Matching Concrete for Façade Repairs

By Lenny Weiss, Jay Paul, Boris Dragunsky, and Joe Tomes

The main administrative building for the University of Illinois at Chicago was in need of concrete façade repair, and this visual determination prompted the need for a detailed study of the condition of the façade. The condition survey, which highlighted several areas of deterioration, was followed by a study of concrete repair mixtures and surface preparations. These mixtures, when installed, would maintain the aesthetic integrity of the structure for a concrete rehabilitation program. To achieve a uniform appearance on the building, a pigmented coating applied over the concrete repairs was recommended to provide the most consistent appearance. The university, however, wished to maintain the aesthetic integrity of the structure and the exposed concrete façade. This prompted a mixture design investigation to determine the acceptability and compatibility of mockup samples.

Overall view of the building

Exposed Concrete Façade

The façade for the top 25 floors of this 28-story building consisted of exposed-aggregate, precast concrete wall panels with narrow, vertical fixed windows set back 3 to 6 ft from the exterior cast-in-place framing. The bottom three floors consisted of large, prominent exterior columns and transfer girders with a heavy sandblast finish, deeply exposing the very large Size 357 (up to 2-1/2 in.) aggregate.

Concrete Deterioration

Deterioration of the exterior façade elements included cracks, delamination, spalls, and corroded reinforcing steel. Deterioration was most prominent on the front faces of the spandrel beams. The deterioration mainly consisted of shallow-depth degradation of the material and did not impair the structural capacity of the building. Of greater concern was the serious threat that dislodging concrete spalls and failed patches posed to public safety.

Causes of Deterioration

Most of the deterioration was caused by corrosion of the underlying reinforcing steel. Carbonation, salts, and air pollutants had lowered the alkalinity

(Above and below) Corroded reinforcement of face of spandrel. Note the inadequate cover

of the concrete and destroyed the passivating properties near the surface of the concrete. Laboratory testing of concrete samples removed from the building, which included compressive strength evaluation, chloride content analysis, and petrographic examination, indicated that the depth of carbonation was up to 1/2 in., which was beyond the depth of the cover of numerous reinforcing bars.

Additional factors that contributed to the deterioration of the concrete included a high water-cement ratio (*w*/*c*) and a poorly developed air-void system. These factors caused a lack of durability that resulted in the concrete being more susceptible to freezing-and-thawing damage.

Mockup Program

The mockup program consisted of a review of original concrete mixture designs, testing of concrete core samples, installation of concrete mockup patches, and a concrete cleaning mockup test.

Form and Pour Mockups for Top 25 Floors

The building had varying shades of concrete color throughout its façade. This was due to variations in the original color of the concrete as well as the long-term effects of weathering. In general, the columns were of a lighter shade than the spandrels. In addition, the spandrels had several color variations within a given spandrel and from one spandrel to the next. Because there were significantly more locations of deterioration on the spandrels than on the columns, the mockup program focused on creating a mixture that would most closely match the color of the concrete on the spandrels. Although separate design mixtures could be developed for various elements of the structure, such a scheme would not have been economical.

To use the most representative test area, a spandrel with an approximate average of the colors observed on the building was selected for the background on which to install the mockups. Also, samples of concrete with various shades were removed from the building during the investigative program to be used a basis for developing trial mixtures.

Forty-three different mixture designs were developed during this study. The original mixture designs were recreated for use as the initial trial mixture. The dried samples of this mixture were not consistent with the concrete on the building due to cement and aggregate color change over the years. For a closer match, the mixture was modified with a dry color additive. But due to the water demand in the mixture, the color of these samples was inconsistent. The color was then developed with blended cements and with various aggregates in lieu of using the dry color additive. This resulted in a greater consistency. Ten trial samples were made using varying amounts of Type 1 cement, Federal White Type 1 cement, and Type C fly ash to achieve the desired paste color. In addition, another 12 grades of aggregate were mixed to achieve the desired look. Once the desired color mixture was chosen, three mixture samples were prepared for installation on the building.

The primary installation of mockup materials included the placement of the three different trial mixtures, each with three different surface finishes, for a total of nine patches. The mixtures varied in color, and the finishes included surface retardation, surface grinding, and building-out. The mockup with the closest match was tweaked in the laboratory to achieve an even closer match. Additional parameters for the final mixture were incorporated so that the mixture could be designed for compatibility with the existing concrete in the actual rehabilitation project. In addition, compressive strength testing of the mockup mixtures was performed to aid in adjusting the mixture design during the mockup program. It was estimated that the concrete on the exterior concrete frame could be matched for color and texture at approximately 90% success.

