Concrete Restoration of Yale University's Paul Rudolph Hall

New Haven, Connecticut

Submitted by Hoffmann Architects, Inc.

The iconic Art + Architecture Building at Yale University, now rededicated as Paul Rudolph Hall in honor of its legendary designer, was completed in 1963. Constructed of cast-in-place concrete, the 114,000 ft^2 (10,590 m^2) structure is terraced into some 37 levels on nine stories, two below grade. With its distinctive use of heavy concrete forms and rich textures, this landmark of modern architecture anchors a gateway corner of the Yale campus. Just 6 years after it was completed, however, the building was damaged in a fire, and subsequent repairs so marred the original design that Rudolph is reported to have teared up when he visited the building in the late 1970s.

A 1994 renovation replaced most of the original steel-framed single-pane windows with insulated glass aluminum-framed units, but doing so altered the building profile. Reinforcing bars in the original concrete spandrels had been placed too close to the surface, and the 1994 window renovation endeavored to address the problem by attaching precast concrete panels to the spandrel face, shifting the vertical plane of the building face outward by several inches.

This restoration of Paul Rudolph Hall aims to return the building to its original appearance. Renovation was accompanied by the addition of a History of Art building and an Arts Library. The completed complex achieved a Leadership in Energy and Environmental Design (LEED) Silver rating.

SPANDREL REHABILITATION

Rudolph Hall was designed in bold strokes, and the spandrel beams were no small affair. What made the restoration particularly difficult was the beams' impressive size; some spanned as much as 70 ft (21 m). Like much of the concrete in the building, the spandrels bore a distinctive finish—a horizontal board finish that would need to be replicated authentically. Plus, the problems inherent to the original concrete, including shallow reinforcement placement and spalling, would need to be remedied.

Exploratory removal of precast concrete repair panels. Note steel lintel angles and damage to original, underlying concrete spandrel

Replacing the windows to conform to the original design intent posed multiple challenges. The new glazing, some of the largest single sheets of glass ever used, would be vast and heavy. To that engineering feat, add the inward shift of the building face to its original plane, the expanse of the spandrels, and the texture of the finished surface, and the concrete restoration became a massive undertaking.

Exploratory window removals revealed that the superimposed precast concrete panels were secured via noncontinuous steel lintel angles attached by stainless steel anchors into the spandrel beams. When the original window receivers—which were cast into the concrete structure—were removed during the earlier renovation, portions of the spandrel beams were damaged. Removal of the precast panels would necessitate some further damage to the original concrete.

To determine the best restoration strategy, the design team completed a series of mock-up concrete tests. First, the original concrete surface would need to be cut back and prepared, leaving a fractured aggregate surface for adhesion of the repair material. Steel reinforcement would then be treated (where possible), replaced, or reinforced, and positioned to ensure appropriate concrete coverage.

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Spandrel rehabilitation in progress. Note narrow depth and wide span of repair area

Interior beam cut back to treat reinforcement and prepare surface for concrete repair overlay

For the concrete repair, wood forms would be anchored to the spandrels with bolts positioned to replicate the size and spacing of anchor holes on the original beams. Using hooked rods, a mesh screen would be secured to the substrate both as reinforcement and as protection against shrinkage.

Specifying the right concrete mixture was the challenge. To accommodate the restrained conditions, as well as the multistory ascent from the concrete truck, the design team specified a high-performance, small-aggregate mixture. A low water-cement ratio, combined with a proprietary anti-shrink admixture, performed well in tests for shrinkage and cracking. The tongue-in-groove oak flooring provided duplicated the original surface texture of the spandrels. After several color-matching tests, the appearance of the mock-ups replicated that of the original concrete almost exactly.

The true test came in construction. What the mock-ups couldn't reproduce was the extremely long width of the spandrels, as well as their height off the ground. Using a long, continuous pour technique, the project team set the concrete evenly across the span. By all rights, such a long expanse could well show cracking every few feet. Yet, the final product held up even beyond expectation. No visible cracking occurred, and the building profile was restored.

