Repair and Rehabilitation of the Shipping House

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Before

After

This striking high-rise building, located at Nariman Point, Mumbai, India, is the exclusive head office of the Shipping Corporation of India. The structure, in the heart of one of the busiest business districts in the world, consists of a basement level, ground floor, 19 upper stories, and a 7-story mast section. The complex commands one of the best views in the city and has occupants of around 1000 workers, with an additional 3000 business visitors each day.

The structure has a combined built-up area of approximately 150,000 ft^2 (14,000 m^2) and is situated on prime property, overlooking the Government Secretariat and the Arabian Sea. The real estate value of this property is approximately $50,000,000 (U.S.).

Evaluation of the Structure

The building's main façade elements are 3.75 ft-deep (1.1 m) box sections, which were approximately 3 in. (7.6 cm) thick. The entire building is a part elliptical aesthetic design, intended to resemble the shape of a ship.

Due to inappropriate fixing details of aluminum windows over the peripheral reinforced concrete walls, the concrete of these elements, as well as the box section, showed extensive damage. Corrosion had also set in to the main reinforcing steel, resulting in the spalling of the concrete and setting off chain reactions for enhanced deterioration and damage.

The top of the box section showed weather-related heavy damage, caused by a too-thin coat of a screed on the weather beating top face. This screed was significantly delaminated due to poor weather resistance and fatigue. This also led to progressive ingress and penetration of carbon dioxide, rainwater, and other moisture into the body of the concrete, causing extensive spalling.

Carbonation penetration was measured at 1.8 in. (45 mm) at the edges of box sections, and, in many places, the spalling was so severe that the reinforcing steel was visible.

Reinforced concrete shearwalls were found to have nonuniform corrosion-induced macrocracks, and the plaster overlay was delaminated. External joints between reinforced concrete members and masonry cladding panels had also opened up. Varying intensities of water leakage were reported and observed from almost every office, and the terrace offices needed to be virtually abandoned during the monsoon season to escape the vagaries of the weather.

Rainwater disposal down-takes provided through concealed ducts in some offices were another factor contributing to heavy water leakage during monsoon season.

A professional consultant undertook a physical survey of every office and identified the areas of distress, damage, and deterioration by thorough visual inspections of the building components. These were documented by mapping on plans, sketches, and photographs. Locations of leakage/seepage points, cracks and spalls, as well as the condition of the reinforced concrete elements were noted. Various nondestructive tests were carried out to evaluate the adequacy of concrete strength and cover to determine the appropriate repair and restoration strategies.

Causes of Deterioration

As mentioned, the structure is a high-rise building facing the sea, braving hostile coastal weather throughout the year, especially during the intense monsoon season when wind-driven acid rain attacked the exposed surfaces. Despite the fact that the building was constructed by one of the most respected contractors in India, poor maintenance, combined with the complete failure of a previous repair, had resulted in severe deterioration of the concrete of the external façade.

The box sections were extremely thin, only 2.5 in. (6.3 cm) of concrete with only ordinary cement render screed for waterproofing. The lack of adequate top cover to provide proper insulation to the reinforcing steel against the variation of the tropical weather had resulted in the failure of the screed. This gave rise to the penetration of rainwater and a subsequent faster rate of corrosion-related damage.

Rainwater disposal pipes, drainage pipes, as well as water supply pipes had been placed in small sized ducts within the building and as such were difficult to maintain because of lack of access. These pipes were found damaged in places and consequently perpetually leaked, also causing considerable unnoticed structural damage.

The main causes and mechanisms of damage and deterioration were identified as:

- Lack of adequate cover to reinforced concrete elements, particularly thin elements;
- Incorrect positioning of the windows and a poor weep system, which caused cracking of the concrete on the peripheral walls, and the consequent carbonation and corrosion of the reinforcing steel resulted in delamination and spalling;
- Improper detailing and maintenance of the concrete façade elements;
- Lack of proper dense rendering to the masonry external cladding walls led to penetration of wind-driven rainwater;
- Cement/sand rendered walls were exposed to atmospheric forces, and the lack of adequate detailing at the reinforced concrete/masonry joints left them unable to withstand wind loading and to accommodate rain and thermal cycles; and

Delamination of façade render with corrosion-induced cracks

Deterioration in façade concrete elements

- The east and west façades lacked meticulous detailing to keep water away from the façade door and window openings to prevent excessive water flow along the building façade.

Repair System Selection

Because the extent of the façade failure was nearly 70% of the exposed surface area, and corrosion cracks were visible at practically every floor level on blank/shearwalls, it was concluded that an isolated patch repair would be futile and short-lived. It was also determined that repairs to only the affected reinforced concrete areas using epoxy or polymer materials were also ruled out due to high material cost and the uncertain volume of work involved.

In view of the requirements to arrest the causes of deterioration and damage along with the restoration of the areas for longer durability in the Indian scenario and work culture, a time-tested system of shotcrete applications to the entire damaged façade was proposed to ensure proper cover to the reinforced concrete elements. A dense jacket was also proposed to the vast masonry render. The joints between the reinforced concrete and masonry were also made watertight, and the overall structure was strengthened so the integrity and adequacy of the structure would withstand the lateral geophysical forces.

