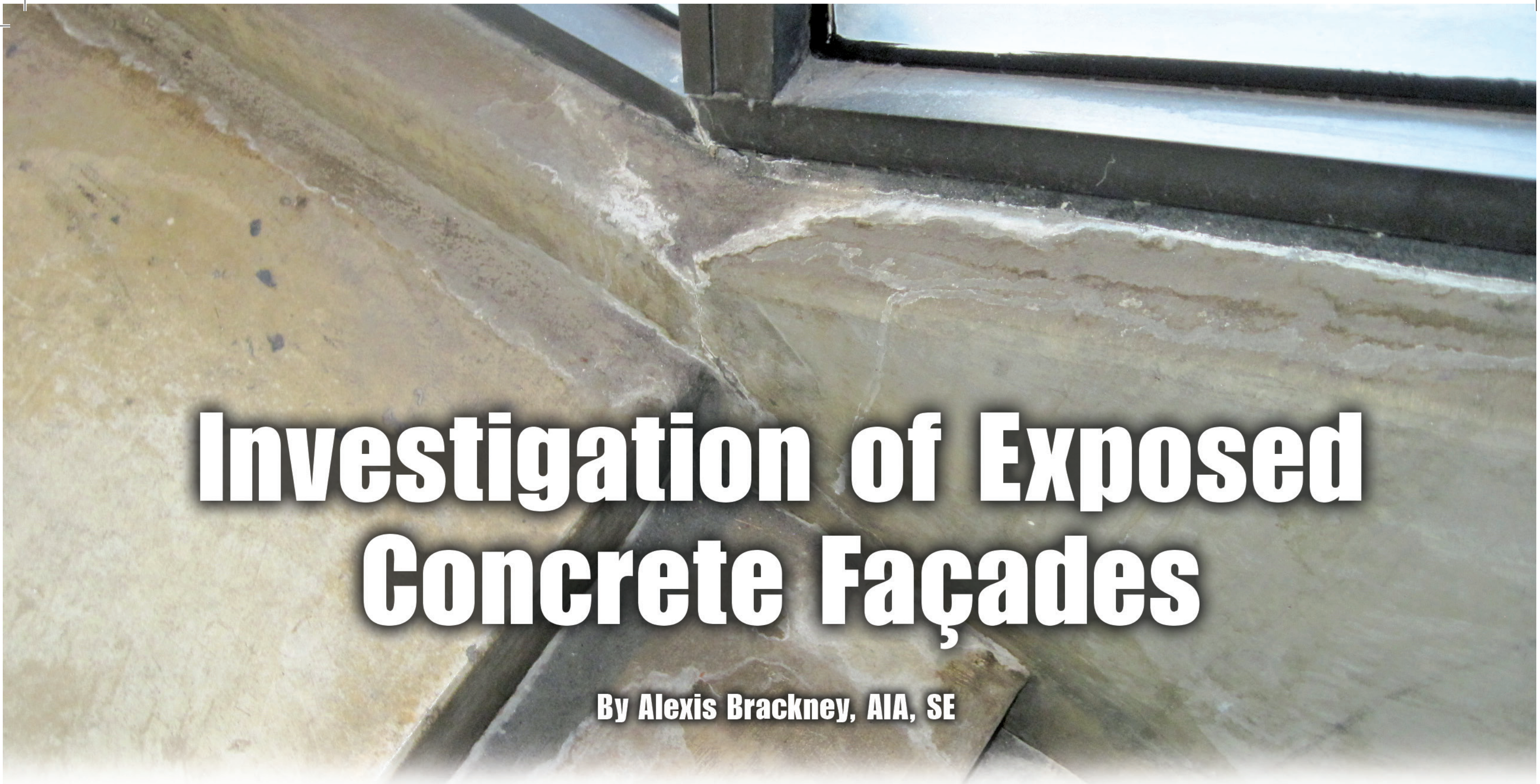

Investigation of Exposed Concrete Façades

By Alexis Brackney, AIA, SE

Exposed concrete façades synonymous with the brutalist architectural style have been featured on buildings for over a century. Constructed between 1906 and 1908, Frank Lloyd Wright's iconic Unity Temple was one of the earliest structures to contain a poured-in-place reinforced concrete façade.[1] In the 1960s, Walter Netsch designed several buildings on campus for the University of Illinois at Chicago using exposed concrete structural elements and precast concrete window panels with intricate details and textures.[2] While concrete façades are durable and unique in their varying textures and coloring, aging façades present challenges when deterioration starts to emerge.

