Façade Woes... to WOW!

By David J. Mastay

Figure 1: The North and East elevations with the extent of the façade repairs.

The Graphics Arts Building located at 25 Foster Street in Worcester, MA fell into a critical state of disrepair due to years of neglect, vacancy and poor early 20th century construction. A major construction project was undertaken to upgrade this aging building into a state-of-the-art multi-use educational facility when it was purchased by the Massachusetts College of Pharmacy and Health Sciences (MCPHS). Established in 1823, MCPHS has one of its three campuses located in the City of Worcester, Massachusetts. A growing student body numbering nearly 3400 had placed a severe strain on the college facilities. To address this situation, the college has invested nearly $100 million dollars in its physical plant since 1997. The development of this property, renamed the Living and Learning Center, completed this phase of the Worcester campus development.

The overall scope of this project consisted of a complete gutting of the interior and an extensive rehabilitation of the 1913 exterior concrete and masonry façade (*Figure 1*). The 9 story, 100,000 square foot building is listed on Massachusetts' *Inventory of Historic and Archeological Assets of the Commonwealth*. Contractors involved worked closely with the Worcester Historical Commission to complete the extensive restoration. Approximately 35 percent of the exterior façade envelope required replacement due to the extensive structural decay of the reinforced concrete (*Figure 2*). All these challenges presented to the architect, engineers and contractors were met successfully.

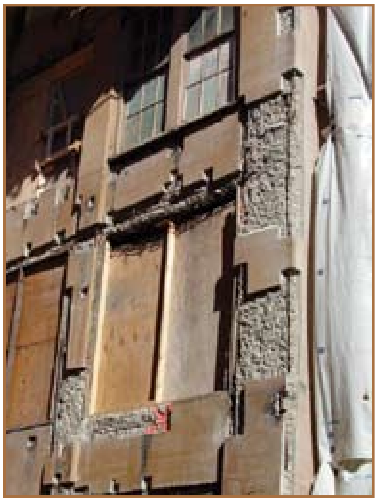

Figure 2: Close up view of the prepared concrete in the South elevation. Removal depths of three inches were commonplace.

MCPHS hired the architectural firm of Perkins + Will, Boston, MA and the engineering firms of Souza, True & Partners, Watertown, MA and Gale Engineering, Inc., Weymouth, MA to provide the "vision" to complete the restoration of this building. The contractors involved in the façade construction were Payton Construction Co. and specialty façade restoration contractor Monaco Restoration Co., Southbridge, Massachusetts. In the end, 175 graduate student apartments, shared common living spaces, kitchens and bathrooms were constructed along with classrooms, nursing labs and a glass enclosed executive conference room on the ninth floor. The project received the "Silver Hammer Award" in 2005 from the Worcester Regional Chamber of Commerce. The award recognizes "construction and renovation projects that have made an *extraordinary visual and aesthetic impact on the physical landscape of the community* or that have had *positive economic impact on the region*".

State of Disrepair

The building construction is of the early 20th century era. It consists of a reinforced cast-in-place concrete floor with a concrete spandrel-column façade with masonry infill panels. The effects of time with freeze-thaw cycling, acid rain attack, poor placement techniques during the original construction, atmospheric and biologic soiling, poor maintenance and vacancy over the years had left the concrete façade in a poor state of disrepair. In many areas, surface spalling was in excess of three inches in depth. Shallower spalls from one-half inch to one inch in depth were caused from reinforcing steel that had been placed with insufficient coverage to protect it from the environment. The reinforcing steel utilized in the original construction consisted of twisted flat bars with a size equivalent to a #8 bar today (*Figure 3*). Concrete coverage over the bars varied widely from zero to four inches in depth. As expected, the reinforcing steel located close to the surface often resulted in cracking of the cast-in-place concrete. Concrete cracking was exacerbated by freeze-thaw cycling, extended wetting and drying cycles and the presence of a carbonation front.

Carbonation

Figure 3: Workers placing the cementitious repair mortar via form and pour methodology into a sealed plywood form.

