Norick State Fair Arena Structural Repairs

Oklahoma State Fair, Inc., Oklahoma City, OK

By Dean Brunken

Norick State Fair Arena is a multipurpose arena located on the grounds of the Oklahoma State Fair in Oklahoma City, OK. Construction on the arena was completed in 1965. The structure is elliptically shaped, 70 ft (21 m) high, 402 ft (123 m) long, and 318 ft (97 m) wide. The arena exterior was constructed with 42 monumental concrete columns that support a massive concrete ring beam. The ring beam anchors a unique and innovative cable net and precast concrete panel roof system that was designed by T.Y. Lin and Associates at a time when the technology for the design and construction of large cable net structures was in its infancy. The arena has had two major improvement projects that included repositioning and expanding the entrance, adding a 28,000 ft^2 (2600 m^2) exhibit hall, adding an additional handicap ramp, new arena lighting, and a new four-sided scoreboard with four color video screens and sound system.

The arena hosted the National Finals Rodeo from 1965 until 1978 and for over 40 years has hosted the Oklahoma State High School Basketball Championships. For those games, the arena is referred to as "The Big House."

Fig. 1: Cracking in monumental concrete column

PROBLEMS THAT PROMPTED REPAIR

During an examination of the roof structure in 2010, cracks were identified in the monumental concrete columns surrounding the arena. Because these concrete columns provide the main support for the roof structure, a structural engineer was consulted to investigate the cracking and make recommendations regarding the significance of the cracks and necessity of repairs.

INSPECTION/EVALUATION METHODS

A visual inspection of the structure and selective demolition at the lower level of the columns determined the source and anticipated extent of cracking and delamination in the concrete columns. Due to the lower-level structure surrounding the arena, all upper columns could not initially be evaluated. It was specified that during the repair contract the concrete columns would be acoustically sounded by the contractor to determine the extent of subsurface concrete delamination.

Fig. 2: Crack in monumental concrete column

TEST RESULTS/CAUSES OF DETERIORATION

After selective demolition and evaluation, the primary source of the concrete cracking was identified as corrosion of the embedded steel reinforcement in the concrete columns. The cause of the corrosion was determined to be due to a construction detail that allowed water to enter the concrete columns at upper levels and over time percolate through the steel reinforcement network, resulting in corrosion of the steel reinforcement and subsequent cracking and delamination of the concrete.

REPAIR SYSTEM SELECTION

The repair procedure selected by the design team required sounding the concrete columns prior to selective concrete removal to determine the extent of demolition required, followed by removal of all delaminated concrete. All aspects of the concrete repair work were specified to conform to ICRI 310.1R-2008, "Guide for Surface Preparation for the Repair of Deteriorated Concrete Resulting from Reinforcing Steel Corrosion."

Surface cracks were selected for epoxy injection if subsurface concrete delamination was not evident after sounding. Following removal of delaminated concrete, steel reinforcement was sandblasted and examined for adequate critical section. If an inadequate section was identified, additional steel reinforcement was added. The steel reinforcement was coated with an anticorrosion primer. A penetrating corrosion inhibitor was applied to the concrete surface, followed by the application of dry-mix, fiber-reinforced shotcrete.

All sealants in the structure were removed and replaced during construction. Following all structural repairs and sealant removal and replacement, a volatile organic compound (VOC)-compliant, 100% acrylic emulsion elastomeric coating was applied to all exterior surfaces of the arena and supported concrete ring beam to improve the aesthetic appearance of the arena and to mitigate water intrusion into the concrete structure.

SITE PREPARATION

The arena exterior is surrounded by lower roofed exhibit areas. The lower-level structures required the development of innovative scaffolding solutions to access and complete repairs. After using ground-penetrating radar (GPR) to locate embedded steel and post-tensioned steel bundles in the structure's concrete ring beam, holes were cored through the concrete ring beam to allow suspension of swing-stage scaffolding necessary for completing project repairs. All lower-level structures were protected by installing plywood protective measures.