Figure 2 – Concrete spalling observed during investigation of a concrete façade.

Figure 1 – Spalled concrete and exposed reinforcement bars observed during a façade investigation. Many bars had less than ½ in. of concrete cover.

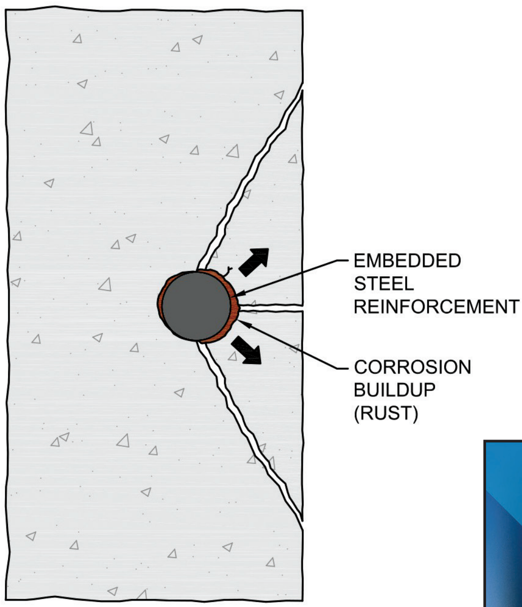

Figure 3 – Graphic representation of spalled concrete as a result of corrosion byproduct buildup on steel reinforcement.

CONCRETE FAÇADE DETERIORATION

After decades of exposure to the elements, concrete façades may exhibit deterioration in the form of cracking, delamination, or spalling (*Figures 1* and *2*). Exposed reinforcement bars are unsightly, and continued expansive effects of corrosion may lead to potentially hazardous situations for pedestrians and property below. Further, cracking and deteriorated transitional areas can offer paths for moisture migration into the building and result in interior leakage.

Corrosion of embedded reinforcement steel within the concrete is the leading cause of deterioration.[3] Carbonation-induced corrosion is a frequent cause of failure on concrete façades and may be exacerbated by shallow cover of reinforcement. Carbonation of the concrete is simply the reaction of 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. Carbonation also increases shrinkage on drying of concrete elements (thus, promoting crack development). If the depth of carbonation reaches embedded steel in a concrete structure, then corrosion of that steel may take place if oxygen and sufficient amounts of moisture are present. Corrosion of reinforcing steel bars embedded in the concrete results in the buildup of corrosion byproducts, such as iron oxide, on the surface of the bars. This rust can occupy volumes up to ten times the original volume of metal from which the rust formed. The surrounding concrete cover restrains the buildup of the corrosion byproducts, resulting in pressure building up around the bars (*Figure 3*). Eventually, the concrete will crack and delaminate due to the tensile pressure created by the expanding steel reinforcement, since concrete has low tensile strength. The shallower the depth of cover over the reinforcing steel bars, the faster the cracking will take place. ACI 318 contains requirements for concrete protection for reinforcement; those requirements vary depending on the size of the reinforcement and environmental exposure.[4]

Of course, spalling concrete represents a great threat to the safety of pedestrians around a building. However, even minor cracking can lead to interior leakage and affect the quality and the comfort of the building occupants. Investigation of leakage at a concrete stairwell indicated that through-wall cracks and failed sealant at the perimeter of the steel window-wall system contributed to water ingress at interior stairs (*Figure 4*). Investigation of a precast concrete window system found that deterioration of the concrete resulted in leakage at the building interior (*Figure 5*). Aged sealant around the window perimeters and localized spalling contributed to the leakage.

Figure 4 – Through-wall cracking and failed sealant resulted in leakage at this concrete stairwell.

FAÇADE INSPECTIONS

Deterioration of concrete façades can be mitigated through regular inspections and maintenance. Several cities across the US have introduced façade ordinances that require periodic inspections of buildings to help protect the public from potentially hazardous situations, including fall hazards from delaminated or spalling concrete. For example, Chicago requires that all buildings over 80 ft. in height are inspected by a registered design professional at intervals ranging from two to six years, depending on the classification of the building (*Figure 6*). Buildings are classified according to the façade materials and require more frequent inspections if the exterior walls or enclosures are reinforced with, or in direct contact with, corrodible metals. Façade inspections are designed to identify areas of distress and provide a comprehensive assessment of the condition of the exterior façade. When deterioration is observed, an investigation can uncover the underlying issues and provide the best path forward for repair.

Figure 5 – Interior leakage at precast concrete window system.

Figure 6 – Façade inspection of exposed concrete from suspended scaffold.

