

FINALIST - 2018 PROJECT OF THE YEAR

LONGEVITY CATEGORY

Smithfield-Liberty Helix Ramp Rehabilitation

PITTSBURGH, PA

SUBMITTED BY CARL WALKER CONSTRUCTION, INC.



Fig. 1: Smithfield-Liberty Helix Ramp

The rehabilitation of the Smithfield-Liberty Parking Garage was undertaken in 1997 and, over 20 years later, the structure exhibits no additional deterioration (Fig. 1). Exposed to several hundred cars each day, this critical structure was rehabilitated using materials and methods designed and installed to provide a long-term service life. The success of the project is best evidenced by the fact that no additional structural repairs or rehabilitation have been required since the work was completed. The design and construction processes used to complete this project in the late 1990s is a testament to the longevity that the project has enjoyed. Based on its current state of performance, it is expected that the ramp will likely experience another 20-year extension of service life without the need for any significant attention.

HISTORY

Originally constructed in 1964, the helix ramp of the Smithfield-Liberty parking garage in downtown Pittsburgh, Pennsylvania, is six levels of post-tensioned concrete slab with perimeter knee walls

cantilevered from a conventionally reinforced concrete cylinder. The post-tensioning system for the structure is composed of solid bar reinforcing encased in a grouted conduit. The solid bars have plates at each end to provide compressive force transfer into the slab. The primary visible distress of the structure was exposed, corroding post-tensioned bar anchor plates at the perimeter of the ramp. This circular ramp provides the only means of exit from the top six levels of the attached seven-story parking structure, so it was decided that conventional rehabilitation project delivery methods would not work for this rehabilitation.

EVALUATION AND DIAGNOSIS

In late 1996, an evaluation of the helix ramp was performed to establish the cause of the observed distress in the structure. The evaluation included a condition assessment of the structure to record visible surface defects including cracks, spalling, and exposed corroding steel elements (Fig. 2); concrete material testing including petrographic analysis, concrete compressive strength testing, acid-soluble

chloride ion testing, and carbonation testing; corrosion testing, including electrical continuity testing, half-cell potential testing, corrosion rate testing, and reinforcing steel location and cover measurements; a review of existing structural drawings; and a thorough structural analysis.

After evaluating the results, the cause of the distress in the structure, consisting of delamination and spalling with exposed reinforcing steel, was determined and three primary causes for the observed distress were identified:

1. The distress recorded on the top of the ramp slabs was determined to be caused by high chloride ion levels in the lower five levels of the six-level ramp. On these levels, chloride contents exceeding the threshold amount necessary to induce corrosion of the reinforcing steel were found in the top 2.5 in (64 mm) of the slab.
2. The distress observed on the underside of the ramp slabs was caused by cracking at old repair areas in the top slab.
3. For the deterioration occurring on and below the concrete knee walls, insufficient concrete cover on the steel reinforcing and plates was identified as the cause of the distress.

SOLUTION ANALYSIS

Solutions were developed to address the causes of distress in consideration of alternative service life expectations.

Chloride Ion Content

To address the chloride ion content problem with the ramp slabs, removal and replacement of the top 2.5 to 3 in (64 to 76 mm) of the concrete floor slab was selected to offer a long-term service life expectation. This solution represented a potential structural problem, however, given that the slab was post-tensioned. Prior to being able to recommend that the top portion of the slab be removed, a structural analysis was necessary to determine the post-tensioned reinforcing forces on the original slab section, the reduced slab section (once the top portion of the slab was removed), and the final slab section (with the original slab and new topping slab). Upon completion of the analysis, it was determined that the top slab section could be removed if the perimeter of the ramp was shored and supplemental post-tensioned cables were added to the final cross-section (Fig. 3 and 4).

Supplemental Post-Tensioned Cables

The requirement for the supplemental post-tensioned cables influenced the decision to recommend a high quality conventional concrete material with a compressive strength of 6,000 psi (41 MPa) to closely match the existing concrete strength. In addition, the use of a shrinkage-compensating admixture was recommended to minimize cracking in the new topping slab.