Mockup patches

Exposed Aggregate Mockups for Bottom Three Floors

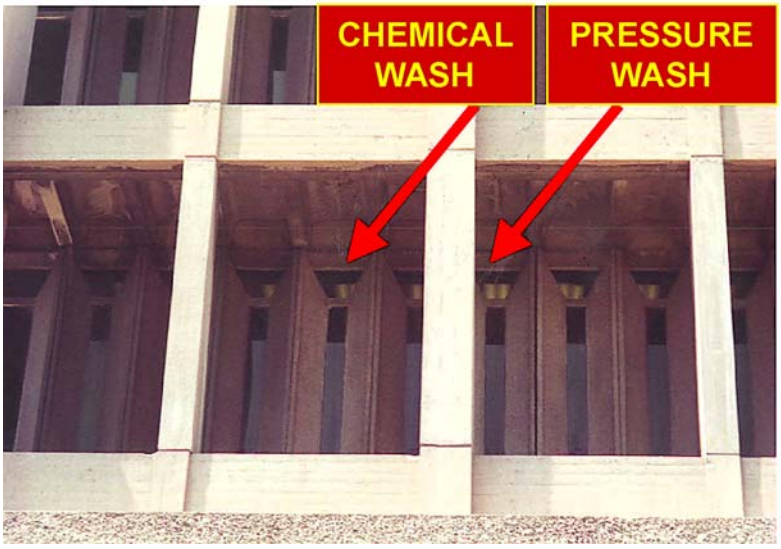
The exposed aggregate concrete on the beams and columns required a different design than that for the concrete on the remainder of the building. Previous repair programs had been performed on these areas, and each had resulted in the failure of patches to remain bonded to the substrate or to provide a reasonably accurate aesthetic match. This indicated that much consideration had to be given to the design of a repair mixture at these locations.

Mockup of exposed aggregate concrete

A concrete sample from one of the columns was removed for development of the new mixture. The form and pour trial mixture was used as a basis for this mixture. A 1-in.-size aggregate was added to this mixture to match the exposed aggregate on the building. Several preliminary samples with varying amounts of cement, aggregate, and surface retarders were developed. Two progress samples were brought to the site for review and were then modified in the laboratory for a greater appearance match. It was estimated that the exposed aggregate concrete could be matched for color and texture at approximately 75% success. Although the mixture could be modified further for a closer match, additional modifications could be deferred until an actual repair program was scheduled.

Concrete Cleaning Mockup

The surfaces of designated areas of the precast concrete panels and the cast-in-place concrete walls were selected for cleaning. The purpose of this test was to determine if cleaning of the concrete surfaces would enhance the appearance of the building. The methods investigated included a high-pressure water-only cleaning and chemical plus pressure-wash cleaning. The cleaning methods tested did not create a significant enhancement in the appearance of the building, and they were not recommended for the repair program.



Cleaning mockup on precast window panels

Concrete Coatings

The university did not wish to apply a pigmented coating to the façades because this would have changed the appearance of the building as a whole. However, the results of the mockup program showed that it was not possible to completely match the appearance of the existing concrete. But because maintaining the exposed concrete aesthetics was of a higher priority than providing a uniform appearance, pigmented coatings were still not considered as an option for the repair program.

Now You See It, Now You Don't

Because a pigmented coating would not be applied to the building, the following factors had to be taken into consideration when evaluating the overall appearance of repair patches.

Clear Coatings (Silane or Siloxane)

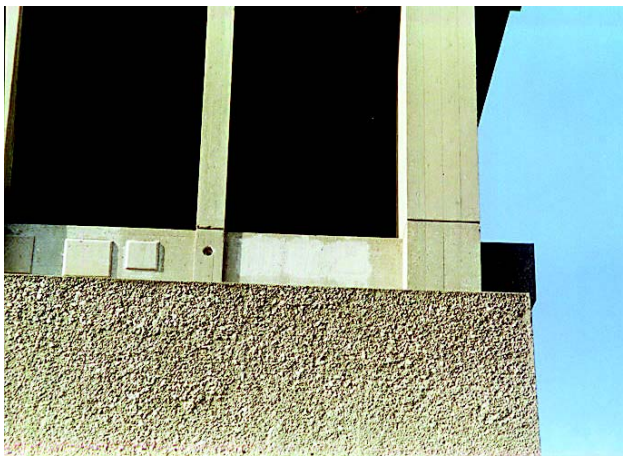
Because the university was opposed to applying an opaque coating to the exterior concrete frame, a clear, silane water repellent could be applied to the exposed surfaces to reduce the amount of moisture which penetrates the concrete. If a clear coating such as a silane was applied to the concrete surface, it could slightly change the appearance of the patches and the parent concrete. Therefore, mockups with this type of coating would have to be reviewed to determine the effect of the sealer on the appearance of the patches.

Lighting Conditions

The appearance of concrete patches changed with different lighting conditions, and this affected their visibility on the building. The mockups were viewed under sunny and overcast conditions to determine the effect to appearance of the surface with various lighting conditions. In addition, the shadows at the build-out patches changed appearance with the varying amounts of light.

Rain and Snow

The mockup patches also had different appearances depending on whether they were wet or dry. The patches matched the parent concrete when they were dry, but they became visible when they were wet. Mixture selections in such a case should be made after observation of the wet and dry appearances of the mockup patches.



Mockup patches viewed under overcast and sunny conditions

The Importance of Mockups

It is critical in a project of this magnitude that the proper studies be done in advance of designing the actual repair program. This allows for aesthetic, durability, and economic issues to be dealt with early on in the repair process. These issues, which are crucial for matching concrete for exterior façades, require cooperation between the owner, engineer, contractor, and material supplier for the project to be successful.

Administration Building, University of Illinois, Chicago

Owner
University of Illinois

Engineer
Klein & Hoffman, Inc.

Contractor
Design Installation Systems, Inc.

Material Supplier
JE Tomes & Associates, Inc.

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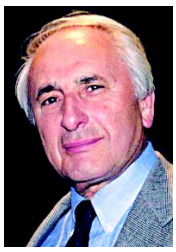

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