DEMOLITION METHOD

Small electric and pneumatic hammers were used for concrete demolition to mitigate damage to surrounding sound concrete. After selective demolition to expose at least 1 in. (25 mm) around steel reinforcement, the limits of the

Fig. 3: Epoxy injection and removal of delaminated concrete of concrete columns

Fig. 4: Applying elastomeric coating to concrete ring beam

Fig. 5: Demolition of delaminated concrete

Fig. 6: Column section following demolition

repair were saw-cut to a depth of 0.75 in. (19 mm) to provide a defined area for repairs.

SURFACE PREPARATION

Structural steel was sandblasted to remove all rust and scale. All concrete surfaces were mechanically cleaned to obtain an exposed aggregate surface profile of ±0.0625 in. (2 mm). Concrete surfaces were cleaned and saturated to saturated surface-dry (SSD) conditions using high-pressure power washing immediately before shotcrete placement.

APPLICATION METHOD SELECTION

Dry-mix shotcrete was selected as the concrete repair method due to the depth, size, and location of the anticipated repairs. Dry-mix had significant advantage over form-and-pour in reducing time and formwork materials required for the project. Dry-mix shotcrete also provided increased consolidation of the concrete repair. Material test panels were produced daily to test for compressive strengths. Mockup panels were constructed to simulate the reinforcement within the columns and shot to qualify the materials, equipment, and nozzleman on the project. The design team

Fig. 7(a) and (b): Dry-mix shotcrete installation

allowed hand patching with a specified high-build repair mortar in areas 2 ft^2 (0.2 m^2) or smaller.

REPAIR PROCESS EXECUTION/ UNFORESEEN CONDITIONS

The repair process for this project required an "adapt and overcome" mentality. The arena remained open during construction and hosted many horse- and cattle-centered events. The horse and cattle were not too tolerant of the construction process and construction activities were constantly being juggled to minimize impact on the animals.

Early in the construction process it was determined that the extent of corrosion was greater than originally anticipated. Due to the large areas affected, the depth of concrete delamination, and the absence of critical steel section in the reinforcement, a new construction sequence was developed that limited the size of an area that could be repaired on an individual column and created an overall schedule that designated column location, area size, and sequencing of repairs. These changes dramatically affected the construction productivity, requiring many more mobilizations to complete repairs than originally anticipated and close coordination with the design team to monitor construction progress.