Rehabilitation Sequence

Because the building structure has large, densely populated offices, the repair sequence dictated very careful implementation to cause minimum inconvenience to the occupants. As such, meticulous detailing was worked out to ensure successful repairs within the schedule allotted.

1. Tubular steel scaffolds were carefully created on the adjacent sides (forming a right angle), anchored at calculated heights for lateral stability. The entire scaffold skeleton was covered with protective hessian screen to arrest any falling debris during repairs. Working platforms at convenient locations were erected to facilitate safe working conditions for workers and to facilitate faster progress by allowing work to be executed at different levels.
2. Large aluminum windows on the east and west façades were removed from each office floor and dismantled by section, with demarcation for reassembly after the repairs, since the windows were made up of very high-value aluminum sections. The exposed window openings were carefully boarded with sheeting to protect the offices from exposure to the atmosphere. The existing costly floor finishes were protected with additional layers of hessian and gypsum during repairs.
3. The existing cement mortar rendering on the external walls was carefully removed manually without undue damage to the masonry or the concrete substrate, and cracked, loose, and delaminated concrete from the reinforced concrete elements was also removed manually up to a required depth without disturbing the core of the concrete.
4. Falling debris was collected over the protected platforms at respective levels and lowered down through construction chutes to the grade level for disposal. Necessary additional precautions were taken in view of the increased wind velocity at varying heights for labor to work safely with safety belts, netting, and platforms.

Shotcrete in progress

5. The exposed corrosion-inflicted reinforcing steel was cleaned with a pretreatment to loosen the rust scales and passivated against corrosion with epoxy-based formulations. Extreme edges of box sections and composite beams were rebuilt with additional steel reinforcement and concrete. The entire façade was treated alike and eventually shotcreted with a rich polymer-modified cement mortar that averaged 1.6 in. (40 mm) thick, reinforced with a 10 gage welded mesh on a 3.9 x 3.9 in. (10 x 10 cm) grid.
6. Level screeds, cover blocks, and leveling strips were fixed to ensure correct line and level and to follow the original aesthetic lines of the building. Because the building was a high-rise, with a height of approximately 260 ft (80 m), a compressor with adequate capacity was not available. The mechanical division of the contractor had to modify the compressor engine to achieve the required pressure at these heights. To maintain the aesthetic value and features of the building, utmost care was taken to ensure the correctness of the lines and the workmanship.
7. The shotcrete layer was cured for 10 days by continuous wetting through a sprinkler system created especially for this purpose and was then rendered with cement mortar overlays in two coats with a sponge textured finish. To achieve waterproofing and thermal insulation of the top of box sections, a layer consisting of small brick pieces (as thermal insulation) fixed in cement mortar bedding was first laid with the correct slope and then overlaid with a jointless waterproof

screed coat with polymer-modified rich cement float, finished with false checkered lines to minimize map cracking and plastic shrinkage.

8. The shearwalls were also treated with a corrosion control treatment on the exposed steel and shotcrete reinforced with mesh and finished with two coats of cement render. Bands were introduced at every floor level to limit thickness of the mortar and to reduce the scouring velocity of rainwater during monsoon season. Special attention was paid to the joints of the masonry and concrete. A "V" groove approximately 2 in. (5 cm) deep was made by chiseling at the joint, and after cleaning, a cement mortar was pressed in. Dry aggregate pieces were then pressed firmly into the mortar. Nozzles for grouting were placed every 5 ft (1.5 m). After shotcreting and the first coat of cement render, cement slurry mixed with an expandable additive was injected under pressure into the nozzle. This helped ensure that the joint would not reopen in the future.
9. On the east and west walls, the aluminum windows had originally been fitted flush with the external finish surfaces. Thus, in the monsoon season, rainwater traveling down the building walls would rush into the windows, especially at the joints. Sealants proved to be ineffective to keep the mass quantities of torrential rainfall out and thus the offices would get flooded at times of heavy rain. To prevent this, after the aluminum windows were removed, the consultants designed reinforced concrete weather shades supported by newly created reinforced concrete brackets, the steel of which was hooked on and welded to the peripheral concrete walls. Brand new weather shades were created and lightweight, air-entrained concrete blocks were erected above the brackets forming an aesthetically pleasing grid pattern, which greatly enhanced the façade of the structure.
10. The aluminum windows on peripheral walls were fixed back in a specially designed and created step-form sill housing of stone to ensure long-term performance against leakage

Bracket concreting and compacting using a needle vibrator

Fins being constructed with air-entrained lightweight concrete blocks

(Above and below) Construction of new 12 ft-cantilevered canopy

of rainwater and also to prevent the wind-driven rain from coming into and over the bottom aluminum section due to the tremendous wind pressure.

