Repairs to Paulina Street Parking Structure

Chicago, IL

Submitted by CTLGroup

The Paulina Street Parking Structure is a 38-year-old concrete facility comprised of post-tensioned one-way slabs and beams and conventionally reinforced columns. Typical slabs are continuous over six spans, while beams are continuous over two or three spans. The post-tensioning system consists of unbonded, monostrand tendons in heat-sealed sheathing. Post-tensioned members also contain bonded, conventional reinforcement at locations of maximum flexural stress. The garage was constructed in 1976 using 5000 psi (34.5 MPa) lightweight concrete and 3/4 in. (19 mm) concrete cover was specified over conventional uncoated slab top reinforcing.

In plan, the structure is approximately 270 x 263 ft (82 x 80 m) and consists of five similar east-west bays. Five elevated levels and one slab-on-ground provide a total floor area of approximately 408,000 ft^2 (37,900 m^2). An expansion joint is located between the three northern and two southern bays. Another expansion joint, centered on the structure (in a north-south orientation), divides each of the five east-west bays.

The garage serves 1100 vehicles at the University of Illinois at Chicago and is exposed to harsh environmental conditions including vehicular traffic 24 hours per day, heavy snowfall, cyclical freezing and thawing, and deicing chemicals.

Parking structure

INVESTIGATION

In 1991, after 15 years of service, an investigation of defects in the Paulina Street Parking Structure was initiated. At that time, the structure exhibited widespread delaminations; spalls; and exposed, corroded reinforcing steel in slab top surfaces. Some tendons were exposed and had erupted through slab surfaces. The investigation revealed that deterioration was primarily attributable to high concentrations of chloride ions absorbed by the lightweight concrete and shallow concrete cover over reinforcing. Approximately 20% of deck top surfaces were either delaminated or spalled.

Structural calculations were performed to assess service load and strength requirements of the local building code. It was determined that the as-designed structure contained significant strength deficiencies in several beams and columns.

Prior to 1991, the structure had undergone at least one unsuccessful repair program. These repairs consisted of localized removal of deteriorated concrete followed by the installation of various types of patch materials. Virtually all of these patches were delaminated and many had dislodged from substrate concrete.

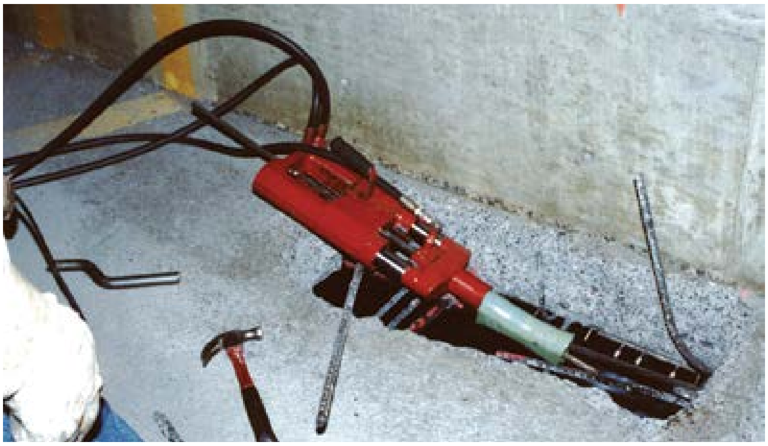
Approximately 10% of post-tensioning strands were inspected in the field during the investigation to assess current conditions. Inspections were performed at high points of draped tendon configurations. This revealed minor corrosion and two detensioned slab tendons. The post-tensioning system was judged to be in relatively good condition overall, but with localized deteriorated conditions. Spacing of slab tendons was relatively wide, resulting in a general lack of redundancy in the event of a tendon failure.

REPAIR DESIGN

Objectives of repairs were to strengthen structurally deficient members, restore deteriorated deck surfaces, enhance long-term durability, and minimize future maintenance efforts and costs. Additionally, the garage could not be closed during repairs and the number of parking spaces which could be taken out of service during construction was severely restricted.

Many strategies were considered, and the final repair approach chosen included strengthening of deficient beams and columns; removal of deteriorated deck concrete, patch materials, and slab top reinforcing steel; roughening of all deteriorated deck concrete; repair of defective slab post-tensioning tendons; and installation of a continuous, bonded, reinforced concrete overlay to deck top surfaces.