Underside Slab Condition and Water Infiltration Problems

To address the underside slab condition and water infiltration problems, conventional partial-area repairs were recommended



Fig. 2: Original slab edge deterioration

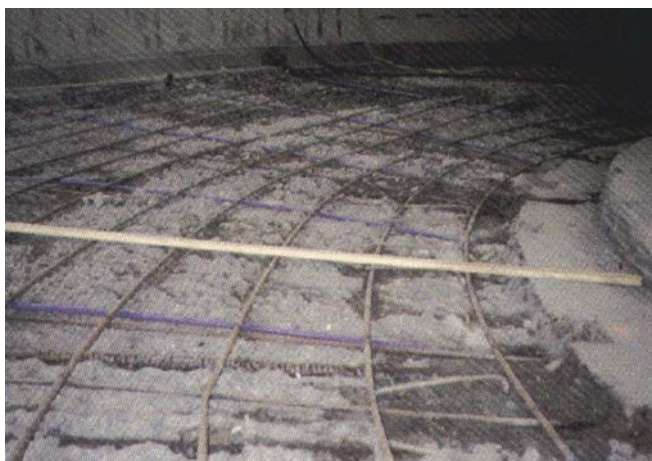


Fig. 3: Demolished ramp slab surface with supplemental post-tensioning cables installed throughout central cylinder

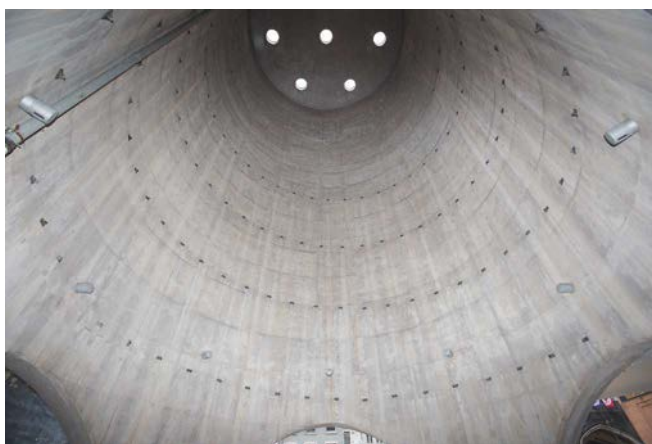


Fig. 4: Exposed post-tensioned tendon anchor heads at central cylinder

in conjunction with the application of a hybrid polyurethane fluid-applied membrane with epoxy wear course and specialized aggregate on the ramp top surface. The repair material recommended for the underside slab repairs was a polymer-modified cementitious material to facilitate use of the form-and-pump repair technique (Fig. 5 and 6). The repair material was selected to have compressive stiffness characteristics that closely matched that of the existing concrete. This was necessary to provide uniform compressive stress distribution throughout



Fig. 5: Slab edge soffit demolition and formwork



Fig. 6: Slab edge formwork and shoring



Fig. 7. Completed slab soffit repair with integral drip edge

the concrete slab when stressing supplemental post-tensioned reinforcement.

Concrete Cover Issues

To address the concrete cover problem on the post-tensioned reinforcing anchor plates on the perimeter of the ramp, a new concrete cap was installed to provide suitable cover for the plates. In addition, a drip edge was provided to prevent water from running down the underside of the ramps (Fig. 7). Although this repair detail reduced the depth of the reveal at the slab perimeter, the architectural appearance of the ramp was not significantly changed. To address the concrete cover problem on the existing reinforcing steel in the knee walls (Fig. 8), the repair areas were slightly over-built to obtain suitable concrete cover on the reinforcing steel.

REHABILITATION

The repair solutions described above were incorporated into the contract documents and issued for bidding by experienced repair contractors. The successful bidder was awarded the contract in the summer of 1997 and the work was immediately scheduled to be completed in under 10 weeks during the summer to coincide with the garage's off-peak season.

Garage Ergonomics

Prior to beginning repairs, the traffic in the garage required re-routing as the helix was the only means of exit for the upper levels of the garage and closing the garage was not an option. After considering alternate scenarios to solve this dilemma, a solution was developed to convert the one-way traffic flow into two-way traffic. To accommodate the two-way traffic on the upper six levels, turn around areas were established on alternating levels to facilitate cars changing direction. Although the turnaround areas resulted in a reduction in parking spaces, the traffic flow was not significantly hampered and the disruption to patrons was minimized.

