Houston Hobby Airport Parking Structure Rehabilitation

Houston, TX

Submitted by Whitlock Dalrymple Poston & Associates, Inc.

The primary parking structure for Hobby Airport was constructed circa 1980. Within the first 20 years of service, the parking structure exhibited various signs of distress, including post-tensioned tendon failures that had erupted through the concrete. Confronted with the possibility of repair or replacement, the owner retained a consulting engineering firm to perform a condition assessment of the structure.

The four-level parking structure is located adjacent to the Hobby Airport terminal building. The parking area encompasses about 1.2 million ft^2 (111,485 m^2) and 3500 parking spaces. The structure is constructed of cast-in-place concrete—unbonded post-tensioned concrete one-way slabs and beams and conventionally reinforced concrete columns. Vehicular access and egress for the structure are provided by four helical ramps, which are connected to the main structure by bridges comprised of precast concrete slab units spanning between precast spandrel concrete beams. The exterior faces of the structure are clad with architectural precast concrete.

Prior to the investigation, immediate observations of distress included widespread exposed top reinforcement, reinforcement corrosion, failed expansion joints, and severe cracking within bridge elements.

INVESTIGATION

The field investigation included:

- Visual survey of distress, including use of a fiberscope to observe structural components hidden from direct observation;
- Sounding of the concrete surfaces to determine extents of delamination;
- Nondestructive testing (NDT):
  - Impact-echo testing,
  - Surface-penetrating radar,
  - Measurement of half-cell potentials, and
  - Measurement of corrosion rate;
- Probe openings to inspect embedded conventional and prestressed reinforcement and verify NDT methods;
- Concrete chloride ion concentration sampling and testing;
- Concrete carbonation testing;
- Concrete core sample removal;
- Laboratory strength testing; and
- Petrography of selected core samples.

Most of the expansion joints (approximately 7000 ft [2130 m]) had failed (Fig. 1). Joint sealants between precast and cast-in-place concrete elements had also deteriorated. The ingress of water through the joints not only created a serviceability problem but also left the anchorages of the slab post-tensioning vulnerable to corrosion.

Throughout the parking structure, selected areas exhibited undesirable construction practices as evidenced by exposed reinforcement (both conventional steel and post-tensioned tendons) and poor concrete surface grading and drainage. Chloride contents were generally between 200 to 300 ppm, which suggested chloride ingress from environmental exposure and the likelihood of continued exposure without mitigation. Surface-penetrating radar was used to verify as-built reinforcement distribution and post-tensioning trajectories.

Prior to the investigation, it was reported that some of the slab post-tensioning had failed and erupted from the concrete surface. These areas had since been repaired. However, it was a primary concern to verify the condition of the post-tensioned tendons in the slab. Invasive probing was

Fig. 1: Expansion joint failure

performed at select locations, which revealed the tendons to be in generally good condition. Significant levels of deterioration were only observed when the tendons were exposed and their sheathing was compromised. Additional tendon failures occurred between the investigation and repair phases (Fig. 2). Corrosion testing did not indicate a significant level of corrosion activity where deterioration was not present. The slab had not, in general, experienced widespread corrosion of the embedded steel reinforcement, including the post-tensioned tendons.

The bridge structures, which link the main parking structure to the entrance and exit helixes, were identified as a potential safety concern by the engineering consultant and were immediately shored as a result. The investigation revealed some progressive deterioration of these structural elements, evidenced by significant cracking in both transverse and longitudinal directions on each face (Fig. 3). Additionally, the precast hollow-core concrete slab units that were supported by the girders were experiencing significant deterioration evidenced by cracking, efflorescence, and failure of prestressing strands.

Various columns, slab sections, and a limited number of beams throughout the structure were deteriorating as a result of limited concrete cover and corrosion. Some of this deterioration had resulted in concrete spalling and delamination. Limited structural cracking was also discovered in elements that were significantly loaded. The cracking was isolated to bridge corbels and columns around the bridge structures, where slight deficiencies in the structural capacities of those elements were determined.

Fig. 2: Post-tensioned tendon failure

Fig. 3: Deteriorated bridge beam (inside face)

REPAIR CONSTRUCTION

Based on the results of the investigation, it was determined that the parking structure could be rehabilitated and its service life extended for less than 20% of the cost of replacement. The economy dictated that the parking structure repair be performed in phases while in service to accommodate the heavy demands for parking and maintain a revenue stream. The structural rehabilitation focused primarily on minimizing further water and chloride infiltration into the concrete and post-tensioning system to inhibit future corrosion. The principal components of repair included repair of concrete deterioration, installation of a traffic-bearing multiple-layer epoxy overlay, replacement of expansion joint seals, replacement of damaged post-tensioned tendons, strengthening of select concrete elements incorporating the use of fiber-reinforced polymers, and bridge replacement.

Construction was divided into eight phases, incorporating all elevated levels of the parking structure in each phase so that operation of the structure could continue. At the beginning of each phase, general concrete repair was performed within the slabs to provide a satisfactory substrate for the epoxy overlay and restore proper surface drainage. The concrete repairs consisted of removal of delaminated or unsound concrete, cleaning and zinc-priming of the conventional reinforcement, and replacement of concrete. Both full- and partial-depth repairs were performed, some of which required shoring. The repair areas were carefully excavated using small chipping hammers to minimize damage to post-tensioning components.

Concrete repair was also performed on deteriorated columns. Where column tie reinforcement was exposed, additional concrete cover was provided. Carbon fiber-reinforced polymer (CFRP) strips were used to provide additional confinement and capacity for select columns. Epoxy injection was performed on select cracks to restore integrity to the columns prior to CFRP strengthening.

Select concrete repair was also performed on deteriorated concrete that had an exposed aggregate finish. Although an exact match could not be made for the aggregate, the repair material was made to closely mimic the appearance of the surrounding concrete surfaces.

Broken post-tensioning tendons that were discovered during the investigation and repair were replaced by extracting the existing steel strands, pushing new strands through the existing sheathing, and stressing the strands.

Expansion joint seals were replaced throughout the structure and incorporated the use of prefabricated, compartmentalized, elastomeric joint seals with integral flanges (Fig. 4). The flanges were bonded to the adjacent concrete using an elastomeric concrete header material, providing a robust expansion joint system. Prior to installation of expansion joint seals, extensive concrete repair was performed at the edges of the joints, which included reconditioning and select relocation of corroded post-tensioning anchorages.

Leakage mitigation was also accomplished by replacement of damaged drains and cleaning of the remaining existing drains. Additional drains and concrete overlays were also added in select areas to promote better water drainage. All joint sealants were replaced.

To reestablish concrete cover and provide added protection for the post-tensioning components, a low-permeability multiple-layer epoxy overlay was installed (approximately 1 million ft^2 [92,900 m^2]). For this particular application, the epoxy overlay (Fig. 5 and 6) was a cost-effective, impermeable, robust overlay with an extended service life in comparison to other coating systems, such as concrete sealers and elastomeric membranes. To provide additional leakage protection for the interior space below a portion of the second level, a hybrid urethane/epoxy waterproof overlay system was provided in this area.

As a result of the extensive deterioration discovered during the investigation, the bridges connecting the main parking structure to the helixes were replaced. The bridges were generally replaced in kind, except that solid prestressed slab units were used instead of hollow-core slab units. The new bridges were sandblasted to achieve a uniform, exposed aggregate surface finish similar to the existing, adjacent precast concrete façade panels.

PROJECT SUCCESS

The parking structure rehabilitation was completed over a 23-month period, ending November 2012. The project was performed ahead of schedule and for approximately $10 million, which was under the construction budget. Based on service life modeling, it is estimated that the service life of the structure was extended by 25 years, eliminating the need for costly, wasteful replacement of the parking structure.

Houston Hobby Airport Parking Structure

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Houston Airport System
Houston, TX

PROJECT ENGINEER/DESIGNER
Whitlock Dalrymple Poston & Associates, Inc.
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REPAIR CONTRACTOR
United Restoration & Preservation, Inc.
Houston, TX

MATERIAL SUPPLIERS/MANUFACTURERS
The Euclid Chemical Company
Cleveland, OH

Lymtal International, Inc.
Lake Orion, MI

Fig. 4: Replacement expansion joint (epoxy overlay on right; existing concrete slab on left)

Fig. 5: Epoxy overlay installation

Fig. 6: Epoxy overlay