

Restoration of 945 Green Street

San Francisco, CA

Submitted by Sika Corporation

Located on Russian Hill, 945 Green Street is one of the most iconic residential buildings in San Francisco, CA. After almost 100 years in service, the 14-story building was beginning to show major signs of deterioration, including spalling, cracking, and exterior delamination.

INITIAL CONCERNS

This building, built in 1920, was steel frame construction with reinforced concrete slabs and exterior. As with many buildings in the area, it was subjected to the marine environment, which led to corrosion of the reinforcement and steel frame over time. Small repairs were conducted periodically, but large-scale restoration had been avoided. Eventually, the observable repairs were significant enough to warrant a full-scale investigation.

INSPECTION

In November 2012, a corrosion evaluation of the north face of the building was performed. The concrete was sounded and many large areas were marked as delaminations. Electrical continuity was then tested to determine the corrosion mitigation methods to apply. Holes were drilled in multiple locations and physical connections were made to the existing reinforcement. A high-impedance multimeter was used to test continuity, and if the difference in potential was less than 1 mV, the steel was deemed electrically continuous. All reinforcing steel tested was found to be continuous; therefore, cathodic protection was considered a suitable method of mitigation.

Concrete cover was also measured, and much of the coverage depths were between 1.5 and 3 in. (38 and 76 mm) with only a few areas tested found to be less than 1 in. (25 mm). These low-coverage areas were typically concentrated where the reinforcement hooked over the top of the structural steel I-beams.

Cores were then taken to determine the depth of carbonation in the concrete. Out of the six samples taken, three showed signs of carbonation, and of those, two showed significant carbonation at depths where reinforcement was present.

To measure chloride content, samples were taken from eight locations and four of them showed a chloride content higher than the recommended limit of 0.030% chlorides by weight. Of those four samples, two showed this elevated chloride level only in the outer 1 in. (25 mm) of concrete, but the remaining two showed elevated chloride levels 2 to 4 in. (51 to 102 mm) into the concrete, possibly indicating accelerated corrosion activity.

Half-cell corrosion potential was measured in accordance to ASTM C876. The results of the corrosion potential measurements confirmed what was seen in the chloride sampling, carbonation



Concrete cover



Evaluation testing

sounding, and visual evaluations. With significant high readings located at the depths of the steel reinforcement, it was apparent that active corrosion was occurring. The worst area was the top of the building, although the lower portion was still at high risk for corrosion. These findings, coupled with the cracks found throughout the exterior and the continued exposure to a corrosive environment, showed that the entire building was at high risk for large amounts of corrosion.

CORROSION SOLUTION

After the results of the inspection were reviewed, several options for repair were considered, ranging from chipping and patching to full-depth removal and replacement. Ultimately, the chosen method consisted of the use of sacrificial cathodic anodes; polymer-modified, vertical repair mortars; and a vapor-permeable membrane to coat the entire exterior. The anodes were used in the patches as well as in some areas of sound concrete to prevent future corrosion issues.

PRECONSTRUCTION

Once the repair solution was chosen, the site was prepared for demolition and repair. With the tower location at the top of a fairly steep hill, scaffolding was its own challenge. The steep terrain, coupled with a neighboring building directly adjacent to the western face of the building, made the allowable scaffolding footprint very small. Another scaffolding challenge was to work around the front entrance driveway, as it had to be usable for the duration of the project, so a structural bridge was constructed over it.

DEMOLITION/PREPARATION

Before the concrete could be repaired, the original exterior coatings had to be 100% removed. Due to the presence of lead in multiple layers of paint, the entire building had to be abated. After this was completed, the delaminated concrete was then removed to solid concrete and clean reinforcing steel using hydraulic and electric chipping. Only light-duty equipment could be used due to continuous occupancy in the building during the entire restoration process. At this point, it was noticed that many of the concrete architectural details were seriously damaged or even missing. Once work began, these missing areas were addressed.

APPLICATION

As the restoration work began, any exposed steel was covered in an anti-carbonation coating and an anode was attached when the steel was more than 3 in. (76 mm) from the concrete surface. Then, the patch was filled with polymer-modified cementitious repair mortar containing a penetrating

corrosion inhibitor. As the patching mortar was being applied, the contractor was also overseeing the repair and replacement of the architectural details. The first area to be restored was the line of 20 decorative columns between the 11th and 12th floor panels. Only one column had a capital and footer, so a foam mold was created with a profile of the detail. The mold was then used to recreate this detail for the other 19 columns. Around the outside of the building there had been busts of a woman's head and, like the panels/columns, most were missing. One bust was found in decent condition so, after minor repairs to the original, a mold was created and the remaining busts were cast using a pre-bagged, self-consolidating concrete mixture.



Restoration of decoration flower detail



Restoration of architectural details

These decorative elements were then reattached. Many of the decorative panels surrounding the façade were badly damaged or missing, so a similar procedure was used to restore these as well.

As the workers made their way to the ground level, they began work on the breezeway, which had been altered over the years due to changes in modes of transportation. An entire row of columns had been removed to make way for wider vehicles to pass through, and to make up for the missing support system, beams were put in place to carry the load. This replacement meant that many of the original decorative arches had been removed. The existing arches were modeled along with the medalion and decorative trim surrounding them. As for the arches, to fill in the gap left by the removed



Arch restorations



Completed restoration

columns and to keep the radius consistent across the span, the contractor created a vertical element. This eliminated the gap and created a full half circle.

The building received a topically applied penetrating corrosion inhibitor on all bare concrete. After allowing the inhibitor to penetrate the surface and onto the steel, the remaining surfactant was removed using a power washer. Finally, for added waterproofing and long-term protection, the entire building was coated with a high-performance elastomeric wall coating system.

UNFORESEEN CONDITIONS

When natural gas became an available fuel source, gas meters were installed on the wall of the breezeway, necessitating the coverage of the meters with stucco wall. Because the old gas meters were replaced with new units and relocated within the building, the wall was ripped down and behind it, a two-tiered fountain topped with a lion's head was uncovered. Half the fountain had been cut out to allow for the wall to be built, so the missing areas had to be recast and the entire fountain was patched and coated with a waterproof membrane.

SUCCESSFUL COMPLETION

Phase 2 of the project, which consisted of the bulk of the repairs, was completed in February of 2014. Only detail work remains around the breezeway, front entrance, and fountain. The success of such a large concrete repair project could only have been possible with a thorough evaluation of the project beforehand and exceptional planning throughout. The skilled work and great execution of all involved has kept the project on schedule despite numerous challenges and unforeseen obstacles.

945 Green Street

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