Windsor Suites Hotel Parking Garage Restoration

Philadelphia, PA

Submitted by Carl Walker, Inc.

The 192-car Windsor Suites Hotel valet parking garage, constructed circa 1963, is on the second through fourth floors of the 23-story hotel in historic Philadelphia, PA. The structural frame consists of cast-in-place flat concrete slabs, varying in thickness from 7 to 9 in. (178 to 229 mm). The slabs are supplemented with beams at the edge of the slab and at various interior locations. The column arrangement requires reinforcing steel to be placed at asymmetrical strips parallel to lines that connect column centerlines. The lateral load resistance is provided by the shear walls of the elevator core and stair towers. The foundation system includes caissons that bear on rock strata.

PROBLEMS PROMPTING REPAIR

In 2008, after a large piece of concrete fell through the suspended ceiling on the mezzanine level, a condition survey was conducted immediately to confirm findings of a 2007 evaluation. The evaluation revealed:

- Significant deterioration of concrete slabs;
- Failure of previous top/bottom slab repairs;
- Delaminations around columns;
- Severe corrosion of reinforcing steel at top/bottom sides of slabs; and
- Punching shear failure around columns.

Immediate actions included closing 40% of Level 2 and 15% of Level 3 parking areas. The Mezzanine Floor office area was closed and the Level 2 slab was shored.

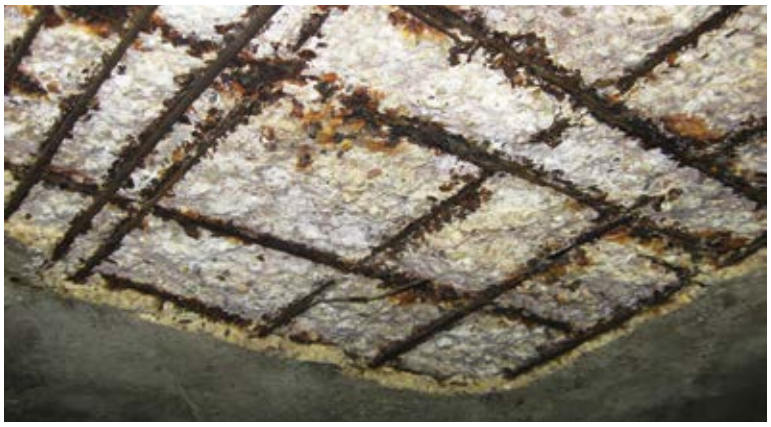
EVALUATION

Once areas exhibiting potential failure were safe, the investigation of garage slabs commenced. Visual observations of spalls and exploratory excavations at top/bottom of slabs revealed critical section loss on reinforcing steel. Horizontal cracks extending into the bottom of the slab at the line of reinforcing steel indicated that corrosion continued after previous repairs. Sounding of the top side of the slab revealed delaminations at each column.

Crack patterns around columns were consistent with flat plate punching shear failure. Vertical displacement measured along cracks was up to 1/8 in. (3.2 mm) from one side to the other. The maximum slab deflection measured 4.5 in. (114 mm) at mid-panel on Level 2. Also, the laboratory tests indicated poor-quality concrete.

23-story Windsor Suites

Failed coating and concrete



Overhead spall and corroded reinforcing steel

Ramp restoration

QUALITY CONTROL

The Philadelphia Department of Licenses and Inspections was informed of the problem and measures were taken for public safety. Keeping the building authority involved proved effective in expediting the review process for construction permits. Construction extended over a 5-year period, and one permit was secured with the understanding that notifications would be given when each construction cycle began and ended.

Quality control was provided by the engineer during construction, including review of the reinforcing steel layout and installation. An independent testing laboratory provided material testing.

CAUSES OF DETERIORATION

The condition was the result of three groups:

- **Original construction deficiencies:** High water-cementitious material ratio (*w*/*cm* = 0.68); elevated air entrainment (8.2%); low cement content; low compressive strength (1900 to 2800 psi [13.1 to 19.3 MPa]) and design strength 3000 psi (20.7 MPa); low cover on top reinforcing steel (approximately 1/2 in. [13 mm]); and drainage limited to four floor drains and a trench drain at bottom of speed ramps;
- **Defects:** Inadequate drainage; previous slab repairs found unbonded to substrate; extensive corrosion of reinforcing steel at previous slab repairs; deck coating system terminated at vertical surfaces of columns, allowing chloride-laden moisture to wick into slab; evidence of trapped moisture at failed deck waterproofing, restricting moisture evaporation; and no drainage provided on south and west sides of garage; and
- **Deterioration:** Concrete freezing-and-thawing damage below failed deck waterproofing; severe corrosion of top/bottom reinforcing steel of slab system, resulting in large areas of concrete delaminations; section loss of reinforcing steel reducing the capacity of slab; excessive deflections occurred; and beginning of punching shear failure at columns, noted patterned cracking, vertical displacement one side of crack to the other.