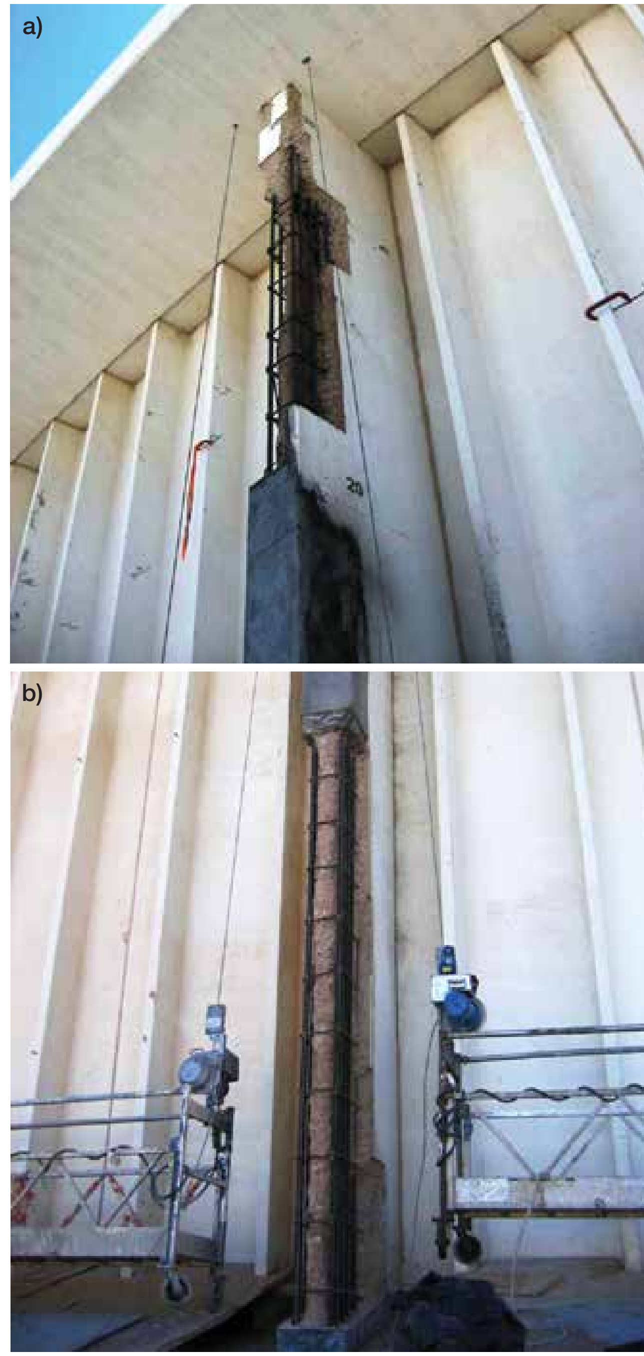


Fig. 8(a) and (b): Phasing structural column repairs. Note cored holes in upper ring beam to support our swing stages

Although the construction sequence was altered dramatically, all repairs were completed satisfactorily with minimum impact to the owner's operations and met the repair designer's objective of repairing the arena's structural problems.

Many projects can be completed with a construction schedule that requires minimal changes from original planning other than allowances for weather. This project required dramatic scheduling changes due to the unique construction environment that required working in close proximity to horses, cattle, and their owners.

The project also required the willingness to adapt to the challenge of dramatically changing construction requirements

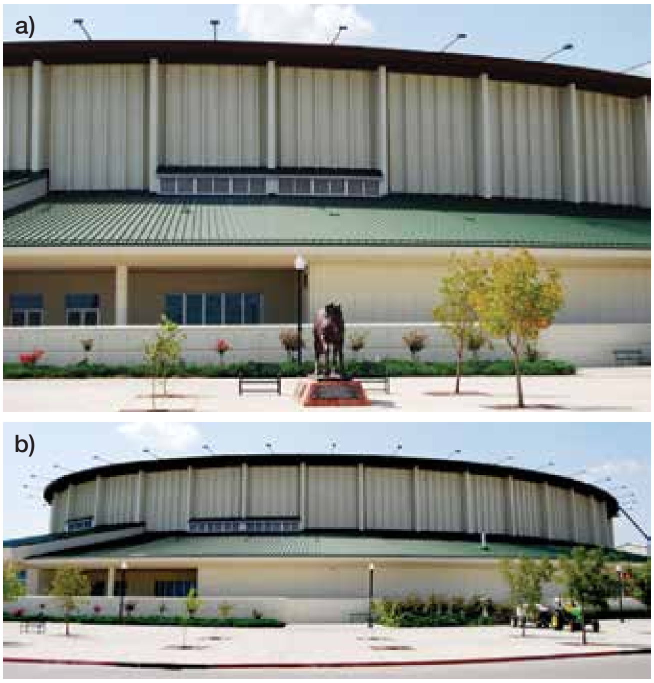
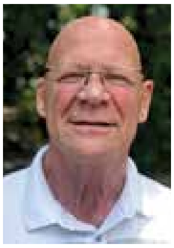


Fig. 9(a) and (b): Norick State Fair Arena repairs complete

that required balancing productivity with limited access to the structure.

This was an ideal project for shotcrete placement of the repair concrete. Shotcrete allowed the repairs to be accomplished with no formwork to erect or remove that made the work less expensive, more sustainable, and quicker. It also provided high-strength, low-permeability concrete that will likely be much more durable than the original concrete. Thus, shotcrete's quality, efficiency, and durability have helped to extend the service life of the arena for decades to come.



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