Inspired Innovation

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A job that begins as a routine inspection for façade restoration suddenly turns into a challenging structural replacement project when severe underlying structural failures are found.

ELEVEN WAVERLY PLACE WAS BUILT IN 1929 AS A 12-STORY HOTEL WITH A BRICK AND TERRA-COTTA FAÇADE. As with many historic New York buildings, its function has changed over the years, and it now houses commercial space on the first floor and residential apartments above. And also as with many vintage buildings, façade restoration work was inevitable.

Agassi Consulting Engineers and Bond Street Architecture & Design were initially called in for the restoration of the building façade and compliance with New York City Local Law 11, Façade Inspection Program. However, the discovery of unsafe structural conditions during our initial inspection prompted the owner to expand the scope of our work.

Our initial façade inspection identified two main issues: the extensive spalling of the salmon exterior brick and the deterioration and instability of the building parapets. To ensure the safety of the pedestrians below, a sidewalk bridge was immediately erected before we proceeded with an intensive exploration and testing program to determine the causes of the façade deterioration.

A Deeper Problem

Our examination revealed that the deterioration was not confined merely to the façade, but in fact extended further inside the building. We discovered severe corrosion of the spandrel steel at the main roof level. Also, the roof cinder concrete slab, which was supported by the corroded structural steel frame, was itself spalling. The slab reinforcing bars were severely corroded and some were completely severed. Large chunks of concrete had already fallen and were lying precariously on the flimsy stucco ceiling, which had never been meant to carry loads and which itself was hanging from the same deteriorated roof slab some 30 in. below.

The discoveries from the façade examination raised a red flag but did not provide sufficient conclusive information for decision-making concerning the entire roof slab and framing system. Was this a local weakness or was the decay more widespread?

We immediately apprised the owner of our findings and requested to conduct hands-on observation of the entire cinder concrete slab and the steel framing system from inside the 12th-floor apartments.

After this further exploration, we ascertained that the problems observed during the façade inspection were indeed widespread. Water leaks over the years had caused severe corrosion of the structural steel and reinforcing rods and non-reversible deterioration of the cinder concrete slab over the entire roof area. When we tried to core the slab, it simply crumbled. The deteriorated slab had little strength, if any, to support itself and the other rooftop loading. The flimsy 1-in. stucco ceiling that was hanging from the deteriorated roof slab was the only barrier between the falling concrete debris and the occupants of the 12th floor—truly a disaster waiting to happen.

The façade of Eleven Waverly Place wasn't the only thing that needed attending to.

Our first response to these discoveries was to address the safety of the building occupants. With the owner's complete cooperation we were able to vacate the entire 12th floor and the penthouse from the potentially dangerous situation. In order to protect the occupants of the 11th floor, the stucco ceiling of the entire 12th floor was completely removed, and all deteriorated roof slab sections were immediately shored as each apartment was vacated.

Replace or Repair?

The most obvious solution would have been to reinforce the structural steel members and connections. However, this would necessitate the removal of the three-story penthouse, as it was supported by the structure that required reinforcing, and the sections most in need of reinforcement would have been inaccessible while the penthouse remained intact.

In addition, the steel members and connections would have had to be exposed first, necessitating the immediate demolition of the deteriorated roof slab, so that the steel members and connections could be inspected, cleaned, and repaired. This in turn would have required the construction of a collapse platform to contain debris and safeguard the occupants of the 11th floor below.

Removal of the slab meant removal of the existing roofing as well, a step that would have left the building exposed to the elements. Tenting the building as a measure for weather protection would have added significant cost and become a maintenance item, and could also have interfered with the repair work itself.

Full replacement wasn't an option either, as it would have necessitated the use of a crane to lift the new steel to the roof. According to the NYC Department of Buildings Regulations, swinging of structural steel members by a crane or crane boom over the main roof area would have required that two floors below the roof level be vacated.

So, full replacement was out as an option, and reinforcement looked to be a daunting task as well; project constraints were quickly narrowing down our choices.

Reframing the Challenge

At this point, the challenge was to repair the corroded steel while at the same time leaving the penthouse intact and all of the main building services in full operation. Furthermore, we were determined to do all work without swinging a crane over the building in order to avoid having to evacuate the 11th floor. We also wished to avoid tenting the entire roof while removing the existing slab and roofing system, in order to avoid significant additional costs. To do this without exposing the 12th floor directly to the elements, we would have to leave the existing roof in place until after the structural steel repairs were completed from inside the 12th floor. With this in mind, the questions we now had to answer were:

1. How would we repair the underlying steel structure without removing the penthouse and while keeping the existing slab and roofing in place?
2. How could we achieve the imperative objective of protecting the occupants on the 11th floor from the deteriorated roof while gaining the access we needed to do the repair work? In other words, how would we protect the 11th floor from direct impact during demolition and possible collapse of the deteriorated slab, and how would we avoid the forest of shores from impeding the repair work?
3. How would we protect the building's interior from the elements, and how would we maintain the stability of the roof parapets and penthouse structure during the process of removing and replacing the existing roof slab once we began this process?

An Unexpected Solution

Once it became clear that there was no practical way to increase the load-carrying capacity of the steel structural system through reinforcement, we had to come up with an alternative. Our chosen solution was load reduction combined with a novel relief and transfer system.

