, *carbonation-induced corrosion* damage occurs most rapidly when the depth of concrete cover over the embedded reinforcing steel is low. This was evident at delaminated wall locations with exposed corroded reinforcing bars that were placed at the outer regions of the parent concrete. However, carbonation will continue advancing in depth in the concrete, with continued exposure to carbon dioxide and the passage of time.

In general, the repairs involve complete removal of all deteriorated concrete, cleaning and applying corrosion-inhibitive coating to the exposed steel to protect it from further corrosion, and installation of a patch material designed to be durable and match the finish of the surrounding concrete surfaces.

4. Durability, performance, and aesthetics of 2001 trial repair patches installed at selected delaminated sections of the exterior walls appeared satisfactory. Hence, the concrete mix design that was developed during the 2001 Phase 1A repairs was reutilized and refined during the 2014 concrete repair mockups for future repairs of the exterior walls and fascias.

5. The majority of the observed new wall cracks appeared to be extensions of existing cracks that were documented during our 1999 condition survey. Wall cracks may grow in length over time as a result of thermal and moisture cycles within the concrete that cycles crack widths. Cracks will allow water ingress that may promote corrosion of embedded reinforcing or other deterioration. Therefore, it is imperative that the wall cracks be properly sealed and the seals maintained in order to alleviate water penetration into the walls. Continuing long term water penetration will lead to continuing delamination of the shotcrete layer and degradation of the underlying concrete along the cracks.

6. Previous attempts at wall crack repairs by others (e.g., along the west planter screenwall) appeared unsightly since these rout-and-sealed repairs resulted in a visible accentuation of the underlying cracks. These cracks were routed (to a much larger width than the actual crack width) and sealed with caulking that did not match the surrounding concrete.

7. CTLGroup trial crack repairs installed in 2014 on the east parapet wall of Unity Temple appeared to closely match the color and texture of the surrounding concrete when viewed from a close distance (less than 10 feet) from the wall.

8. The rust stain removal repairs that were performed during the 2001 Phase 1A of the exterior rehabilitation program at readily accessible wall areas have remained effective. The rust stains at the remaining wall areas should be addressed in a similar fashion.

3.3. REPAIR RECOMMENDATIONS

1. Remove cracked and delaminated shotcrete layer from deteriorated areas.

2. The shotcrete at highly deteriorated shallow fascias along the top of the walls of stair towers at Unity Temple and the fascias along the top of walls of storage room enclosures at Unity House should similarly be removed and replaced. This work will also require removal and replacement of the roof flashing over the top of these walls.

3. <u>Shotcrete and Cast-In-Place Concrete Repair Approach</u>

   Based on findings from the concrete repair mockups at the south elevation of Unity House, we recommend that the concrete repair approach include the following procedures. In addition, following deteriorated shotcrete removal, the condition of the exposed underlying concrete substrate, including any pre-existing cracks, should then be assessed and appropriate repairs performed.

   a. Identify Deteriorated Area
      i. Identify and mark areas of deteriorated concrete prior to concrete removal work.

   b. Unsound Concrete Removal
      i. Provide ½-inch deep sawcut around the entire patch perimeter. Do not cut any existing reinforcing bars.

      ii. Remove concrete to sound concrete using 15 lb. electric or pneumatic chipping hammers to minimize damage to adjacent sound concrete. Remove concrete to provide ¾-inch minimum clearance behind any reinforcing bars in sound concrete.

iii. Chip along the patch perimeter to eliminate the straight sawcut lines and provide a smoother transition from patch area to immediate surrounding concrete.

c. Repair Cavity Preparation

i. Clean exposed rebars to remove all corrosion products and old concrete using commercial blast cleaning, SSPC-SP6 using sand or other grit blasting.

ii. Exposed rebars with more than 10% loss of original cross-section diameter shall be supplemented with new stainless steel rebar/dowel.

iii. Sandblast cavity to remove deleterious materials such as laitance and dirt. Roughness of cavity shall have minimum surface amplitude of approximately ¼-inch. The cavity shall be blown clean with oil-free compressed air.

iv. Clean rebars shall be thoroughly painted with an approved corrosion-inhibitive coating.

v. Add epoxy-grouted stainless steel dowels around the perimeter of the patch to minimize shrinkage cracks around patch perimeter.

vi. Add stainless steel welded wire mesh in the repair cavity to minimize shrinkage cracking of shotcrete repair material. In addition, installation of the wire mesh over existing cracks/joints in the parent concrete will inhibit cracks from telegraphing through new shotcrete repairs.

vii. At form-and-pour repairs, add epoxy-grouted stainless steel dowels and/or supplemental steel reinforcement to control shrinkage cracking and provide additional anchorage of patch material to parent concrete.

d. Preparation for Concrete Placement

i. Match existing drip notches, chamfers and profiles.

ii. Final Surface Preparation: Predampen cavity surface with clean water. Cavity substrate shall be saturated surface dry with no free water.

e. Concrete Placement , Finishing & Curing

i. Use approved concrete mix design from concrete repair mockups for both shotcrete and form-and-pour repairs.

ii. For shotcrete repairs, maintain proper finishing techniques established during concrete repair mockups. Do not over-finish the shotcrete surface. Apply two coats of curing compound after shotcrete surface has slightly hardened and protect the patch with polypropylene sheets if necessary. After the shotcrete has cured for 3 days, perform grit blasting (using “Black Beauty” material) to achieve the desired exposed aggregate finish.

iii. For form-and-pour repairs, consolidate using pencil vibrators, or other methods as required to ensure no voids exist in the patch. Provide curing of patch material using polypropylene sheets.

