Chase Field Repairs

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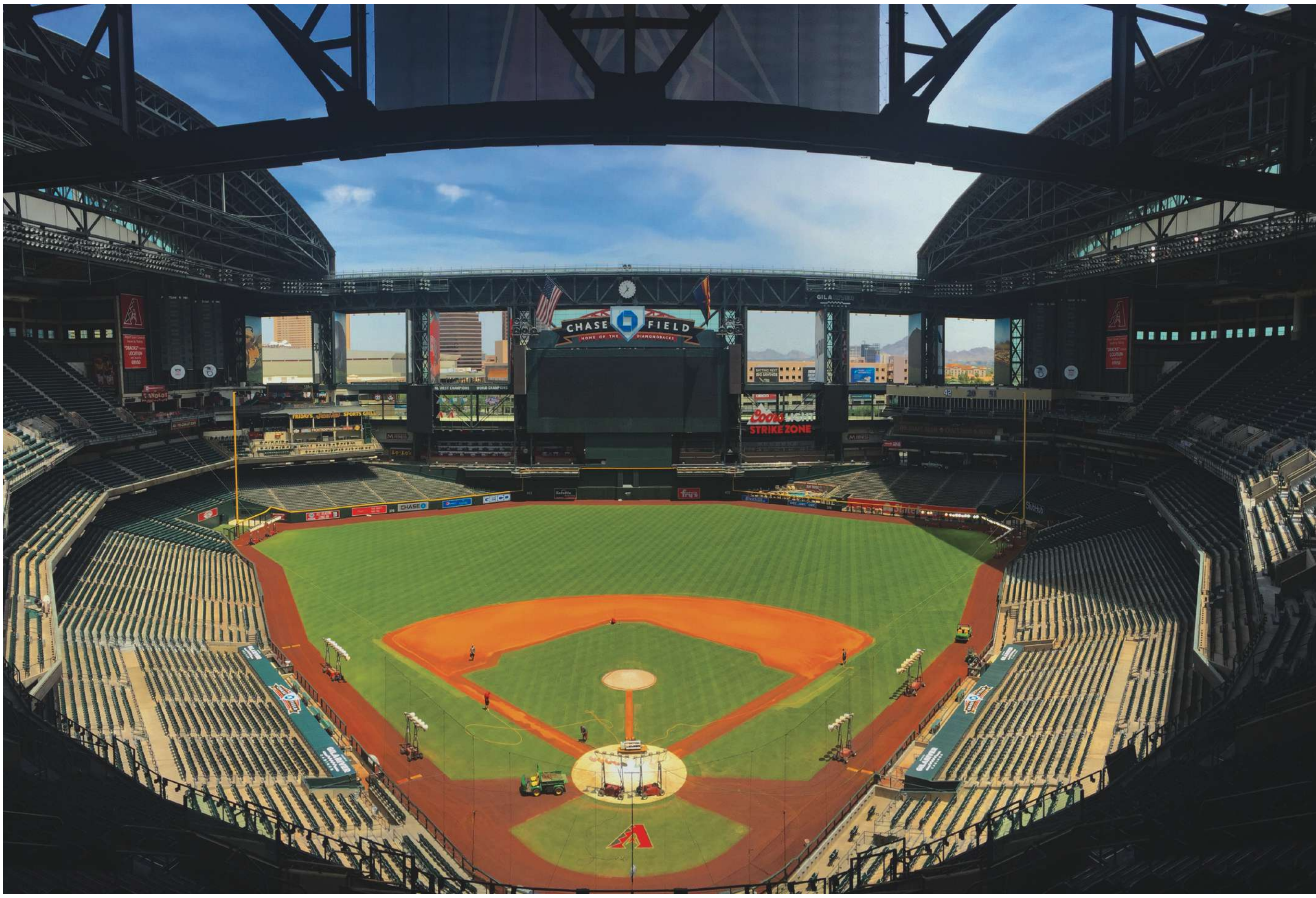

Fig. 1: Interior view of Chase Field

Chase Field (Fig. 1), owned by the Maricopa County Stadium District and managed and operated by the Arizona Diamondbacks Major League Baseball team, has undergone annual structural repair programs from 2011 through 2017. The vast majority of the repairs have been the result of corrosion damage due to frequent cleaning wash-downs after events during its 19-year existence since construction in 1998. The Stadium was built without any type of waterproof protective membrane in seating areas. However, an extensive gutter system, intended not to protect structural elements but to prevent nuisance water damage to ceilings/floors, was installed under the precast concrete joints. As a result, corrosion damage has occurred to the structure as water leaks through the joints, traveling across structural members before entering the gutters.