Carbonation is the most common cause of loss of passivating alkalinity in concrete. It is a natural process and occurs when atmospheric carbon dioxide (CO_2) reacts with the soluble alkaline calcium hydroxide in concrete and is converted to insoluble calcium carbonate, which has a more neutral pH. When the pH is reduced to between 9.5 and 10, the passivating protection of a high pH environment is no longer afforded to the reinforcing steel. In the presence of moisture and oxygen, corrosion of the reinforcing steel begins. Eventually, rusting steel causes cracking and finally spalling of the concrete. A test procedure to determine the pH of the concrete using phenolphthalein was employed. This chemical reacts with alkaline environments and creates a bright pink reaction. Carbonated concrete does not react with the chemical (*Figure 4*). Results for this building confirmed the presence of the "carbonation front" to an average depth of 15 millimeters (0.6 inches).

The carbonation effect will also take the path of least resistance, allowing it to migrate deeper into cracks in the concrete. Permeable concrete from poor consolidation, improper curing and improperly placed reinforcing steel, as well as concrete with surface defects and cracks, is most susceptible to carbonation. Field testing of this building confirmed carbonation contamination to a depth of nearly 80 millimeters (over 3 inches) in some locations.


Figure 4: Photo showing the chemical reaction of phenolphthalein with an alkaline environment and it clearly identifies the presence of a "carbonation front".

The Concrete Rehabilitation Process

Spalled concrete repairs consisted of the contractor providing a minimum surface preparation in conformance to the International Concrete Repair Institute guideline of a minimum of a Concrete Surface Profile of a CSP-6. A CSP-6 represents a broken aggregate with a concrete profile of +/- ⅛ inch. This was accomplished by saw-cutting the spall perimeter using hand held grinders with diamond blades, and chipping hammers using both spade and bush hammer heads. During this process, the reinforcing steel was examined. The contractor's mechanics followed American Concrete Institutes (ACI) guidelines by preparing the reinforcing steel back to a clean condition if 25 percent or less of the steel was exposed. When more than 25 percent was exposed, the crew took care to remove concrete behind the rebar to a minimum of ¾ inch. Where loss of steel was a factor, additional mild steel was attached to replace what was lost, under the direction of the engineer.

In areas where no reinforcing steel was found yet large repairs were required, the repair procedures were as follows. Crews drilled ⅝ inch holes into sound concrete approximately 12 inches on center. The holes were then cleaned with wire brushes and blown clean with oil free compressed air; they were then examined to ensure all surface contaminants were removed before proceeding. Next, "L" shaped #4 bars were embedded into a two component acrylic anchoring adhesive and a 2-inch x 2-inch stainless steel mesh was fastened to the embedded anchors. Some of the shallower corner spalls were reinforced with stainless steel self-tapping screws, and were then weaved with stainless steel wire for added strength.

The next step involved providing a SSD (surface saturated dry) concrete onto which a bonding bridge and anti-carbonation coating was placed via brush or hopper gun spray equipment. A cementitious water-based epoxy cement repair compound was used for both applications. The contractor was able to capitalize on the benefit of a one product source for both applications, and the added feature of an open time of up to 16 hours sped the installation process of the repair mortars.

Much of the exterior façade rehabilitation work was to be completed during the winter months. Many of the products that were used were water-based and needed to be protected from freezing temperatures. This was handled by the contractor with the use of a self-contained, heated work environment provided on the exterior mounted platform lifts. Propane fired torpedo heaters were used to provide an environmentally controlled work area. Electric mixers were used to facilitate the mixing of the repair mortars. The restoration contractor's carpenters were kept busy by creating customized formwork utilizing plywood and a 2 x 4 wood stud construction. A form release agent was applied to the surface of the forms to aid in their removal. An expanding polyurethane foam was used to ensure a leak proof seal for the forms. The repair mortar was mixed, with much of it extended using a ¼ minus stone since the vast majority of the repairs were over one inch in depth. It was then placed into buckets and poured into the formwork to complete the form and pour placement. The cementitious repair mortar used for the form and pour portion of this project was a single component, polymer-modified, silica-fume enhanced product (*Figure 5*). This selection was based on density, flexural values, bonding characteristics and ease of placement. Vibration was critical in the placement of this mortar to ensure all voids were filled, and to eliminate void and bugholes in the final product. In the larger forms, to provide a void free finish, the contractor used a combination of rebar's to tamp in the mortar and hammers to tap the formwork.