4. <u>Crack Repair Approach</u>:

The crack program that is described below is presented to address the cracks that have not yet been sealed, as well as cracks that have been routed-and-sealed at some point in the past.

Based on findings from the trial crack repairs at the east elevation of the parapet walls at Unity Temple, we recommend that these cracks be addressed as follows:

a. Crack Routing:

i. Mark entire length of joint/crack to improve visibility of crack during routing. Rout out full length of crack to form a V-groove centered on crack.

ii. At cracks that were previously routed-and-sealed, remove existing sealant where present. Clean crack or rout the crack to establish a proper joint geometry, if it does not currently exist.

iii. Clean routed reservoir with brush to remove grinding dust and provide a clean, dry and sound surface.

b. Sealant Installation/Application:

i. Install bondbreaker (tape or crayon marking) along the base of the entire reservoir of the V-shaped grooves. Prime surfaces of grooves to receive new sealant.

ii. Apply a two-part polyurethane sealant (sealant product and sealant color approved from the trial crack repairs). Tool the sealant to recess the sealant slightly below the wall surface.

iii. Broadcast coarse aggregates (approved from shotcrete mix design but without sand) on the uncured sealant. Brush off excess aggregates.

iv. Cure sealant in accordance with sealant manufacturer's recommendations.

c. Cleaning

i. Remove excess sealant material and smears to provide a neat appearance at work areas.

For exterior architectural walls, including ornamental planter boxes and screenwalls located at street level, we recommend that rout-and-seal crack repairs be performed since crack widths are significant. If crack repairs at street-level locations are unacceptable due to aesthetics, complete removal and replacement of the outer shotcrete layer may be necessary. Any cracks that may develop thereafter would be addressed with the crack repair approach presented above.

4.0 ORNAMENTAL COLUMNS

4.1 CONDITION UPDATE

1. The 2001 Phase 1A of the exterior rehabilitation program included application of a penetrating silane sealer to all ornamental columns to mitigate future moisture intrusion.

2. Remote visual review of the ornamental columns located at the four elevations of Unity Temple and at the east and west elevations of Unity House did not detect any new visible distress.

3. Repairs were performed on the southernmost column (in the region of the column with precast hollyhock ornamental features) on the west elevation of Unity Temple during the 2001 Phase 1A of the exterior rehabilitation program. Visual review at this column indicated that the 2001 Phase 1A repairs appeared to be performing well.

4.2 CONCLUSIONS

1. The ornamental columns at the four elevations of Unity Temple and at the east and west elevations of Unity House did not exhibit any new visible distress in 2009 and 2013.

4.3 REPAIR RECOMMENDATIONS

1. No immediate repairs are deemed necessary at the time of this report. However, the silane sealer that was applied in 2002 to all the ornamental columns will need to be reapplied at approximately 10 year intervals in the future life of the building. Whenever access might be available, a tactile examination should be performed.

5.0 STRUCTURAL ROOF SLABS

5.1 CONDITION UPDATE

The original specifications for the building prepared by Wright indicated the use of “cinder concrete” for the roof slabs. A “portland cement facing layer” was also specified for use at the exposed surfaces of the roof slabs. In work to date, we have noted that the “portland cement facing layer” was present at slab topsides, undersides and fascias.

A. Concrete Roof Slabs on the Exterior of both Unity Temple and Unity House (Roof Slab Topsides and Fascias, and Exterior Soffits):

1. In 1973, a rehabilitation program was performed which included removal of the “portland cement facing layer” followed by application of a shotcrete layer at the top and front faces of the fascias along the perimeter edges of the cantilevered roof slabs.

2. Following the recommendations of the 2000 CTLGroup report, UTUUC and UTRF implemented Phase 1A of the exterior rehabilitation program in 2001. The program included replacement of the fascia beams along the perimeter of the cantilevered roof slabs over Unity Temple at its four elevations, and Unity House at its east and west elevations. The Phase 1A program also included complete replacement of the severely deteriorated “portland cement facing layer” on roof slab undersides (soffits) with shotcrete in the exterior zone beyond the clerestory art glass windows.

    a. Remote visual review of the fascias and soffits of the cantilevered roof slabs over Unity Temple and Unity House indicated that the 2001 repairs appeared to be performing well.

    b. During the 2001 rehabilitation program, replication of the profile lines of the existing fascia beams, including the curvature resulting from slab deflections, was accomplished. In general, the fascia beams at all cantilevered roof slabs were reconstructed with the midpoint of the beams being 1 inch higher than the two opposite ends of the beams.