With a seating capacity of over 48,000, and 5½ acres (2.2 hectare) under the retractable roof, Chase Field is huge, and the damage that has occurred and repairs needed are not isolated to just a few areas. Because they occur throughout the stadium, the repair areas have been prioritized based on levels of deterioration. Because it is impossible to do this extent of repairs with the stadium "open for business," repairs have been performed during the off-season from October to April in localized areas over the last six years, focusing on repairing and protecting all items in that area. However, the off-season is not free of events either. Each year, several major events occur during the off-season, requiring the stadium to be fully operational. Therefore, repairs were phased so that they were complete and seats put back for the event, only to be torn apart the next day. The old saying, "How do you eat an elephant? One bite at a time," applies here. Each year, for the last six years, another piece of this elephant has been repaired.

Problems Prompting Repair

Over the last six years, corrosion-related concrete repairs and waterproofing protection have totaled over $16 milion. How could a stadium in the Phoenix desert require that much corrosion-related repairs? Moisture infiltration resulted in the corrosion damage to reinforcing steel (rebar), prestressing strands, embedded steel connection plates, structural steel members and their connections, and steel guardrails/handrails. In 2011, when the stadium was only 13 years old, a facility assessment identified corrosion-related damage to concrete and steel members and it has been under repair ever since.

The reason for the corrosion damage was not weather-related or atmospheric. Phoenix is in a hot, dry desert. Stadium cleaning methods include a thorough wash-down with pressure washers that caused severe corrosion damage from the following:

- Frequent wetting/drying cycles (over 100 cleanings per year);
- High temperatures (corrosion rates double for every 18°F [8° C] rise in temperature);
- High chloride contents (salted peanuts shells are dropped onto the floor and washed down during cleanup);
- Inconsistent replacement of joint sealants when damaged or at end of their service life. Failing joints between precast members (both caulk joints and building expansion joints) allowed water infiltration to reach critical structural members and connections (typically preventive maintenance issues); and
- Although the original design did not include waterproofing, it did include an extensive gutter system beneath the precast joints to collect water if joints leaked, diverting the water to uninhabited spaces (Fig. 2). As a result, corrosion damage occurred to the structure as water leaked through the joints, traveling across structural members before entering the gutters.

Many repair methods and materials were used in the repair programs, with careful attention paid to protecting the stadium from future moisture intrusion in the repair areas. Every steel connection, embed plate, rebar, etc., was sandblasted/epoxy-coated, corrosion inhibitors applied, and repair areas covered with a waterproof urethane deck coating. The repairs covered the spectrum of available materials from ready-mix to pre-bagged materials, and utilized many different placement methods.

Fire Protection Complications

Repairs were located in areas requiring up to 3-hour fire ratings. The original fireproofing, although industry standard materials at the time (spray applied cementitious, mineral-wool or gypsum based intumescent coatings), absorbed moisture and held it next to the structural elements, thereby promoting corrosion (Figs. 2 through 5). Repairs included intumescent epoxy coating (¼ to ½ in [6 to 13 mm] thick waterproof epoxy) on all steel raker trusses and threaded rebar anchors to achieve the required 3-hr. fire rating (Fig. 6 and 7). Instead of mineral wool, which absorbs water, fire-rated building-expansion joints or intumescent tape were used at precast caulk joints to achieve floor-floor fire ratings. Because the bottom side of the joint was over the concrete raker beam/wall and inaccessible to caulk from the bottom side, a standard UL rated fire caulk assembly was not possible. An intumescent tape was inserted into the joint, with backer-rod and standard polyurethane sealant installed on the topside, providing the required fire rating.

