Good Samaritan Hospital Clifton Avenue Garage

The Clifton Avenue Garage, built in 1966, is the oldest of three parking structures at Good Samaritan Hospital, Cincinnati, OH. It consists of one on-ground and three supported parking levels.

This is a unique structure due to its lift-slab construction, whereby each of the three supported levels was cast on the ground (one level on top of the other) and then lifted vertically into place. The slabs were connected to preconstructed columns by means of steel bars placed through the columns and below the slabs. Each of the three supported levels consists of three independent 11 in. (28 cm) thick lift-slabs—nine lift-slabs in total. The structural system for each of the lift-slabs is a two-way unbonded, button head, post-tensioned (PT) system. The PT tendons are paper wrapped and placed in a draped profile such that, in both directions, they are near the top of the slabs at column lines and near the bottom of the slabs at mid-bay.

In each direction, the primary tendons (running the full length and width of the individual lift slabs) consist of ten 1/4 in. (0.6 cm) diameter wires at spacing ranging from 7 to 30 in. (18 to 76 cm) on center. At some perimeter locations there are six- or 10-wire additional supplemental tendons, typically 20 ft (6 m) long.

The lift slabs contain only minimal amounts of mild steel reinforcing (reinforcing bars), located near the top of slabs and generally in the vicinity of columns. Except for tendon support, there is no mild steel reinforcement at the bottom of the slabs.

A shearhead/lifting assembly is cast into each lift slab at every column. These assemblies consist of steel channel and rectangular bar elements welded into a unit. At the time of construction, the assemblies were the connection points used to lift the slabs. After the slabs were erected, a 3.5 x 5 in. (9 x 13 cm) steel bar was placed through each column and the slabs were lowered slightly, allowing the assembly to bear on the bar, transferring the weight of the slab to the column. The assemblies also function as slab shear reinforcement.

Deterioration Conditions, History of Past Repairs, and New Restoration Scheme

The garage has undergone several rounds of extensive investigation and restoration beginning in the early 1980s. During these initial efforts, significant chloride-induced corrosion of the slab PT system was discovered. Failed tendons were observed at various locations at all supported levels. Exploratory excavations revealed significant corrosion at tendon high points and anchorage zones.

Following a conventional repair project in the mid-1980s, a long-term slab monitoring program, measuring slab deflections at 3- to 6-month intervals, was initiated in the early 1990s. This revealed defection patterns consistent with increasing loss of PT force. Thus, in 1994, a permanent shoring system at all nine lift slabs was installed as a means of providing precautionary support for the deteriorating structure.

In 2004, as the hospital administration began to consider the cost, disruption, and temporary parking loss implications of demolishing the structure and building a new parking facility, the question of long-term restoration options arose. Repair of the existing PT system was dismissed because the large numbers of anchorages buried within the walls made this option unfeasible. Trenching in new tendons was also dismissed because the complicated geometry of the existing draped two-way tendon system made this approach impractical.

A new two-way external PT system installed at the underside of each of the nine lift slabs would be effective to extend the service life of the structure. The intent of the new external PT system was to introduce sufficient PT force into the slabs, in both directions, to allow for a nearly complete loss of the original PT system. To transfer the external PT force into the slabs, bonded concrete elements (slab bands) were placed in the east-west direction at every column line.

Construction of the New External PT System

The success of the new structural system relied on the ability to achieve bond between the new slab bands and the existing lift-slab soffit and ensuring adequate consolidation of new concrete. To test the means and methods, significant mock-up work was undertaken. Mock-ups stringently adhered to the requirements of construction documents in regard to surface preparation, conventional and PT reinforcing, concrete mixture design, and placement procedures. After curing and form removal, full-depth cores were extracted to test consolidation and bond. Despite the time-consuming nature of this work, several mock-ups were created to ensure that success could be replicated on a consistent basis.