Hydrodemolition in progress



Post-tensioning tendon repair

Placement of concrete overlay

The final design phase required several tasks, including the following:

1. Removal of deteriorated deck concrete would be performed by hydrodemolition. In this way, the potential for tendons damaged by chipping hammers would be minimized. Moreover, the resulting surface profile of the substrate would be conducive to achieving high bond strengths.
2. Structural analyses revealed the presence of excessive cambering of slabs and tensile flexural stresses at unreinforced regions of slabs after concrete removals. Existing slabs could not be practically detensioned and then retensioned after completion of repairs. Therefore, a means of controlling cambers and construction stresses had to be developed. The inability to detension slabs also meant that overlay concrete would not be prestressed. Thus, another concern was the potential of flexural cracking of the overlay when subjected to vehicular traffic.
3. A system of shoring and counterweighting slab spans was devised to maintain structural integrity during construction and to minimize flexural cracking after reinstatement of the facility.
4. Repair methods were developed to correct detensioned and significantly corroded post-tensioning tendons.
5. Microsilica concrete was chosen as the overlay material due to its relatively high strength, low permeability, and low maintenance requirements. Reinforcing steel for the overlays consisted of epoxy-coated welded wire reinforcement and some supplemental reinforcing bars.
6. Strengthening techniques for deficient beams and columns consisted of enlargement of existing cross sections with reinforced concrete.

CONSTRUCTION

Construction started in March 1992. Three overlay mockups were performed to calibrate hydrodemolition equipment and to evaluate the bond characteristics of three methods of substrate surface preparation. Two mockups included the use of bonding grouts between the overlay and substrate; one mockup included only the use of saturated surface-dry conditions in the substrate (that is, no bonding grout was used). Results of this work indicated that a saturated surface-dry condition in the substrate prior to overlay installation was sufficient to provide good bond strength. This information resulted in significant time savings and simplification to the overlay installation procedures.

Hydrodemolition resulted in exposing a relatively large number of slab tendons at their high points, which simplified condition inspections. However, soon after work started, deep nicks and corrosion were found in some tendons located adjacent to concrete patches. It appeared the misuse of demolition hammers in the previous repair program(s) resulted in nicked tendons and torn sheathing, neither of which was remediated at the time. Obviously, if all existing patches concealed nicked and/or corroded tendons, and all such defects required repair, construction costs would quickly escalate. It was decided to repair tendons exhibiting extensive corrosion. However, to determine the significance of the observed nicked conditions, a laboratory testing program was developed. Results of this study provided an assessment of the strength reductions in tendons containing nicks and severed wires. Acceptance criteria for existing conditions (such as shapes, sizes, and numbers of nicks) were developed, resulting in significant savings in construction time and costs.

Pitted strand segments were replaced. In most instances, replacement was performed by rethreading new, greased strand into existing sheathing and splicing to existing strands. In a few instances, replacement required trenching of the slab followed by installation of new sheathed strand and anchorages.

Slabs in each typical bay contained 21 structural tendons (that is, tendons oriented parallel to slab spans) and there are a total of approximately 1050 slab structural tendons in the structure. During the course of the work, a total of 170 structural tendons (or an average of three to four per typical bay) required repair. The worst bay required repairs to 13 of its 21 tendons.

Because target concrete removal depth was limited, most tendons were not exposed during hydrodemolition. Where tendons were exposed and sheathing was damaged, tendons were vacuumed thoroughly to remove as much water as possible. Then, after allowing tendons to further air dry, tendons were coated with a bituminous coating. It should be noted that current technology would allow improved protection of tendons through use of cable drying and grease injection techniques.

REPAIR PERFORMANCE

Based on a 2013 inspection and discussions with the university, the garage has required minimal maintenance over the past 21 years. It appeared that two repair programs have been performed since 1993 repairs. The repair programs consisted of only isolated patch repairs, routing and sealing of some slab topside cracks, and some joint maintenance. The total area of patch repairs reflects significantly less than 5% of the total surface area of the 1993 overlay. No soffit deterioration was observed. Isolated topside delaminations were identified during the inspection; delaminations sounded relatively shallow and appeared to be located in areas where cover over overlay reinforcing was locally shallow.

The inspection did not identify any evidence of tendon repairs or breakage since the 1993 repairs. No tendon eruptions were present. The number of full-depth slab repair areas that might indicate tendon repair locations appeared generally consistent with the number created for the 1993 repairs.

Overlay and localized repairs

Overlay and localized repairs

Paulina Street Parking Structure

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