During our 2009 field review, field measurements of the relative deflections along the top of the fascias were difficult to obtain due to the presence of a continuous metal coping that was installed as part of the existing roofing system. However, approximate relative deflection profiles of the top of the metal coping using a laser level indicated that the ends of the fascia were approximately 1 inch below the fascia midpoint. It appeared that no significant deflection of the ends of the fascia had occurred since 2001.

c. There was shrinkage cracking along the fascias at the perimeter of cantilevered roof slabs. These shrinkage cracks are anticipated to occur over the length of the 40-feet span of the front (fascias) outer and the fascias on the return faces of the cantilevers. We noted that the majority of these shrinkage cracks occurred within 1 year after the fascia beams were reconstructed in 2002. In general, these shrinkage cracks are relatively tight in width.

d. At the west elevation of Unity House, localized staining on the soffit of the cantilevered roof slab was observed. CTLGroup noted that these stains occurred soon after the roofing system was replaced (sometime between 2004 and 2008). The dark stains appear to be due to infiltration of water containing roofing-related bituminous material through cracks in the roof slab in this region.

e. Based on field observations and core sampling during the 2009-2010 south roof slab repairs, the following is a summary of our findings as related to the overall condition of the south roof slab:

   i. The structural roof slab is approximately 9-1/2 inches in thickness, consisting of 8-1/2 in. structural “cinder concrete” with a 1 inch “portland cement facing bottom layer”. There is also a ¼-inch thick “portland cement facing layer” on the top of the roof slab. A lightweight concrete fill material was present over the structural slab prior to the time of the 2001 rehabilitation program.

   ii. Topside delaminations in the structural roof slab were found to be localized and appeared to be due to cyclic freeze-thaw deterioration. Freeze-thaw degradation of the structural cinder concrete appeared to be shallow in depth and concentrated in the cantilevered zone of the roof slab.

iii. Based on field observations during the 2001 rehabilitation program, we noted that the layer of lightweight concrete fill material on the roof slab topside had extensive freeze-thaw degradation. Since 2001, the deteriorated concrete fill was removed during a previous roofing replacement program and replaced with roofing insulation material.

iv. Exposed top layer of slab reinforcing bars in the structural roof slab consisted of 1 in. square twisted and ½-inch smooth round bars extending parallel to slab and cantilever spans, with clear concrete cover of approximately 4 inches to the top of structural slab. In general, exposed top bars appeared to be only slightly corroded.

B. Concrete Roof Slabs in Areas Inside Unity Temple and Unity House (Interior Slab Soffits):

1. Unity Temple Roof Slabs Over Upper Balconies (North, East & West Elevations) & Over Organ (South Elevation):

Following concerns due to a concrete/ceiling plaster spall adjacent to the southeast corner column in the Sanctuary, CTLGroup performed an evaluation of the roof slab undersides/ceilings in the Sanctuary of Unity Temple from November 2008 to January 2009. Our findings, conclusions and recommendations from that evaluation were included in a CTLGroup report entitled “Evaluation of Cantilevered Roof Slabs & Ceilings in the Sanctuary of Unity Temple” and dated February 20, 2009. For the reader’s convenience, the following is a summary of our findings from that evaluation:

a. Localized deterioration in the form of cracked, delaminated and spalled concrete was observed on the roof slab underside regions in the Sanctuary at the north, west and east elevations. In comparison, observed concrete deterioration on the south roof slab underside was more extensive.

b. Observed concrete deterioration appeared to be typically worse in the regions below the roof drains and parapet walls. The majority of the observed severe concrete and ceiling plaster deterioration on the slab undersides is attributable to active water leakage from malfunctioned roof drains and/or plumbing lines, and parapet walls over time. At slab underside areas below the roof drains at the south roof, corrosion had progressed to the extent that there was 100% loss of steel cross-sectional area in the bottom slab reinforcing bars. Another location with persistent water leakage problems (likely due to defective drain and/or plumbing systems) is at the north roof of the Sanctuary directly below the northeast corner roof drain.

c. In some isolated instances, localized delamination and spalling were due to reactivity problems with iron-containing slag used as an aggregate in the structural cinder concrete layer of the roof slabs.

2. **Unity Temple Roof Slabs over Corner Staircases:**

   a. Concrete and ceiling plaster delaminations exist on the roof slab undersides at each of the corner staircase structures.

   b. Evidence of water leakage in the form of cracked and debonded ceiling paint and/or ceiling plaster was present.

3. **Unity Temple Roof Structure:**

   a. The concrete beams that span in both directions across the Sanctuary ceiling and support the gridwork of laylights over the Sanctuary were surveyed and hammer-sounded during our 1999-2000 study. Localized areas of delaminated concrete were removed and patched to insure that they not fall to the Sanctuary floor or upper balconies.

   b. Remote visual reviews in 2009 and 2013 did not indicate presence of any cracked or displaced concrete.