To complete the form and pour process, cutouts above the forms, where bird mouths were placed and in areas with smaller spalls not requiring formwork, were filled with a single component, polymer-modified, silica fume enhanced, non-sag cementitious repair mortar. A water-based curing compound meeting ASTM C-309 was applied to exposed repairs. Patches were protected from freezing through the use of insulated blankets. Forms were often left in place for a few days to protect freshly placed mortar from low temperatures overnight during the winter months. In other areas, forms were stacked on top of other forms as the work proceeded up the building. In a few instances, tremie tubes were used to aid in the placement of the mortar to prevent the freefall of mortar farther than six feet.

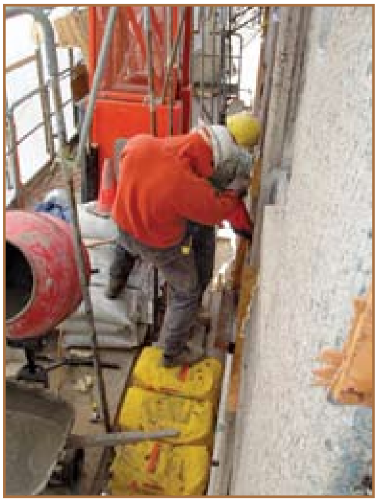
Figure 5: Contractors set up including repair mortar, bagged stone, electric mixer and wheelbarrow.

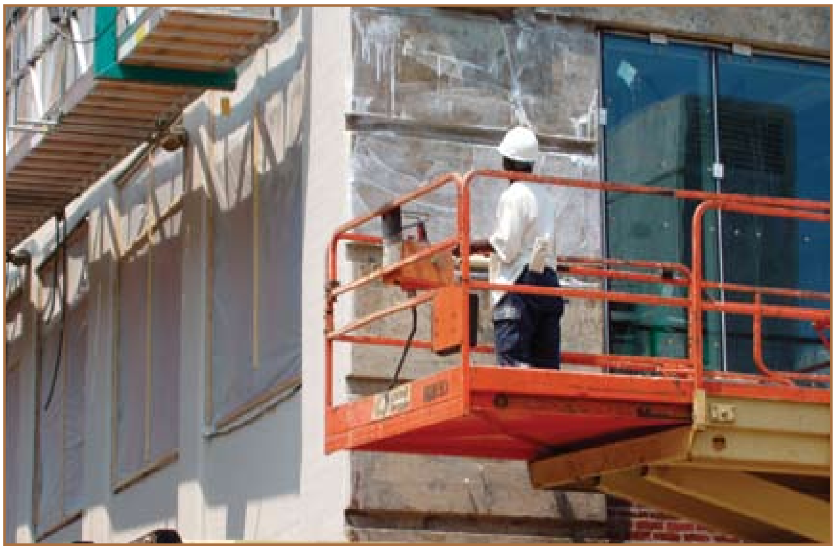

Figure 6: Contractor placing the SACI to the façade via a pump sprayer.

