Shotcrete Repair of Auditorium Plaza Garage

by Mike Land and Richard R. McGuire

The Auditorium Plaza Garage (APG) is the largest municipal parking structure in downtown Kansas City, MO. Constructed in 1954 and designed by Structural Engineering Associates, Inc. (SEA), of Kansas City, MO, this large, three-level garage occupies an entire city block, with a parking capacity of approximately 1000 spaces. Located opposite the Bartle Hall Convention Center complex, it is convenient for several hotels and commercial office buildings. The reinforced concrete structure consists of two framed/elevated slab levels, with a lower level that is a slab-on-ground. The APG has over 280,000 ft^2 (26,020 m^2) of supported/framed slab area, excluding the roof slab.

SEA was retained by the City of Kansas City to perform a structural condition study of the parking structure in 2001. The outcome of that comprehensive assessment and testing prompted the need to address the severe corrosion of the slab, soffit, columns, and walls that had occurred since the last major repair project in 1984. Additionally, the garage exhibited moderate to severe leaking of the under-street tunnels, a poorly-lit and deteriorated interior pedestrian walkway that connected the garage to the tunnels and buildings beyond, and the need for repairs and waterproofing to the large water feature above the garage and facing Twelfth Street. There were also a myriad of nonstructural repairs and needs for improvements, which included lighting, electrical service, a new garage revenue control system, repairs to slab drainage, signage, wayfinding, and ADA accessibility.

The structural concrete parking level slabs are four-way reinforcing, flat-slab construction, with column capitols and drop heads/panels. These slabs are 10.5 in. (267 mm) thick and have a nominal 2 in. (50 mm) latex-modified topping slab that was added in 1984 to provide a further level of protection to the structural slabs in the parking levels. There are also three reinforced concrete tunnels that connect the APG with three large hotels on the north and east side of the garage, and on the south side with the City's Municipal Auditorium facility. All of these tunnels are under major city streets that receive numerous applications of deicing salts during the rough, unpredictable winter weather that strikes Kansas City every year.

Auditorium Plaza Garage

During the preparation of the condition study, forensics testing of the structural slabs and soffits was performed and included chloride-ion content (ppm) at three depths to evaluate the corrosion threshold levels at various locations on framed levels; electrochemical (half-cell) potential testing of the reinforcing steel in selected, high-delamination areas; and 3 in. (75 mm) diameter concrete core samples to examine whether the larger delamination areas of the slabs were due to corrosion of the embedded steel or debondment between the latex-modified topping/overlay slab, and the underlying structural slab. These test results, coupled with the condition surveys and analysis, led the City of Kansas City to move forward with the preparation of the construction documents, which were completed in early 2005.

The APG Repairs and Improvements project was bid in May 2005, and was initially budgeted for approximately $4.1 million. The majority of the project budget was targeted for structural repairs and restoration, and included architectural, electrical, civil, and parking revenue control improvements. Work commenced in June 2005, and the general contractor, Kraus-Anderson Construction Co., Inc., and the repair contractors, soon realized the many challenges that were ahead in phasing extensive soffit and slab repairs while maintaining garage operations.

In February of 2006, Mid-Co Contractors, Inc., proceeded with the contract to perform the dry-process shotcrete repairs to the soffit. The first order of business was to determine the phasing and traffic control during repairs, as the city required the garage remain in service at all times. It was agreed that the best approach would be to section off approximately one quarter or quadrant of each floor per phase. This required a high level of automobile and pedestrian protection around the work zone from dust exposure, flying debris, and exhaust fumes. This proved to be a difficult task because two of the parking levels were below grade. Mid-Co installed curtains at the work zone perimeter, sealed at the ceiling and floor. The curtain had two lines of protection. The outer layer was reinforced poly and the inner layer was a heavy filter fabric. The filter fabric was misted with water on a regular basis to help attract the concrete dust. The double-layer curtain would also ensure that flying debris would not penetrate the work zone. Large exhaust ducts were built on site and routed up to the surface of the garage through stairwells or ventilator shafts. Next to the exhaust ducts were flexible, heat-resistant exhaust lines that were attached to the exhaust pipes of the air compressors and generators to safely remove carbon dioxide fumes from the work site.