4. **Unity House South Playroom Ceiling:**

   a. Review of our 1999 condition survey indicated presence of extensive water leakage through roofing defects over a prolonged time period. As a result, there were slab underside areas with concrete deterioration due to corrosion of embedded reinforcing bars. Roofing repairs over this room (reportedly performed between 2002 and 2006) appeared to have mitigated the source of continuing moisture penetration into the roof slab at these areas.

   b. We could not perform a visual review of the underside of the concrete roof slab in this room in 2009 and 2013 since the slab soffit was covered with a suspended drywall ceiling system. Removal of the ceiling panels would be required for hammer-sounding of the slab underside. We noted, however, that there are localized leakage stains on the ceiling.

c. It is our understanding that no concrete repairs have been performed to address deteriorated concrete on the roof slab underside observed during our 1999 condition survey. The previous major repair work that was performed to the underside of the concrete roof slab was reportedly during the 1973 restoration program.

5. Unity House – Concrete Roof Slabs Over the 2nd Floor Corner Storage Rooms:

a. Two of the four storage rooms at the northeast and northwest corners of Unity House exhibited extensive concrete deterioration on the roof slab undersides and delaminated/spalled ceiling plaster in 1999-2000. Concrete deterioration in the form of delaminations and spalling of concrete with exposed severely corroded reinforcing bars were present.

b. Roofing repairs were recently performed (reportedly performed between 2002 and 2006) over these corner storage rooms. It appeared that the roofing repairs were effective in addressing previous leakage issues since there are currently no visible signs of active water leakage.

6. Unity House – Concrete Roof Slabs Over the 2nd Floor/Mezzanine Classrooms:

a. The ceilings of the 2nd floor/mezzanine classrooms located at the east and west ends of Unity House were also surveyed in 1999-2000. Localized areas with debonded ceiling plaster were identified. Without removing these debonded ceiling plaster areas, it was difficult to assess whether concrete behind the ceiling plaster areas was delaminated as well.

b. No leakage stains are currently visible on the ceilings of both classrooms. Therefore, it appears that no water leakage has occurred from the upper level roofing systems and into the enclosed spaces that are directly above the classrooms since the re-roofing project.

5.2 CONCLUSIONS

A. <u>Concrete Roof Slabs on the Exterior of both Unity Temple and Unity House</u>:

1. The 2001-2002 Phase 1A repairs involving replacement of the fascia beams/panels of the cantilevered roof slabs and the exterior portions of roof slab undersides at Unity Temple and Unity House appear to be performing well.

2. Roof slab topside delaminations encountered in 2009-2010 at the south roof appeared to be due to cyclic freeze-thaw deterioration. Freeze-thaw degradation of the structural cinder concrete appeared to be shallow in depth and concentrated in the cantilevered zone of the roof slab where both the slab topside and underside are exposed to the elements. In comparison, the zone of the roof slab between the ornamental columns and parapet walls exhibited a lesser degree of freeze-thaw degradation of slab topside likely due to moderating effects from the temperature-controlled Sanctuary space below the roof slab.

3. The top reinforcing bars that were exposed in the south roof slab during the 2009-2010 repair program appeared to be only slightly corroded. The top slab reinforcement can be characterized as "in relatively good condition" considering the age of this historic structure.

B. <u>Concrete Roof Slabs on the Interior of both Unity Temple and Unity House</u>:

1. Unity Temple Roof Slabs Over Upper Balconies (North, East & West Elevations) & Over Organ (South Elevation):

a. Localized concrete deterioration was observed on the roof slab underside regions in the Sanctuary at the north, west and east elevations. Temporary plywood panels were installed on the slab undersides at these three elevations in 2009 to provide protection from future delaminations that may develop until repairs are performed.

   At the south elevation, the extensive nature of the deteriorated roof slab underside areas resulted in spalls and falling hazards that prompted repairs to be performed in 2009-2010.

b. In general, observed concrete deterioration is largely due to water leakage, carbonation-induced corrosion of embedded reinforcing bars, lack of adequate concrete cover over bottom slab reinforcing bars and the relatively poor quality of concrete.

c. Observed concrete deterioration appeared to be typically worse in the regions below the roof drains and parapet walls at the north, west and east elevations in the Sanctuary. It is our opinion that the majority of the observed severe concrete and ceiling plaster deterioration on the slab undersides is attributable to active water leakage from malfunctioned roof drains and/or plumbing lines, and parapet walls over time.

d. Based on the localized nature of concrete deterioration on the slab underside areas in the Sanctuary at the north, west and east elevations, it is our opinion that the overall structural integrity of these roof slabs had not been significantly compromised at the time of our investigation in 2009.

e. Water Infiltration: Water infiltration into the cantilevered roof slabs in the Sanctuary is attributable to one or a combination of the following:

- Unsealed cracks in the parapet walls.
- Malfunctioned roof drains and/or associated plumbing lines.
- Deteriorated roofing (prior to recent re-roofing project).

