

FINALIST - 2017 PROJECT OF THE YEAR

PARKING STRUCTURES CATEGORY

Harvard Towers Parking Garage Concrete Repair and Waterproofing

CAMBRIDGE, MA

SUBMITTED BY SIMPSON GUMPERTZ & HEGER, INC.

The Harvard Towers parking garage located in Cambridge, Massachusetts, is a two-level below-grade cast-in-place (CIP) concrete structure built around 1962, with an overall footprint of about 16,000 sf (1490 sm) that holds approximately 200 vehicles. The northern portion of the garage is located below a ten-story apartment building and the southern portion is located below a plaza at street level. The lower and upper parking levels are identified as Level G2 and Level G1, respectively, with the ceiling of Level G1 identified as the Plaza Level.



Fig. 1: Concrete deterioration at existing concrete joist.

The elevated decks (Level G1 and Plaza Level) consist of three-span CIP concrete pan-joint systems. Each pan-joint system is comprised of 3 in (76 mm) thick slabs on 12 in (305 mm) deep joists at 25 in (635 mm) on center, supported by two lines of CIP concrete beams and a CIP concrete foundation wall. The lowest parking level (Level G2) is a 5 in (127 mm) thick CIP concrete slab-on-grade.

The parking garage underwent concrete repairs in previous years. In general, the repairs involved repair of beams and joists on Level G1 and the Plaza Level, and placement of a 1 in (25 mm) thick concrete topping slab over the entire surface of Level G1. The majority of these repairs had failed. The elevated parking decks exhibited numerous signs of distress and deterioration to varying degrees including cracked, delaminated, and/or spalled concrete on the topside and underside of the slabs, joists, and beams; delaminated and/or spalled concrete on the columns and walls; failed previous concrete repairs; debonded topping slab at Level G1; and active leakage through the foundation walls.

CONDITION ASSESSMENT

A condition assessment of the parking garage structure was performed to identify the extent and causes of deterioration, and to identify alternatives for remedial work intended to repair existing deterioration. Readily accessible portions of the parking garage structure were visually surveyed and sounded to document the types and approximate extent of deterioration and distress. Exploratory openings were made on the Level G1 topping to observe hidden conditions.

The parking garage had been exposed to chlorides for more than 50 years by significant quantities of deicing salts brought into the garage by vehicles. This exposure caused corrosion of the embedded steel reinforcement, and subsequent delamination and spalling of the concrete. Findings included the following:

- Concrete deterioration in the slabs and joists of the pan-joint system of Level G1 and Plaza Level was widespread and severe in several instances (Fig. 1 and 2). Approximately 90

percent of the surveyed slabs and joists showed signs of moderate to severe concrete deterioration or distress, mostly at previous repairs;

- The thin concrete topping on Level G1 was debonded from the original concrete slab, allowing moisture infiltration to the underlying structural elements; and
- Damage in the concrete columns, beams, and foundation walls was localized. Previous repairs to the foundation walls had failed with some showing active leakage.

REMEDIAL WORK

Repair System Selection

Based on the results of the condition assessment, and considering the widespread concrete deterioration observed at Level G1, several remedial alternatives for concrete repairs of that level were identified and included replacing the Level G1 slab and performing conventional concrete repairs on the remaining joists and beams at that level (Alternative 1); replacing the Level G1 pan-joist system (slabs and joists, leaving the beams) with a new pan-joist system (Alternative 2); and a combination of the first two, with full pan-joist system replacement occurring only at the drive lanes (Alternative 3).

Based on the construction cost estimates and expected service life of the repairs, the Owner decided to proceed with Alternative 2. The general scope of the remedial work involved the following:

- Replacing the entire Level G1 pan-joist system (leaving the beams) with a new pan-joist system;
- Performing conventional concrete repairs at the beams at Level G1, at the Plaza Level pan-joist system, and at the columns and walls at Level G2 and G1; and
- Installing a new vehicular-traffic-bearing waterproofing (VTBW) system on Level G1 and a new plaza waterproofing system on the Plaza Level.

Temporary Lateral Bracing of the Existing Structure

Removal and replacement of the Level G1 deck created a big challenge for the construction process, since the existing deck provided lateral bracing to the existing foundation walls supporting lateral soil loads, and to the existing columns supporting gravity loads from the Plaza Level and building above.

To reduce the number of lateral braces required, and minimize impact on construction activities, a cost-effective temporary lateral bracing system was developed that required demolition and reconstruction of Level G1 in two phases to utilize portions of the existing and then new deck structures as reaction and load transfer elements, as described below:



Fig. 2: Concrete deterioration at existing concrete beam.

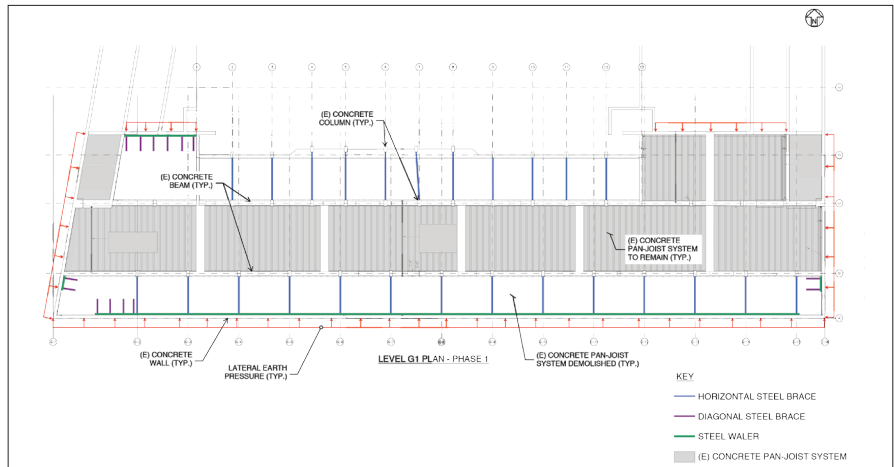


Fig. 3: Phase 1 Demolition and Temporary Lateral Bracing Plan for Level G1



Fig. 4: Demolition and temporary lateral bracing in Phase 1

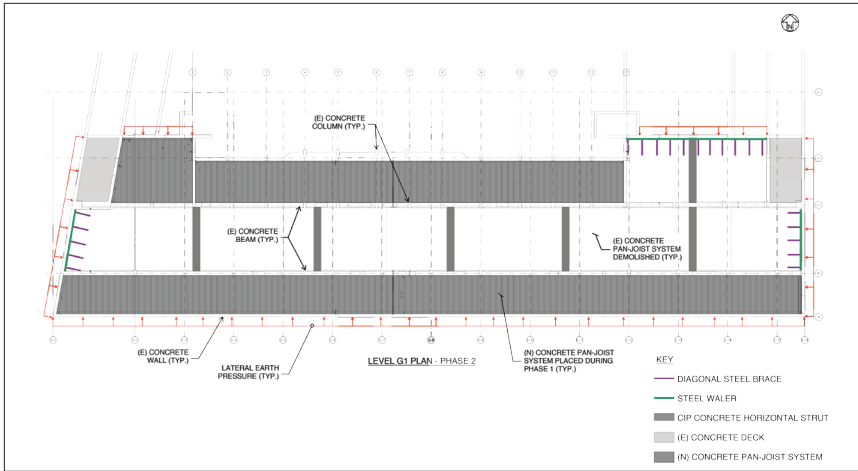


Fig. 5: Phase 2 Demolition and Temporary Lateral Bracing Plan for Level G1

Phase 1 (Fig. 3 and 4)

- Install Phase 1 lateral bracing system, comprised of horizontal steel walers along the foundation wall, horizontal steel struts bracing the walls and columns, and diagonal steel braces at the garage corners;
- Demolish the outer two spans of Level G1 (with the existing middle span of Level G1 remaining);
- Demolish strips within the middle span of Level G1 for construction of concrete struts (to be utilized during Phase 2); and
- Construct a new pan-joist system in the outer two spans of Level G1 and in the middle span at concrete strut locations.



Fig. 6: Demolition and temporary lateral bracing in Phase 2

Phase 2 (Fig. 5 and 6)

- Install Phase 2 lateral bracing system, comprised of horizontal steel walers along the foundation walls, and diagonal steel braces at the garage ends;
- Demolish the inner span of Level G1 (with the new outer spans and concrete struts at the inner span remaining); and
- Construct a new pan-joist system in the inner span of Level G1.

Demolition, Surface Preparation, and Concrete Repairs

Large heavy-duty sawcutting and jack-hammering machines were utilized to perform the large-scale demolition. The pan-joist system was sawcut along the beams and allowed to collapse to Level G2 below (Fig. 7). Chipping guns were utilized for most of the demolition detail work (Fig. 8). Hydrodemolition was utilized to remove the concrete from the topside of the existing beams.



Fig. 7: Large-scale demolition during Phase 2

A new reinforced concrete pan-joist system was designed for Level G1, connected to existing concrete elements (Fig. 9 and 10). Due to the phased demolition, continuity of the top steel reinforcement was provided at the topside of the existing beams to remain through use of form saver couplers and threaded steel bars.

Special surface preparation requirements were specified at existing concrete elements to remain (i.e., foundation walls and beams). In addition to dowels, all existing concrete in contact with new concrete was roughened and keyed to provide a “seat” for the new pan-joist system.



Fig. 8: Detail demolition during Phase 2

Structural Strengthening

During construction, it was discovered that one of the concrete beams supporting the Plaza Level had previously been cut for installation of a ramp at the front entrance to the building. Close to half of the top portion of the beam, including reinforcement, had been cut. In addition, two joists had been removed to allow installation of the ramp. The structural alteration made during this previous project resulted in the need for structural strengthening of the beam and adjacent joists.

The structural strengthening of the beam required concrete section enlargement with new shear reinforcement (“U” bars) and a

combination of longitudinal steel bars with externally bonded carbon fiber reinforced polymer (CFRP) laminates on the beam underside. The structural strengthening of the joists adjacent to the ramp involved joist section enlargement and CFRP laminates on the joist underside. CFRP laminates were not an option for shear strengthening because the structural inadequacy exceeded limits for the use of CFRP strengthening.

Waterproofing

To protect the new and existing concrete elements and reduce water intrusion to the new repairs on the underside surfaces and to the elements below, a VTBW system was installed on Level G1 (Fig. 11).

As part of the apartment building renovation project, the topside of the Plaza Level was developed and landscaped to include unit pavers and green roof plantings (Fig. 12). Below the new landscaping elements, a plaza waterproofing system was installed to reduce water intrusion and protect concrete elements below.

CONCLUSION

The Harvard Towers Parking Garage Repair project was unique in that it required extensive structural support to existing structural elements. The concrete repair procedures required the design and installation of temporary structural systems (lateral bracing) to provide support to existing structural elements (foundation walls and columns) during demolition and reconstruction of an entire elevated parking level.

Given the challenges of the repair and lateral bracing approaches, the owner, architect, engineer, and contractor worked closely throughout the project to identify efficient and effective solutions to the planned repairs and unforeseen conditions. ■



Fig. 11: Vehicular traffic-bearing waterproofing (VTBW) system installed on Level G1



Fig. 12: New landscaping on the Plaza Level topside)

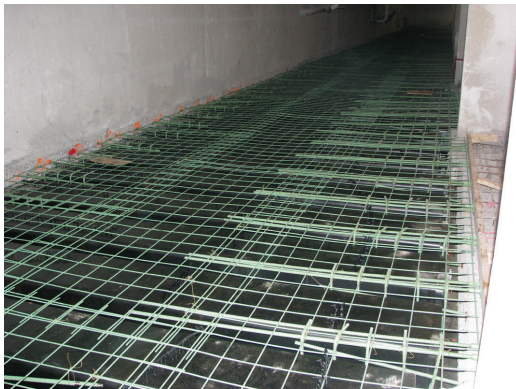


Fig. 9: Steel reinforcement for new pan-joist system (Phase 1)



Fig. 10: Steel reinforcement for new pan-joist system (Phase 2)

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SUBMITTED BY
Simpson Gumpertz & Heger, Inc.
Waltham, MA

OWNER
Blu Ridge Management
Boston, MA

PROJECT ENGINEER/DESIGNER
Simpson Gumpertz & Heger Inc.
Waltham, MA

REPAIR CONTRACTOR
Consigli Construction Co., Inc.
Boston, MA

MATERIALS SUPPLIER/MANUFACTURER
Aggregate Industries
Saugus, MA