Load reduction was achieved by implementing a plan to eliminate 3 in. to 15 in. of cinder fill used to slope the roof towards the roof drains, approximately 3 in. of cinder concrete topping, and 2 in. of built-up roofing. This was accomplished by adding 13 more drains in addition to the two original drains, and by using a waterproofing membrane that did not require the roof to be sloped. As a preventative measure, however, we required that the top of the new concrete be sloped by up to 1 in. at high points. Relieving and transferring loads, nonetheless, had to be done first and required further ingenuity.

Fortunately, the original roof was constructed with a plenum space for ventilation and for containing the building's main mechanical piping system. The plenum space offered room for new support girders but limited them to a shallow depth of 8 in. to 10 in. These new, shallow support girders, installed a few inches below the existing ones, would undergo relatively large deflections but would function suitably as a stage against which the existing girders could be jacked and partially relieved of their load, while the roof slab stiffness would be maintained by the coupled system of the existing and new girders acting in unison. By jacking and "freezing" the deformed position between the existing and new girders at specific jacking points, locking in a predetermined force through the insertion of calibrated bearing plates, we were able to permanently relieve the existing corroded girders of their excessive load, transferring it to the new support girders.

The jacking system had to be worked out in detail and required careful calibration of forces and deflections at each jacking location, coupled with proper sequencing. Two pre-calibrated jacks were used at each jacking location, one on each side of a permanent bearing plate. Where a few existing girders were interconnected, a simultaneous jacking of all interconnected girders was necessary.

A mock-up was performed, which proved useful in confirming our expectations. It indicated that reaching an exact pre-specified jacking force was possible, but it took some time to calibrate the desired force and the thickness of the corresponding permanent bearing plate. To speed up the field operations, we provided an acceptable range for the final jacking force in lieu of a specific force for each jacking location.

Rather than placing a crane on the roof and swinging a boom over the building, the structural steel fabricator and erector used a crane at street level to haul all steel members to the 12th floor, delivering them through the windows and rolling them into place. Long steel members were cut into manageable 10-ft to 12-ft segments to be spliced in place during erection.

In the end, completely jacking the existing girders eliminated the need to reinforce the corroded steel girders while permanently increasing the overall load-carrying capacity of the roof's structural system.

Maximizing Efficiency

In order for the structural steel repair work to advance from beneath the roof and relieve the 12th floor from direct loading and impact during the roof slab demolition, or in the event of a possible collapse of the deteriorated slab, we had to remove the temporary shores. At the same time, we still needed a shoring platform in place until the deteriorated slab could be replaced.

Our solution incorporated a temporary shoring scheme with permanent supports for the roof into one system. This way we were able to confine both the problem and solution to the roof level. The combined system eliminated the temporary shores altogether, ensured the efficient and orderly implementation of the work, maximized the protection of occupants and workers, and minimized the building's exposure to the elements.

Like the existing girders, the existing steel filler beams supporting the roof slab were left in place and not repaired at all. Instead, new sister beams were installed in each bay and were fitted with steel shelf angles welded to the beam webs. The angles supported a temporary metal deck placed against the bottom of the existing roof slab. This temporary deck served two functions: as a collapse-protection platform during construction and as a stage for demolishing the existing slab. Once the deteriorated roof slab was demolished, the temporary deck was removed and a new permanent metal deck was installed on top of the sister beams. The reason for moving the position of the metal deck and placing it above the sister beams was to avoid 3 in. of concrete dead load in the new roof.

The process of demolition and replacement of the roof slab took place from above. Before removing the existing slab, however, we needed to stabilize the roof parapets since widespread deterioration at the parapets caused a concern for their stability if the existing slab were to be demolished. This was accomplished by reinforcing the parapets and anchoring them to the spandrel beams.

The building was kept watertight by a temporary, loosely laid rubber membrane using the new permanent drains we had installed at the main roof. This membrane was installed in sections immediately following the removal of the existing roofing and cinder fill, and remained in place until the new waterproofing system could be installed.

The demolition of the deteriorated roof slab and the installation of the new concrete slab were accomplished by dividing the roof area into predetermined workable sections. We used a carefully planned pattern of sequential demolition and reconstruction in order to maintain the stability of the penthouse structure while the roof slab diaphragm was open. The temporary rubber roofing system was rolled open in the morning and closed at the end of each workday. This approach entirely eliminated the need for tenting the roof and penthouse, which would have impeded the slab demolition and reconstruction, and would have added significantly to the cost of the project.

New steel members were lifted by a crane at street level and needled through a 12th-floor window for installation under the main roof.

Chunks of the deteriorated cinder concrete roof slab landed on the flimsy stucco ceiling. The ceiling was hung from the same deteriorated roof slab.

Penthouse Project

Underneath the penthouse itself, the damage to the existing slab at roof level was less extensive than the damage at the open roof area. Therefore, to further maximize efficiency and cost, we left the existing slab in place and re-supported it from below. We installed a new metal deck ½ in. to 1 in. under the slab, and the space between the slab and the metal deck was grouted using SikaGrout 212. Injecting the grout into this narrow space, so that it completely and uniformly filled the gap between the slab and the metal deck, presented a significant technical challenge, but one that was met successfully. A full-scale test panel of an entire bay confirmed that we succeeded in applying the grout as needed, thereby solidifying the slab and providing it with a firm and continuous support.

Completing the Project

After completing the restoration work at roof level, we turned to the penthouse, which required individual treatment of a few elements such as the partial reinforcing of exterior columns and the restoration of a distinctive copper roof over the water tank. At the same time we picked up the pace with the façade cleaning and restoration, which required the installation of hung scaffolding from the now-restored roof level. MSC

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