2. Unity Temple Roof Slabs over Corner Staircases:

a. Concrete/ceiling plaster delaminations and water leakage stains are evident on the roof slab undersides at all four corner staircases.

3. Unity Temple Roof Structure:

a. No visible cracked or displaced concrete was observed on the gridwork of concrete beams that span across the Sanctuary ceiling and between the laylights. However, the beams should be sounded to identify any areas with possible delaminations.

b. The areas of cracked delaminations (observed during our 1999-2000 study) were due to carbonation-induced corrosion of reinforcing bars embedded in the concrete beams. The sources of moisture to feed this corrosion were the ambient relative humidity inside the building, and leaks through the skylight structure above.

4. Unity House South Playroom Ceiling:

a. The concrete roof slab underside conditions were not visible in 2009 or 2013 due to presence of a suspended ceiling. Based on our 1999 survey findings and our understanding that no concrete repairs have been performed to date, concrete deterioration due to corroded reinforcing bars is present on the slab underside.

b. Roofing repairs over this room appears to have mitigated the majority of the leakage sources; however, localized leakage continues as evidenced by leakage stains at a few locations. Embedded reinforcing bar corrosion will continue since the roof slab concrete cannot dry sufficiently to stop the corrosion.

5. Unity House – Concrete Roof Slabs Over the 2nd Floor Corner Storage Rooms:

a. The northeast and northwest storage rooms exhibited extensive concrete deterioration on the roof slab undersides in 1999-2000. Debonded/spalled ceiling plaster was also present in both rooms. Roof leaks through the ceiling slabs had occurred over an extended period of time until roofing repairs were performed. The roof leakage, combined with carbonation of the concrete in the roof slab, led to the observed severe corrosion damage.

6. Unity House – Concrete Roof Slabs Over the 2nd Floor/Mezzanine Classrooms:

a. Localized areas of debonded ceiling plaster were present in 1999-2000. It is unknown whether any subsurface concrete delaminations exist behind the delaminated ceiling plaster areas without removing the plaster.

5.3 REPAIR RECOMMENDATIONS

A. <u>Concrete Roof Slabs on the Exterior of both Unity Temple and Unity House</u>:

1. At the north, west and east elevations, perform condition survey of the roof slab topside in conjunction with the proposed roofing replacement program. Roof topside delaminations should be performed to address any observed delaminations and/or freeze-thaw degradation on the slab topside.

2. At the west cantilevered roof slab of Unity House, we recommend that the existing roofing systems be replaced due to localized dark stains on the roof slab underside that apparently have resulted from infiltration of water through the roofing carrying roofing bituminous material through roof slab cracks. After roofing replacement is complete, shotcrete repairs should be performed to address the deterioration on the cantilevered roof slab underside using the repair approach implemented in the 2001-2002 repair program.

B. <u>Concrete Roof Slabs on the Interior of both Unity Temple and Unity House</u>:

1. Unity Temple Roof Slabs Over Upper Balconies (North, East & West Elevations):

a. Perform roof slab underside concrete repairs in the Sanctuary at the north, west and east elevations of the cantilevered roof slabs. Localized roof slab topside repairs should also be performed concurrently to address the observed freeze-thaw degradation of the roof slab topside. The repair program should incorporate the following:

   i. Perform roofing system replacements. The new roofing system should include a layer of insulation to protect the structural roof slab against cyclic freeze-thaw degradation in addition to improving the thermal characteristics of the Sanctuary space.
   ii. Install new roof drains and associated plumbing systems.

2. Unity Temple Roof Slabs over Corner Staircases:

a. Perform roof slab underside concrete repairs (form-and-pour repairs).

b. The slab topside conditions are unknown at this time since they are covered by existing roofing systems. Roof slab topside repairs should be performed in conjunction with the proposed roofing replacement program to address any observed delaminations.

c. Install new roof drains and associated plumbing systems to address leakage into the staircases. Replacement of existing roofing systems may be necessary to provide comprehensive concrete repairs and waterproofing on the staircase roof slabs.

3. Unity Temple Roof Structure:

a. Perform a close-up condition survey, including hammer sounding to detect subsurface concrete delaminations, of the beams that span in both directions across the Sanctuary ceiling grid with laylights. Perform concrete repairs to address any observed delaminations.

4. Unity House South Playroom Ceiling:

a. Removal of existing suspended ceiling will be required for hammer-sounding of the slab underside. Perform necessary repairs (form-and-pour repairs) to address any observed concrete deterioration on slab underside.

b. The slab topside conditions are unknown at this time since they are covered by existing roofing systems. Roof slab topside repairs should be performed in conjunction with the proposed roofing replacement program to address any observed delaminations.

5. **Unity House – Concrete Roof Slabs Over the 2nd Floor Corner Storage Rooms:**

   a. Complete removal and replacement of the roof slabs at the northeast and northwest storage rooms, including installation of supplemental slab reinforcement over the storage areas is recommended. This work can be performed in conjunction with the proposed roofing replacement program.

6. **Unity House – Concrete Roof Slabs Over the 2nd Floor/Mezzanine Classrooms:**

   a. Localized areas of debonded ceiling plaster are present. Removal of debonded ceiling plaster areas will be necessary to assess the condition of the slab underside for presence of delaminations. Perform necessary repairs to address any observed concrete deterioration on slab underside.

   b. Roof slab topside repairs should be performed in conjunction with the proposed roofing replacement program to address any observed delaminations.

6.0 PARAPET WALLS ON UNITY TEMPLE & UNITY HOUSE

6.1 CONDITION UPDATE

1. **Delamination and Spalling of Shotcrete from Underlying Concrete**

   a. In comparison with the findings from the 1999 comprehensive condition survey, new areas of the shotcrete layer of the parapet walls appears to have delaminated from the underlying concrete, including at the short fascia elements that run along the top of these walls. Some new delaminations occurred along wall cracks, likely due to water infiltration through these cracks.

   b. Review of a concrete core sample taken at a location of cracked shotcrete indicated that the crack was due to an existing crack in the concrete substrate that telegraphed through the shotcrete layer.

   c. Lateral displacements of cracked and delaminated shotcrete were noted at the ends of the short fascia elements at all elevations.

   d. The areas around some of the scupper boxes (for upper roof level drainage around the large pyramidal-shaped skylight) also exhibit new areas of spalling.

2. Cracking

a. In general, there are two main types of wall cracks: shrinkage cracking of the shotcrete repair layer and cracks that have reflected through the thin shotcrete layer due to cracks in the underlying concrete structure. Most of the cracks in the parapet wall surfaces are reflections of shrinkage cracks that existed in the parent concrete prior to the application of the shotcrete coating in 1973.

b. The majority of new wall cracks that we observed were merely extensions of existing cracks that were documented during our 1999 condition survey. Wall cracks may grow in length over time as a result of thermal and moisture cycles within the concrete that cycles crack widths.

c. A significant feature of the cracking distress of the parapet walls that was noted in our 2000 study was the existence of prominent, horizontally-orientated cracks/joints located several feet above the surface of the roofs below. These unsealed cracks, together with other unsealed wall cracks, provide avenues for water infiltration into the space below.

   At Unity Temple, these horizontal cracks are located along the bottom of the scupper openings through the parapet walls. These cracks also coincide with the existing construction joint between the structural concrete beams (that span across the four sides of Unity Temple between the large corner columns) and the ‘true’ parapet walls that extend above the structural concrete beams. In our 1999 condition survey, we documented that there were some horizontal out-of-plane displacements across these construction joints. These displacements are possibly related to rotation of the structural concrete beams due to loadings imposed from the perpendicularly framed roof and ceiling slab and beam construction. We note that these displacements did not appear to worsen since 1999.

   Similarly, at Unity House, these horizontal cracks coincide with the construction joints between the structural concrete trusses (that frame across the large interior spaces below) and the ‘true’ parapet walls that extend above the concrete trusses.

6.2 CONCLUSIONS

1. As with the exterior architectural walls, the existing shotcrete layer on the parapet walls is approximately 42 years old (installed during the 1973 restoration program). New areas of shotcrete deterioration in the form of cracking and delamination were observed on the parapet walls and scupper boxes in addition to those documented in the 1999 survey.

2. Since the parapet walls are exposed to the elements at the top, front and back surfaces, observed wall deterioration is more extensive at parapet walls as compared to other exterior architectural walls.

3. Distress of the deteriorated parapet fascia elements continues, as evidenced by the lateral displacements of cracked/delaminated ends of the fascias.

4. Unsealed wall cracks provide potential avenues for water infiltration into the parapet walls, contributing to continuing concrete deterioration of these walls and underlying roof slabs.

5. Existing displaced, cracked and delaminated sections of the shotcrete at the ends of the fascia elements are potential falling hazards. Recently, temporary enclosures (constructed using stainless steel mesh) were installed to provide protection from falling hazards that may develop until repairs are performed.

6.3 REPAIR RECOMMENDATIONS

Repair recommendations to address observed widespread deterioration include the following:

1. Remove cracked and delaminated shotcrete coating from all four elevations of the roof parapet walls. Work should include removal and reconstruction of the deteriorated fascias along the top of these walls.

2. Following deteriorated shotcrete removal, the condition of the exposed underlying concrete substrate, including pre-existing cracks and construction joints, should be assessed and appropriate repairs performed using approved shotcrete repair approach (described above for exterior architectural walls) to minimize cracks/joints from telegraphing through the new shotcrete repairs.

7.0 CHIMNEY ON UNITY HOUSE

7.1 CONDITION UPDATE

We performed a visual survey and hammer sounding of accessible exposed surfaces of the chimney inn 1999, 2009 and 2013. Extensive cracking and delamination of the shotcrete layer was observed. In general, the majority of this deterioration had occurred prior to 1999 and was documented during our 1999 survey. We noted that the shotcrete layer on the exposed surfaces of the chimney stack is relatively thin with measured thickness of less than 3/8 in some areas. The short fascia elements along the top of all four walls of the chimney are also cracked and delaminated in many areas.

In our 2000 report, we recommended that the chimney cap be replaced with a properly designed cap. The existing (replacement) chimney cap was reportedly installed in 2006 and appears to be functioning well with no reported problems.

7.2 CONCLUSIONS

1. The majority of the extensive cracking and delaminations of the shotcrete layer on the chimney structure was documented in 1999. Since then, some new areas of shotcrete deterioration have developed.

7.3 REPAIR RECOMMENDATIONS

Repair recommendations to address observed problems with the chimney include the following:

1. Remove and replace all existing shotcrete layer on the chimney exterior, including the fascia around top of the chimney. The condition of the exposed underlying concrete substrate, including pre-existing cracks and construction joints, should then be assessed and appropriate repairs performed using approved shotcrete repair approach (described above for exterior architectural walls).

8.0 INTERIOR CONCRETE STRUCTURAL ELEMENTS

8.1 CONDITION UPDATE

We revisited two areas that were reviewed during the 1999 survey of the interior concrete structural elements within the building in 2009.

1. **2nd Floor Concrete Slab in Transition Area between Unity Temple and Foyer Structure:**

    a. Isolated areas of concrete cracking and delaminations on the underside of the floor slab have not grown significantly since 1999.

2. **Concrete Spandrel Beam at West Elevation of Unity House:**

    a. In 1999, we noted that deflection of this spandrel beam (located above 1st floor west-facing art glass windows) had bowed the art glass window framing beneath it without any glass breakage. Further bowing to the window framing since 1999 was not apparent.

8.2 CONCLUSIONS

1. **2nd Floor Concrete Slab in Transition Area between Unity Temple and Foyer Structure:**

    a. Concrete deterioration has not grown significantly since the 1999 survey.

2. **Concrete Spandrel Beam at West Elevation of Unity House:**

    a. Bowing of art glass windows located below the west spandrel beam did not appear to have worsened since the 1999 survey. Any additional beam deflection (due to downward creep of beam) since 1999 appeared to be minimal.

8.3 REPAIR RECOMMENDATIONS

1. **2nd Floor Concrete Slab in Transition Area between Unity Temple and Foyer Structure:**

    a. Perform repairs to address localized concrete deterioration.

2. **Concrete Spandrel Beam at West Elevation of Unity House:**

    a. Although bowing of art glass windows located below the west spandrel beam appear to have stabilized since the 1999 survey, remedial measures are advisable to prevent further damage to the art glass windows.

9.0 ORNAMENTAL PLANTER BOXES

9.1 CONDITION UPDATE

Our recent field review of both ornamental planter boxes, including the concrete screen walls, located outside the east and west entrances to Unity Temple indicated some growth in concrete deterioration since our 1999 survey.

1. **Ornamental Planter Boxes**

   a. The planter boxes were reconstructed during the 1973 restoration program. The original planter boxes had been reportedly removed during the earlier life of the building.

   b. Observed concrete deterioration in 2009 included cracking and delaminations, particularly at areas in the pedestal regions below the planter boxes which may experience critical saturation as a result of water leakage from the flower boxes from defects in waterproofing systems and associated drainage plumbing. Existing planter box drainage pipes/outlets are too short since drainage continues to fall directly on the concrete below. The west planter box had more extensive deterioration as compared to the east planter box. It is our understanding that the planter box waterproofing membrane systems were replaced prior to our 1999 survey. Therefore, it is likely that water leakage from the flower boxes has been mitigated and that the majority of the existing concrete deterioration occurred prior to our 1999 survey. We made this assessment since the growth in concrete deterioration from 1999 to 2009 was not significant.

   c. CTLGroup also removed a core sample from a representative section at the base of the east planter box with wide cracks. The core was comprised of a thin shotcrete layer over the original concrete substrate. Review of the core sample indicated that the cracked shotcrete layer was due a pre-existing crack in the underlying wall substrate that had reflected through the shotcrete layer.

2. **Screenwalls**

   a. Based on reviews in 2009 and 2013, cracking of the concrete screenwalls does not appear to have grown significantly since 1999.

   b. CTLGroup performed an exploratory opening below the east screenwall in 2009 to investigate the conditions below this screenwall. We noted that the bottom of the screenwall is located approximately 22 inches below the existing backfill. The wall base bears directly on a granular backfill with no foundation such as a continuous strip footing. In the absence of a wall footing, it appears that some of the wall cracks are likely due to wall settlements. Most of the wall cracks are due to restrained drying shrinkage of the shotcrete layer and/or the underlying wall substrate. Restraint to drying shrinkage is due to the presence of perpendicular walls restraining both ends of the screenwalls.

9.2 CONCLUSIONS

1. There have been no reported concrete repairs on the planter boxes since their reconstruction in 1973. The buried waterproofing membrane systems (reportedly replaced/repaired prior to our 1999 survey) appeared to be effective in addressing previously reported leakage issues.
2. Growth in concrete deterioration from 1999 to 2009 at both planter boxes and screenwalls was not significant.
3. Based on an exploratory opening below the east screenwall, it appears that the screenwalls were constructed without any foundation such as a continuous strip footing.

9.3 REPAIR RECOMMENDATIONS

Repair recommendations to address observed problems with the ornamental planter boxes include the following:

1. Remove and replace extensively cracked and delaminated shotcrete layer. Due to aesthetic considerations, shotcrete replacement may be in full panel sections at some locations to minimize potential problems associated with matching color and texture of new shotcrete with existing shotcrete.
2. Following deteriorated shotcrete removal, the condition of the exposed underlying concrete substrate, including pre-existing cracks, should be assessed. Concrete areas that were damaged by corrosion of embedded reinforcing bars or welded wire fabric reinforcement, and/or by cyclic freeze-thaw action should be removed and appropriate repairs performed to restore structural concrete profiles prior to shotcrete application.

3. The existing waterproofing membrane systems should also be evaluated and water-tested to verify the effectiveness of the membrane systems. The existing planter box drainage pipes should be extended to divert drainage away from the concrete below.

4. Remove existing vines and other vegetation that have attached to the east planter box and screenwall. Such vegetation can promote deterioration primarily by inhibiting surface drying, thereby maintaining concrete in a wet environment.

5. The west face of the west screenwall was the site where multiple trial crack repairs were performed by others. The aesthetics of these crack repairs were poor since the cracks have been widened (by routing cracks) and sealed with non-matching sealant colors. Owing to the prominence of this wall, we recommend that the entire shotcrete coating along the west face be replaced. Underlying cracks in the concrete substrate should be repaired with appropriate methods, prior to application of a new shotcrete coating.

6. Joint sealants should be installed along the south vertical joints between screenwalls and Unity House walls to accommodate thermal and moisture movements in these exposed screenwalls. Consideration should be given to proper joint width (to provide for maximum tolerance of movements at joint locations) and sealant color/texture compatibility with surrounding wall areas.

10.0 CONCRETE FLATWORK ON THE TERRACED AREA ON EITHER SIDE OF THE ENTRANCES TO THE FOYER

10.1 CONDITION UPDATE

1. The exposed aggregate concrete flatwork that forms the terraced areas on either side of the entrance to the Foyer were all replaced near the end of the 1973 restoration program at Unity Temple. Since then, localized spot patch repairs have been performed, including replacement of several east terrace flatwork panels in 2008, to address potential tripping hazards due to spalls in the panels. However, these repairs are considered “temporary repairs” since they were performed using an off-the-shelf concrete repair material at the direction of UTUUC due to time and cost considerations. The concrete repair material was not air-entrained and did not closely match the existing remaining concrete flatwork color and texture. It is both UTUUC

and UTRF's intention to replace these "temporary" patch repairs during the course of the next comprehensive repair program.

Until permanent repairs are performed, deterioration from cyclic freeze-thaw cycles can be expected to continue. Thus, areas of non-air-entrained concrete flatwork that are poorly drained or exposed to continued wetting will deteriorate progressively.

10.2 CONCLUSIONS

1. Based on observed deterioration, it is likely that the concrete used in 1973 for panel replacements was not air-entrained. Terrace panel deterioration is attributable to continuing cyclic freeze-thaw of panels with moisture saturation (from poor drainage), shrinkage cracking, continuing thermal movements and/or minor soil settlements.
2. Since the 1973 replacement program, temporary repairs consisting of isolated patch repairs and panel replacements have been performed to address potential tripping hazards due to panel displacements and spalling.

10.3 REPAIR RECOMMENDATIONS

There are two repair options:

1. Option No. 1: Panel Patch Repairs/Individual Panel Replacements:

   Perform full-depth patch repairs at small and localized panel areas exhibiting deteriorated concrete. If deteriorated panel area is large, we recommend that the entire panel be replaced to maintain the regular spacing of existing control joints, and thereby minimize objectionable appearance of patch repairs. A "panel" is defined as the rectangular area enclosed by control joints that were originally incorporated into the paving to minimize or eliminate random concrete cracking.

   Repair Option No. 1 is the lesser costly option as compared to Option No. 2 that is presented below. With Option No. 1, however, it will be difficult to match existing panel concrete in color, texture, aggregate type and size, aggregate density/distribution, etc. Repair of cracked panels would require panel replacement. Some continued deterioration of areas that are not repaired would be expected.

2. Option No. 2: 100% Removal and Replacement of Panels.

   This is a relatively costly option but will yield the most aesthetically pleasing appearance and will likely minimize future deterioration. The repair concrete should be air-entrained to provide freeze-thaw durability of repairs. The new panels should be placed with a positive slope to facilitate proper surface drainage to mitigate ponding.