11. Because the areas of the complete façade were fully jacketed and plastered, the sizes of the windows needed to be altered for reinstallation. Thus, every aluminum section, channel, and glass panel was altered and reinstalled. This necessitated great attention to detail, as an error of even 0.08 in. (2 mm) would not allow the aluminum shutter to slide on the nylon bearings.
12. Mortars were properly proportioned, batched, and machine mixed (hand mixing is typical practice in India). Fine aggregates were chloride-free river sand, prewashed at the site by a specially designed sieving and washing machine to ensure silt contents of less than 3%. The measures of washing the sand, the machine mixing addition of an anti-shrinkage polymer, and a high degree of workmanship resulted in the effectiveness and durability of the treatment carried out.
13. An elastomeric protective coating of 250 micron thickness was applied over the exterior jacketed façade after allowing for necessary plastic and drying shrinkage. This was one of the first projects in India where elastomeric paint was used.

Terrace Repairs

The building had two terraces on the 4th floor level, one on the 18th floor, and one very large terrace that is a semi-circular dome shape on the top floor above the auditorium. The parapet walls, which were a very slender concrete section, were demolished and reconstructed using lightweight concrete blocks to reduce the live load and increase longevity because there was no steel used in the concrete block. Lateral rigidity of the parapet wall was attained by constructing pillars every 10 ft (3 m) that were anchored to the floor beam below.

On the dome-shaped terrace, decorative grills were used to enhance the aesthetic appeal. The entire surface of the slab was then covered by a rich cement slurry, followed by a layer of mortar with a ratio of 1:5 cement:sand. Brickbat pieces were laid on the terrace floor to serve as thermal insulation to absorb heat from the direct sunlight that reached temperatures of 120 ºF (50 ºC). These pieces also served as keys for the subsequent waterproofing screeding, which was float-finished.

Care was taken to ensure correct detailing, especially at the joints of the old slab and the newly constructed parapet wall. A haunch made of brick pieces was sealed with hand-packed brick aggregate fixed in mortar so that the joints would not open up. A subsequent layer of render was laid over and above the haunch to ensure that water would not penetrate through.

A wearing coat of 1 x 1 in. (2.5 x 2.5 cm) broken glazed tile chips was laid down in a bed of rich mortar and floated with white cement. After curing for 10 days, the surface was acid washed to obtain a sparkling effect that would reflect the heat of the sun, thus preventing heat penetration into the deck waterproofing to reduce the degenerating cycles of thermal expansion and contraction.

The top of the parapet wall was lined with stone slabs of 5 ft (1.5 m) lengths with a 1 in. (2.5 cm) projection on either side so that the rainwater flowed away from the parapet wall surface. Stone slabs were fixed with a slight slope toward the inner terrace so that the dust settlement caused by monsoon showers would be discharged onto the terrace floor, protecting the outer walls from subsequent moss accumulation and bacterial attack. The joints of the stone slabs were filled up with a flexible polysulphide sealant to allow for expansion and contraction of the stone slabs that can experience 70 ºF (20 ºC) temperature differentials in 24 h cycles.

Decorative Ceramic Screen

The building originally had decorative ceramic latticework fixed on all four sides, up to the 4th level, as well as a large band fixed on the 17th level. These decorative ceramic blocks were readily available 35 years ago when the building was constructed, but even then had to be specially ordered and fabricated. In recent times, however, this industry has died, and there were no suppliers available for these materials. Because the consultant was very keen on maintaining the original look of the building along with the delicate latticework, a hunt was launched over all India to locate a specialized manufacturer. Finally, after 2 months of searching, a small manufacturer was found, located 2000 miles (3200 km) from Bombay and 40 miles (64 km) from the nearest town!

The manufacturer, who was in the business of making ceramic sanitary ware, had never attempted this type of work before but was an entrepreneur, willing to explore new avenues of expertise. Several mock trials and blocks were made and nearly a month was spent obtaining the right mixture of soil and furnace temperature to formulate the blocks correctly.

The latticework design was broken down into small geometrical patterns and a mold was created, wherein the clay could be set, compacted in a hand-press, and then removed from the mold and put into the furnace for baking. Due to the very nature of this process, the rejection percentage of the block was as high as 60%! The blocks were designed to have a male and female socket to create an interlocking pattern, which enhanced the lateral stability of the decorative screen. The blocks were packed in hay (the only packing available in the remote village) and sent by road to Bombay, nearly 2000 miles (3200 km) away.

The blocks were unloaded on site, washed, and reinspected for quality, and then each piece was manually fixed in place by expert masons. The fixing itself was a very slow process because each piece of approximately 0.35 ft^2 (0.03 m^2) had to be manually set in place and held for a few minutes in position until the adhesive took affect.

Approximately 22,000 ft^2 (2,040 m^2) of more than 50,000 blocks were installed. The process took 4 months and around 11,000 man hours. The end result was worth it, however, as the lattice screen enhanced the aesthetic appeal of the building, and the ceramics are made to last 50 to 60 years with virtually no corrosion.

Project Schedule

The time schedule was closely monitored with weekly site meetings and project participant coordination. The contractor presented a complete sequence of events for the project, including inconveniences to be faced by the occupants of the building, so the occupants would know what to expect for the duration of the repairs. This ensured excellent coordination of the project team, along with cooperation from the occupants, and resulted in a timely and successful completion of the project within its budget of $675,000 (U.S.).

Shipping House

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The Shipping Corporation of India, Ltd.
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