Slab band to soffit attachment was primarily achieved by mechanical means and secondarily by adhesive bond of the new concrete. In addition to the thorough sandblasting preparation of the entire slab band area, specific sections received more aggressive bush-hammer profiling. Also, a shear key was chipped into the surface at the ends of all slab bands to transfer PT forces near the anchors for the east-west tendons. Additional mechanical connection was accomplished by the placement of approximately 260 shear pins epoxied into the soffit within each slab band, including a cluster of approximately 55 pins installed at the ends of each slab band.

Repair project with shoring in place

Typical repair around columns

Competed parking bay

Following surface profiling and the placement of pins, new PT tendons and reinforcing bars were set. New draped east-west PT tendons were clustered within the slab bands. Uniformly distributed north-south tendons were passed through PVC ducts within the slab bands, draped over deflector devices between slab bands, and anchored to the end slab bands at each lift slab.

During the performance of this work, the majority of the existing steel shoring remained in place. It was necessary, however, to remove specific pieces of this system and install temporary shores to access repair areas.

The forming system was installed at slab band areas and 5000 psi (34.5 MPa) silica-fume modified concrete was placed via pumping into strategically placed core holes through the existing slab. Full-depth 4 in. (10 cm) diameter cores were extracted along the area of the slab bands at approximately 5 ft (1.5 m) on center. Additional holes were created around columns and at the ends of slab bands to ensure proper consolidation at these critical areas. One and a half in. (3.8 cm) diameter holes were placed at high elevation areas to provide an avenue for the release of trapped air during placement.

At each of the five phased PT work areas, the existing steel shores were removed after slab band concrete had achieved strength and all tendons (in both directions) were stressed.

Structural Repair to the Existing Building Components

Prior to the implementation of the new external PT system, it was necessary to complete the following work:

- Concrete repairs occurred at existing slabs, columns, and walls. There was a heavy concentration of reinforcing steel in the slabs around columns that had experienced significant corrosion. Also, because the lift slabs were tied to the perimeter walls, restrained movement caused significant damage to wall and stair-tower elements;
- Although the basis of the new PT design assumed a nearly 100% long-term failure of the existing PT, efforts were nonetheless made to retain as much of the original PT system as was practical. Existing PT anchors adjacent to two of the stair towers were significantly corroded. At these

locations, new anchors were established within the slab and the tendons and the old compromised anchors were removed;

- Bonded reinforcement was installed at the top of the slab areas around all columns on the elevated levels to increase the amount of slab reinforcement to that required by the ACI Code for unbonded PT slabs;
- Reinforcing was also installed at the perimeters of each level in an effort to restrain anticipated shortening resulting from the new PT system; and
- New steel-bearing angles were installed at all columns to assist in supporting the additional weight of the new slab bands.

Waterproofing Protection Systems and Other Upgrades

After structural repairs were completed, existing expansion joints on all levels were replaced with new winged compression seals. A new urethane deck coating system was installed on the intermediate levels and the roof level membrane was recoated.

Mechanical and electrical upgrades completed the project. The garage was rewired and new lighting was installed. The drainage system was replaced and a new fire suppression system installed. The garage walls and columns were painted to conceal repairs and to create a fresh, clean appearance.

The project was completed within budget and on schedule. As a result of this renovation effort, the hospital gained the 208 parking spaces lost in 1994 and has a structure that will remain in service for the next 25 years. The successful completion of this unique repair project can be significantly attributed to the team effort of the owner, engineer, construction manager, and restoration contractor.

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Owner
Trihealth Good Samaritan Hospital
Cincinnati, OH

Project Engineer/Designer
ERG Structural Engineers
Lawrenceburg, IN

Repair Contractor
Lithko Restoration Technologies
Hamilton, OH

Materials Suppliers/Manufacturers
Dywidag-Systems
Tucker, GA

Sika Corporation
Lyndhurst, NJ

Top deck of garage during repairs

Bonded reinforcement was installed at the top of slab areas around all columns on the elevated levels

Top deck of garage after all repairs, deck coating, and striping