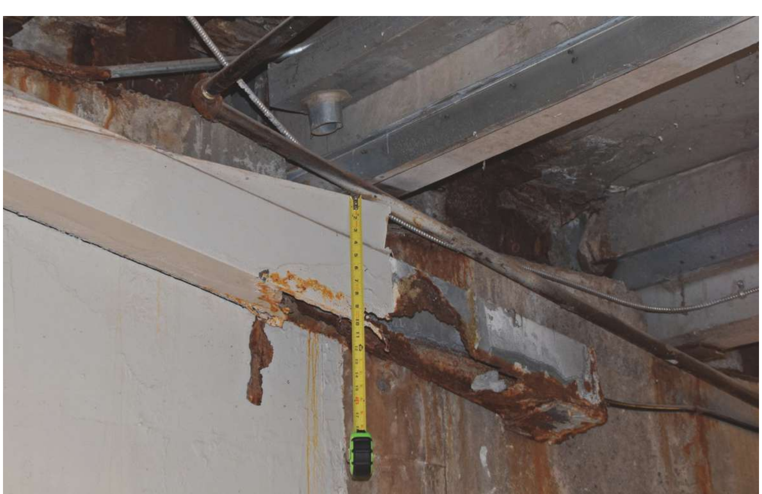

Fig. 2: Bottom side of seating riser at support—seating riser bearings and seismic restraint plates are visible on the bottom side. Moisture penetration through building expansion joint into mineral wool (each side of L-shaped plate) resulted in severe corrosion. Rain gutter system completely corroded through as it enters uninhabited space.

Fig. 3: Raker truss tieback anchor—connection between steel raker truss and concrete frame with sixteen 1-3/8" (35mm) diameter high strength threaded rebar anchor rods. Connection is completely hidden between two masonry walls in a dead space with leaking precast joint directly above. Spray-applied fireproofing absorbs water and never dries out.

Fig. 4: Threaded rebar anchor nut—Severe deterioration of the nut. Corrosion of the threaded anchor rod is not visible due to fireproofing and debris.

Fig. 5: Threaded rebar anchor—large mound at end of tape measure is peanut shells and debris washed through failed joint above.

Fig. 6: Raker truss tieback anchor connection—overall view of the threaded rebar anchor assembly after initial sandblasting.

Raker Truss Tieback Connections

Large cantilevered steel raker trusses support the first 11 rows of seating at the Upper Concourse and are connected to concrete columns with high-strength threaded rebar. Sixteen 1⅜ in (35 mm) diameter threaded anchor rods are embedded into concrete columns and raker beams to transfer the 200,000 pound (90,720 kg) tension force from the steel raker truss to the concrete. This very critical structural connection is concealed between two masonry walls in a small inaccessible "dead space," with leaking precast caulk/building-expansion joints directly above. The spray-applied fireproofing absorbed moisture, never drying out, promoting corrosion. This connection and associated damage was not readily visible without removing a sheetrock cover, but infiltration was evident in the form of efflorescent stains on the column and raker beam (Fig. 3 through 5).

Raker truss tieback connection repairs consisted of the following:

- Removing all fireproofing;
- Sandblasting all steel to a white metal finish;
- Unscrewing the threaded rebar nuts, one at a time;
- Inspecting for damage and replacing nuts as needed;
- Sandblasting the rods and nuts;
- Coating all elements with epoxy before assembly;
- Re-torqueing nuts;
- Repeating this process 15 more times for other anchors;
- Chipping out original grout across top, exposing four top anchors;
- Applying migrating corrosion inhibitor;
- Replacing grout with epoxy grout;
- Injecting epoxy between concrete column and steel embed plate;
- Coating raker truss and threaded rebar anchors with intumescent epoxy; and
- Installing waterproof flashing to prevent moisture from leaking directly onto the anchor assembly.

Thirty-two raker truss connections occur at the upper seating level. They were investigated, prioritized for severity, and 19 locations repaired. If the rods were severely corroded, repairing them to replace lost cross-sectional area would have been extremely difficult. Fortunately, even though standing water was found in the grout pocket directly above the threaded rebar, none of the anchor rods had experienced enough corrosion that repairs were required to restore the rod's tensile strength. Many nuts were severely corroded and required replacement.

Precast Joints

Much of the work has involved the precast seating risers (Fig. 8), and the structures below them due to leaking joints between the precast sections. Precast seating risers have numerous joints, between ends where they butt together (transverse), and longitudinally between sections. Most of these joints are caulked; however, seven are building-expansion joints. All joints were not maintained on a consistent basis. