# SUNY Health Science Center Brooklyn Parking Structure Strengthening

## Brooklyn, NY

## Submitted by Carl Walker, Inc.

The State University of New York (SUNY) Health Science Center Brooklyn Parking Structure is located in Brooklyn, NY. The structure serves as the parking facility for the adjacent medical complex. The structure has a total of 10 levels, three levels below grade and seven above, each with a plan area of approximately 125 x 246 ft (38 x 75 m) totaling 360,000 ft$^2$ (33,445 m$^2$) of parking. The garage has space for 933 vehicles and was constructed in 1967.

The structural system is a cast-in-place, reinforced concrete moment frame consisting of spread footings, columns, walls, girders, and waffle slab. The floor was designed with and construction drawings show a one-way joist/slab supported by beams having the same depth. During construction, however, a change was made to the floor layout. In place of a one-way rib pan system, a dome pan was used that created a waffle floor slab appearance.

Immediately following the completion of construction, a structural crack developed perpendicular to the one-way joists. The crack occurred on all supported levels of the structure at approximately 7 to 8 ft (2.1 to 2.4 m) from the center of the 72 in. (1830 mm) wide columns in the main spans. Investigation of the cause of the crack revealed that a major structural error in the design/construction had occurred. A substantial amount of the negative bending reinforcing steel was not developed sufficiently past the column supports. Upon realization of the error, the garage was shored full height, and approximately 1 year later, a corrective solution was agreed upon and implemented.

The corrective solution consisted of adding a reinforced concrete topping over the center level area and ramps for a width of approximately 26 ft (8 m) on each side of the center concrete walls. The concrete topping slab was designed under the assumption that it would be fully bonded to the original structural slab, and that the new composite section would be resisting the dead and live loads. The added concrete topping varied between 5 and 7 in. (127 and 178 mm) in thickness and added a significant amount of additional dead weight to the structure.

## Problems That Prompted Repair

Over time, the parking structure was found to be in moderate-to-poor condition due to corrosion damage from deicing salts. Much of the waterproofing system and expansion joints were failing. Many beams and columns were spalled from corrosion damage. The structural concrete topping was debonding in large areas.

By 2004, the concrete overlay was experiencing severe corrosion-related deterioration and further debonding of the topping. Repairs were designed and implemented that involved repair of corrosion-induced delaminations in the overlay, pinning of the overlay to the structural slab, and potential injection of a new bonding agent to reestablish the bond between the overlay and the structural slab. Hydro-demolition methods that were being used for removal at spot repairs were found to be further debonding the original concrete overlay. These and other problems during construction and large cost overruns prompted SUNY to stop work on the construction project and seek another opinion prior to continuing with the current repair program. It was at this time that the current team was brought in and began to work on this project.

Parking structure documentation and previous calculations were reviewed and additional structural calculations to verify existing structural capacity were performed. Site evaluation was completed to assess the deterioration and debonding of the structural concrete overlay. Representative areas were mechanically sounded to identify and quantify delaminations and debonding. The quality of past and current repairs to the overlay using similar mechanical sounding techniques was also reviewed.

Exploratory excavations and core sampling for the purpose of determining bond characteristics between the overlay and original slab were completed.

Five core locations and three 2 ft (0.6 m) square excavation locations were completed and were used to corroborate the results of the sounding survey. At the core locations, it was apparent that debonding of the topping was occurring and the bonding agent used in the original concrete overlay was no longer effective.

The 6 in. (15 cm) thick concrete overlay located along the interior columns was found to be in poor condition. Numerous areas were observed where the top surface of the concrete had spalled off, leaving reinforcing steel exposed. Open spalls in the overlay area lead to further deterioration and created potential tripping hazards for patrons using the garage structure. It is also evident that in many locations, the concrete overlay was no longer bonded to the structural system below, raising doubts about the effectiveness of the strengthening retrofit. Based on the survey of representative areas on each level, it was estimated that on some levels as much as 70 to 80% of the overlay was either debonded or delaminated.

Surface cracking indicating delaminations/deterioration of embedded reinforcement was present on the slab surface on all supported levels of the parking structure. Existing cracks and construction joints in the structural slab no longer had effective sealants in them, allowing water to penetrate through cracks and deteriorate the existing concrete and embedded reinforcing steel.

The underside of the waffle slab system was also in poor condition. Many overhead delaminations were noted along waffle ribs, especially along the construction joints. Overhead deterioration and spalls had also occurred at many of the hanger locations for mechanical, electrical, plumbing, and fire-protection systems.

*Deteriorated concrete overlay with trip hazard*

*Load test of trial strengthening area*

## Repair Process Selection

It was very clear that it was not in the University's economic interest to continue repairing a 30+-year-old concrete overlay that was saturated with chlorides, debonded in many areas, and served to be a better liability trip hazard than a structural concrete overlay. The original design/construction defect, however, still needed to be addressed to maintain the safety of the structure.

The design team investigated the use of fiber-reinforced polymers (FRP) to be used for strengthening. The fiber reinforcing would be surface applied or installed in slots cut into the concrete and provide added top reinforcing to bridge across the original structural crack, carrying the tensile reinforcing to the proper length according to the loading conditions. For this repair system to be successful, a structural analysis was completed to verify that the existing floor in its deteriorated state could sufficiently carry unfactored dead and live loads without the FRP should a fire occur, or extreme wear/abrasion over time cause damage. It was also determined that two test areas would be completed and load testing of the structure after strengthening be completed to verify capacity. The trial areas and load testing were completed successfully with the final repair program being bid out after 1 year of successful in-place performance.

In the design stage, it was determined that cutting slots and installing FRP bars was a good solution, the limited cover on the reinforcing steel created a concern of cutting steel. Therefore, the final repair system selected was to shore the floor, remove the concrete overlay, epoxy-inject cracks, apply carbon FRP on the top side of the slab, then install an extra layer of epoxy resin and a urethane traffic bearing membrane.

## Repair System Execution

Prior to installation of the FRP strengthening materials, the existing concrete surface was patched in areas of divots, spalls, and the structure long notch created in the slab to tie in the original overlay. The floor surface was shotblasted prior to FRP installation. The main existing crack was epoxy injected.

*Full-depth concrete repairs*

*Final surface with vehicular traffic bearing membrane*

*FRP strengthening*

*SUNY Health Science Center Brooklyn Parking Structure*

The surface was primed and then two layers of carbon FRP were installed. A saturator was used to saturate the fabric prior to being applied. To provide a durable wear-resistant protection for the structural FRP, an extra layer of epoxy resin was installed on top of the second layer of FRP. A urethane traffic bearing membrane was then installed over the entire area and adjacent unstrengthened concrete areas to provide a uniform and waterproof coating.

## Special Features

The use of carbon FRP on this project is perhaps one of the largest top-side FRP strengthening applications in the U.S. The use of FRP was a very cost-effective repair method that eliminated a serious trip hazard liability, increased headroom in a low headroom clearance structure, and eliminated the risk of future repair costs on a chloride-filled concrete overlay adhered with a 30+-year-old bonding agent and some mechanical pins. All of the beneficial aspects of using FRP for strengthening were evident in the use of this repair technique. In total, 925 $ft^2$ (86 $m^2$) of concrete floor was strengthened with two layers of FRP.

The total restoration cost of the project was $1.9 million. This included the FRP strengthening, waterproofing, and significant concrete repairs on the topside and soffit of the structural system.

### SUNY Health Science Center Brooklyn Parking Structure

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