Fast-Tracked Construction

Once parking traffic was re-routed, the helix ramp was closed, and construction commenced. Given the aggressive construction schedule and limited work area, methods to expedite the repair process were implemented. The primary time-saving measure utilized during the rehabilitation was hydrodemolition, which is a process utilizing water under very high pressure (about 10,000 psi [69 MPa]) to demolish concrete (Fig. 9). This method was used in lieu of conventional jackhammers to remove the top section of chloride-contaminated concrete on the ramp slabs and resulted in significant time savings.

Completion

Following industry standard concrete repair practices and incorporating state-of-the-art materials, the rehabilitation of the ramp was completed on schedule. One of the most important reasons for the success of the project was that the process involved experienced parties for identifying and addressing the causes of the distress in the structure and developing and implementing a repair approach aimed at providing a long-term service life extension.



Fig. 8: Knee wall vertical repair demolition



Fig. 9: Hydrodemolition of upper concrete layer at ramp slab

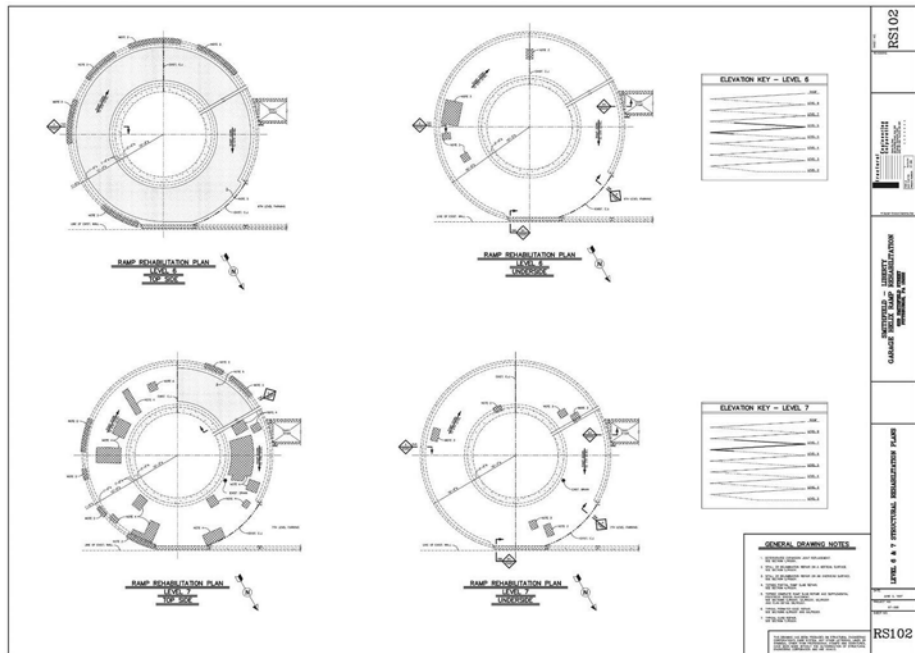
PAST, PRESENT & FUTURE

Prior to implementing the rehabilitation described above, a previous repair of the helix ramp had been undertaken. Partial-area repairs completed during that project were found to be deteriorated at the time of the condition assessment performed in 1996.

Given this situation, the concern becomes whether past repair methods and materials addressed the cause(s) of the distress in the structure. Unfortunately, past evaluation and testing techniques fall short of the standards today. The lack of specialized knowledge about the corrosion process and practice of engaging an inexperienced contractor are primary reasons that past repairs are more prone to premature failure than repairs completed today.

Today, knowledge in the field of concrete structures and corrosion mechanisms is steadily growing through experience and research. Experienced contractors are more prevalent, as are experienced engineers and material specialists. Present day materials and products are being produced to provide a higher quality product. It is expected that these trends toward more specialized experience and product quality will continue.

Although it is difficult to predict the future of concrete rehabilitation, the continued expansion of knowledge and experience in the field is all but guaranteed. Continued research should expand the understanding of the corrosion process and corrosion control mechanisms. This, in turn, will lead to the development of materials and products that can better control the corrosion process and facilitate longer lasting concrete repairs. ■



Project Drawing

Smithfield-Liberty Helix Ramp Rehabilitation

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