Next, Mid-Co determined the most efficient concrete removal method would be hydrodemolition, because the average depth of the soffit repairs was 5 in. (127 mm). The hydrodemolition machine could remove concrete as quickly as a 20-person crew hand chipping. This would also help reduce worker fatigue and injuries. Concrete demolition work took place during the night shift, with crews for cleanup and water control. The existing floor drains were closed off using air bladders. The water produced from the hydrodemolition machine was directed to pumping stations, where the water was filtered before being pumped down the existing drain lines. The day crew concentrated on detail chipping operations around sprinkler lines, electrical conduits, and edges that were closer than 18 in. (457 mm) from walls and column capitals. The detail chipping crew was also responsible for inspecting and removing any concrete that was less than 1 in. (25 mm) around the perimeter of existing reinforcement steel and buried conduits.

After the concrete was removed and the detail chipping complete, the repair areas were sandblasted with an emphasis on the heavily rusted reinforcement steel. The repair specifications called for a protective corrosion-inhibiting coating applied to all exposed steel, along with the installation of 13,500 galvanic anodes at 18 in. (457 mm) on centers. This is a great repair for reinforcing steel to slow down the deterioration process and extend the useful life of the structure. This presented a couple of technical challenges for the crew. The galvanic anodes had to be attached by small wires to the structural steel to exert a slight electrical charge on reinforcing steel to be effective. The corrosion coating was an epoxy and would negate this electrical connection if applied before or on top of the anode wires. The crews had to predetermine all locations for anodes and mask off the connection locations before shooting the corrosion coating. After installing the anodes, the electrical charges were verified using voltage meters.

Prepared repair area with galvanic anodes

Dry-process shotcrete during placement overhead

The last step in the process was to install the shotcrete. The original specifications called for dry-process shotcrete using a prepackaged bag repair material. After reviewing the data sheets for these materials with the structural engineer, it was determined that most of the prepackaged bag materials have a silica fume admixture in them. Manufacturer's testing has shown that the presence of silica fume in the repair material increases resistance to the electrical current of the galvanic anodes. Mid-Co proposed an old-fashioned time-proven mixture design consisting of the bare essentials—portland cement and sand aggregate. The design was mixed at a ratio of four parts sand to one part portland cement by mass. This would meet or exceed the engineer's design criteria for compressive strength. Core testing of shotcrete panels verified the test results. Shotcrete test panels were shot every morning before production shooting for testing and documentation of shotcrete quality.

Typically, this type of mixture design is blended on site. With the hydrodemolition operations ongoing during the night shift, however, the humidity in the air would prematurely hydrate the portland cement. It was decided to store the materials in 3000 lb (1360 kg) bags on pallets. These bags were tightly sealed with plastic wrap to eliminate moisture contact with the portland cement. Mid-Co mixed the materials in mortar mixers and predampened the materials by hand spray. While it would have been nice to use more sophisticated equipment and predampers, Mid-Co had to eliminate as much equipment as possible due to fumes and working space.

Two shotcrete crews were mobilized to perform the work. The crews were led by ACI certified nozzlemen. The owner and engineer were reassured that the quality of work and their investment was in good hands because certified nozzlemen were performing the work. Mid-Co also enlisted the services of Ray Schallom, an ASA certified shotcrete instructor and ACI examiner to review the on-site conditions and provide training to the crews. Mid-Co took this opportunity to hold classes for additional crew members that were ready to be certified. The owner and engineer were invited to be a part of the training classes to further their knowledge of the shotcrete process.

Mid-Co installed approximately 150 tons (136 tonnes) of dry-process shotcrete overhead into an area of approximately 20,450 ft^2 (1900 m^2). The patching consisted of over 600 separate locations, and was spread out over 12 different quadrants. Some of the patches were over 500 ft^2 (46 m^2) each, and required the shotcrete nozzlemen to shoot two and three patches at a time. This would allow the finishers enough time to screed and finish the bigger patches in phases. The shotcrete was finished with rubber floats to achieve the desired finish. The final application of the process was to apply a curing agent over the repaired areas.

The shotcrete remedial works were successfully completed and the shotcrete repairs will definitely extend the useful life of this parking structure for many years to come. Fortunately, shotcrete made the repairs possible and the project successful.

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