Latent Corrosion

In order to provide protection against latent corrosion to untreated concrete areas with existing reinforcing steel, the engineer elected to use a surface applied amino-alcohol corrosion inhibiting treatment (SACI) as part of the overall rehabilitation plan. Surface preparation prior to the application of this treatment consisted of a high pressure water blast to remove any surface laitenance, atmospheric and biologic soiling and any loose, flaky or friable concrete. The concrete was allowed to dry for 24 hours before proceeding with the application. The application of the treatment called for two saturating coats applied at a loading rate of 200 square feet per gallon per coat. One hour transpired between coats to allow for complete penetration of the treatment before the subsequent coat was applied (*Figure 6*). After drying overnight, the surface was rinsed to remove a surfactant residue from the SACI that forms after the treatment is absorbed into the concrete. This surfactant (soap residue) is used to prevent premature drying of the treatment and to aid in the penetration of the SACI into the concrete. In addition, it facilitates the absorption of the SACI through its liquid and vapor phase into the concrete's capillaries. Testing of the SACI confirmed penetration to a depth of 80 millimeters (3.2 inches) after 28 days. The selected treatment migrates through the concrete capillaries and repassivates reinforcing steel in carbonated and chloride contaminated environments. It is effective in chloride contaminated environments with up to six to ten pounds per cubic yard of concrete. The inhibitor achieves this by bonding to the surface of the steel, displacing chloride ions and forming a protective layer on the steel surface. This treatment effectively reduces active corrosion on the surface of the reinforcing steel by a minimum of 65% compared to the untreated concrete and reinforcing steel. Performance testing of the amino-alcohol based corrosion inhibitor (AACI) has been proven utilizing a linear polarization resistance measurement (LPRM) technique. Embedded remote monitoring probes and sensors can be incorporated into the overall scope of the project to provide the owner with an on-going corrosion rate and corrosion potential monitoring system, if desired.

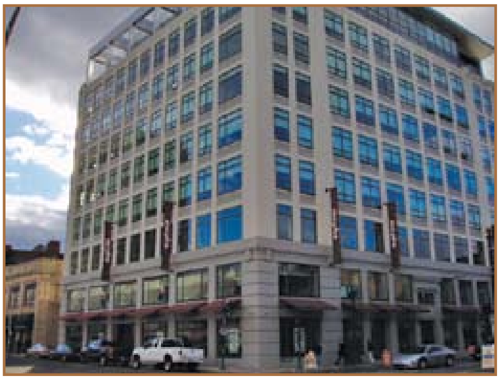

Figure 7: North and East elevations of the finished project.

Anti-Carbonation Coating

The existing concrete presented a few other challenges to the contractor before the finished façade coating could be applied. Cracks, voids and nail holes were found throughout the façade and needed to be addressed as "detailing" before the finished anti-carbonation coating was applied. Cracks over 1/16 inch were routed out using a handheld grinder equipped with a diamond blade and blown clean; then, a bond breaker tape was inserted into the routed crack which was then sealed with a multi-component, chemical curing polyurethane sealant. Bugholes, voids and nail holes were also filled flush with a multi-component polyurethane sealant. The chemical curing sealant provided the contractor with a fast turn around time. Since most of this work was completed during the summer months, the sealant was allowed to cure overnight before the contractor moved on to the next phase of the work.

To provide an aesthetically uniform façade and to halt the progress of the "carbonation front", the architect chose to incorporate an anti-carbonation coating. The coating selected was a state-of-the-art, water-based, elastomeric anti-carbonation façade coating. It provides protection to the underlying concrete from environmental attacks such as ultraviolet light degradation, atmospheric staining, biologic soiling, freeze-thaw cycling and carbonation induced corrosion. The coating chosen incorporates low-temperature crack bridging capabilities down to -20 degrees (F). In order to provide the best methodology to blend the new repair mortars into the existing weathered concrete that remained in place, the architect utilized a textured base coat followed by a smooth top coat. Two standard colors were chosen to provide accent and punch as the final façade finish (*Figure 7*).

In Conclusion

Incorporating as much materials as possible from one manufacturer ensured the owner and design professionals a single source warranty and complete compatibility within those components. Despite some unforeseen ups and downs during the construction process, in the end, Monaco Restoration provided outstanding workmanship and teamwork that met the "vision" of the designers to complete the restoration of this building, thus bringing it into the 21st century and creating a jewel of this college campus.▪

David Mastay is a Senior Project Representative, Repair and Protection for Sika Corporation covering New England. He has over 27 years experience in the concrete and masonry restoration industry, and holds a Bachelor of Science Degree in Marketing from Indiana University of Pennsylvania, Indiana, PA. David is active in both the New England and Connecticut Chapters of ICRI. He can be reached via e-mail at ***mastay.david@sika-corp.com.***