Façade inspections should generally consist of visual surveys of the entire façade supplemented by hands-on and close-up evaluation of enough area as practical to provide a comprehensive assessment. Scaffolding, boatswain chairs, and lifts should be used to provide hands-on access to upper levels of the façade. Hands-on techniques such as hammer sounding to detect subsurface delaminations and nondestructive testing generally give the inspector a more complete view of the extent of deterioration that may be present. In concrete façades with low-cover concerns, ground-penetrating radar (GPR) surveys may be performed to measure concrete cover over embedded reinforcement. Nondestructive measurements may also be confirmed by drilling holes at reinforcement to measure cover at representative locations.

Sample removal and subsequent laboratory testing is also useful to investigate the cause of any deterioration present. For concrete façades, laboratory testing may include petrographic analysis and chloride testing. Compressive strength testing may also be useful if there is any question about the durability or structural adequacy of structural elements that are exposed on the façade. Determining the underlying cause of deterioration is necessary in order to provide an effective repair solution.

FAÇADE REPAIRS

Concrete façade repairs should be designed to address the nature and deterioration present on the building. Repair procedures may include relocating existing steel reinforcement where cover was too low and supplementing corroded reinforcement with advanced section loss. Repair patches should match existing profiles, chamfers, and surface finishes to preserve the original appearance of the concrete façade. However, implementing façade repairs that match the color and texture of the existing concrete is inherently challenging. Source materials in concrete, such as cements and aggregates, are naturally occurring and will vary from historical materials used on older concrete façades. Concrete repair mixtures should be designed with the following goals:

- Replicate existing concrete color using readily available materials
- Produce concrete of similar strength to existing concrete structure
- Produce durable concrete to withstand environmental conditions of the site
- Produce a mixture with suitable workability to allow contractors to place the concrete in a consistent manner throughout the project

In order to assess the effectiveness of trial mix designs, site mock-ups should be used to compare potential repair concrete against the

Figure 7 – Mock-up samples of exposed aggregate concrete.

Figure 8 – Soda blasting used during concrete façade cleaning.

properties of the existing building. Mock-ups may include trial patch repairs on the façade, or separate mock-up samples that may be moved around to multiple elevations or façade elements. It may be helpful to view the mock-ups under multiple lighting conditions (such as full sunlight or shade). Multiple mock-ups should be used to represent different concrete elements or textures, such as concrete with exposed aggregate and smooth concrete with visible form lines (*Figure 7*).

When repairs are implemented, it is important to maintain a quality control program during construction to ensure that the concrete used for the repair matches the approved mock-up and is consistent throughout the repair process. Quality control should consist of regular site visits by the engineer to observe demolition of deteriorated concrete, preparation of repair patches, and final patch approval to ensure that concrete was placed without any obvious defects.

FAÇADE CLEANING

In certain cases, it may be warranted to perform façade cleaning. The objective of a façade cleaning program is to remove visible surface dirt or stains without damaging the façade. Trial cleaning techniques should be conducted with the gentlest methods possible that will achieve the desired results. For example, dry sand blasting is an aggressive technique that may cause damage to older concrete. Alternately, soda blasting is a non-destructive cleaning method that can be used for more delicate concrete façades. Soda blasting uses compressed air to apply sodium bicarbonate (baking soda) to a concrete surface (*Figure 8*). Trial cleaning should be performed at selected locations to determine its effectiveness before cleaning the entire façade.

CONCLUSION

Exposed concrete façades are a unique and important feature of many historic and modern buildings. With regular inspections, maintenance, and careful design and repair programs, owners can avoid failures and preserve the integrity of the original façade.

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Shenzen Museum Will Flow Like a River

"The plan makes full utilization of the landscape in the site. Through a dynamic architectural form, it creates a beautiful, natural, and dynamic nature museum concept."

– Weiping Shao, competition judge, chief executive architect of the Beijing Institute of Architectural Design

Plans have been accepted for Southern China's first large-scale museum of natural history. The Shenzen Natural History Museum, to be built in the Yanzi Lake area of Shenzhen's Pingshan District in Guangdong, China, ran a design competition which received over 70 proposals internationally. The winning design, entitled "Delta," was by 3XN, B+H Architects, and Zhubo Design, and it evokes the watery location of the nearby lake by incorporating river-like curves into the overall building design. It will also feature a vegetative roof that rises gently on each end, making it accessible from ground level, extending the surrounding public park space onto the facility's roof. The final footprint of the new museum will be 42,000 square m (452,084 sq. ft.).

— ArchDaily, Dezeen

All images courtesy of 3XN.