"CORDUROY" CONCRETE REPAIR

Shallow reinforcement placement was also evident within the corrugated concrete portions of the façade. Where corrosion and spalling were problematic, the underlying steel bars needed to be exposed, repaired, and then recovered to an appropriate depth with color- and texture-matched concrete.

Because the corduroy-like vertical ribs were not uniform in dimension, custom molds had to be created for each area of repair. Here again, developing and testing a concrete mixture that would replicate the original appearance, hold up well as a thin overlay, and resolve the problems of the existing construction were the compound challenges of the repair work. To further complicate the restoration effort, Rudolph originally achieved the distinctive rough surface texture by sending the construction crew to strike at the finished concrete. Replicating this effect involved bush hammering the smooth, finished surface of the repaired areas until they became virtually indistinguishable from the surrounding façade.

CAST-IN-PLACE INTERIOR BEAMS

Although the large beams that traverse the studio interior were slated for minor patching, investigation revealed delamination on the lower surfaces of the beams. Here, shallow placement of embedded reinforcing bars was the culprit.

Restoration of the interior concrete involved removal of the delaminating concrete, repair and treatment of the reinforcement, and reformation of the beam surface to match the existing finish plane. The designers' challenge was to develop a firmly bonded, high-strength concrete patch that could restore the structural integrity of the beam with no more than an inch or two (25 or 50 mm) of coverage.

LIGHT WELL RESTORATION

One of Rudolph's innovations in the Art + Architecture Building was the use of "light wells," voids that admitted light from the sidewalk level down into vertical windows in the subbasement. Over the years, these open spaces were covered with roofing materials. As part of the effort to restore Rudolph's original design, the project team removed the coverings, recast the planters, and recreated the

Roof coverings were removed, windows replaced, and concrete reconstructed to recreate the innovative "light wells" Rudolph originally designed

East façade prior to renovation

windows. The unusual functionality of the concrete in these areas, used as both a channel for light and a terrace planter, made their rearticulation a key aesthetic component of the concrete restoration.

CONCRETE CLEANING

Many of the concrete surfaces had been covered with paint, graffiti, and stains. Finished floor surfaces were worn, particularly at high-traffic areas, and portions of walls, ceilings, beams, soffits, and fascias that had been painted created a mottled look, particularly as the building aged.

To restore a uniform appearance, the design team needed a safe cleaning approach. Because some "historically significant" graffiti was to be retained, the methods would need to be selective, while still strong enough to penetrate roughly textured concrete, yet nondamaging to the architectural surfaces.

First, the designers documented locations and types of dirt and coatings (for example, paints, wax, dirt, finishes). Then, they prepared mock-ups of different types of removers, strippers, and solvents and selected the best product for each application. Cleaning and refinishing not only protected Rudolph's signature concrete from further degradation, it recreated the studio's original look while integrating finishes with those in the new addition.

CONCRETE RESTORATION AND REPAIR

Accompanying the addition of the Robert B. Haas Family Arts Library and the Jeffrey H. Loria Center for the History of Art, the restoration of Yale University's Paul Rudolph Hall (formerly the Art + Architecture Building) called for uncommon approaches to unconventional concrete design.

Were Rudolph able to return to see the renovation that once more has changed the face of his building, he might now find solace in the exacting recreation of his original vision, and in its practical improvement.

East façade after concrete rehabilitation and window replacement

Paul Rudolph Hall

OWNER
Yale University
New Haven, Connecticut

REPAIR CONTRACTOR
Turner Construction Company
Milford, Connecticut

MATERIAL SUPPLIER/MANUFACTURER
Frank Capasso & Sons, Inc.
Northford, Connecticut

PRIME DESIGNER
Gwathmey Siegel & Assoc. Architects, LLC
New York, New York

BUILDING ENVELOPE DESIGNER
Hoffmann Architects, Inc.
Hamden, Connecticut