REPAIR SYSTEM SELECTION

Based on investigation findings, partial area repairs were no longer viable. The most effective repair was to replace 3 in. (76 mm) of the top of the slab, including replacement of the top reinforcing bars at each level. Where corrosion extended to the bottom reinforcing bars, full slab replacement was required.

The concrete replacement would include a high-performance 4500 psi (31.0 MPa) concrete design mixture including a maximum *w*/*cm* of 0.40, corrosion inhibitor, proper air entrainment, and slump limitations.

Uncoated reinforcing steel was selected to avoid potential differentials between new and existing areas, and to minimize lap and splice lengths to keep reinforcement from being congested.

SITE PREPARATION

Due to the repair magnitude and work occurring within an operating garage/hotel, critical logistical planning was necessary. Limits were set for the maximum allowable area of a level to be removed so temporary bracing of columns would maintain the structural integrity of the 23-story concrete frame.

PHASING

As initial design neared completion, the U.S. economy entered a major recession. This placed an added burden on the design team, as a single-cycle project was not viable. Because the work would run for an extended time, impact on hotel guests became vital. The repair program was phased over a 5-year period.

WORK AREA ISOLATION/ ENVIRONMENTAL CONTROLS

Special steps were taken for pedestrian protection. Noise associated with concrete removal was a major concern. The demolition contractor used a concrete

road saw to minimize use of pneumatic hammers. Partial-depth areas were shored and the slab cut into small strips for chipping guns. Areas of full depth were shored and the slab cut full-depth and removed in larger pieces. After Phase 2, partial-depth slab removal was replaced with full-depth slab replacement because of significant noise reduction.

REPAIR PROCESS EXECUTION

LOGISTICAL ISSUES

Due to extreme site limitations, coordination between the owner, garage manager, contractor, and engineer were critical. Once sequencing was determined for each phase of the slab replacement, traffic lanes and parking limits were set. To meet the time constraint, it was imperative that all milestone dates were met and decisions on field conditions made in a timely manner.

No laydown area was available outside the building. The active work zone had to accommodate a debris-holding area, a laydown area, and construction equipment.

Prior to beginning saw-cut operations, shoring was installed, consisting of aluminum beams and plywood covered with a layer of foam insulation. Upon removal of the concrete and foam insulation, shoring towers were adjusted, raising the plywood layer into position as the formwork for the new slab.

Phase two required pre-phase work that included engineering a steel framing system to be installed within the double-story height space 5 ft (1.5 m) below the Level 2 slab. This system served as column bracing and a work platform for the contractor, supporting shoring, demolition, and formwork operations while allowing vehicle access.

COMPLEX REPAIRS

Full-depth replacement of a two-way flat plate slab system extending nearly 90% of a floor located in the lower floors of a concrete tower presents certain engineering challenges. Stability of the overall frame and, in particular, the columns in the work area, were of prime concern. Complicating this was the irregular sizing and layout of the building columns. Limits were placed on the total number of columns where the floor slab could be removed while temporary bracing was installed to address the doubled column length with the slab removed.

The concrete slab within the building columns remained in place to avoid the need for temporary vertical support. The original slab reinforcing details resulted in congestion of the reinforcing steel within the column. The slab reinforcing bar details followed current ACI code requirements, reducing the number of bars intersecting the column. Reinforcing bars that intersected the column were detailed using 90-degree hooks to develop the full capacity of the bar. The hooked bars were enclosed by supplemental ties for the length of the hooked section.

Underside shoring

Close coordinated parking and construction

To prevent future deterioration of repaired floors and ramps, methyl methacrylate deck coating system was provided. This was selected because the relative stiffness of the floor would allow for the less flexible material and the material could be applied and repaired in cold weather.

To finish the project, entrance area line striping and graphics followed deck waterproofing. Interior lighting was also replaced on each level.

Windsor Suites Hotel Parking Garage

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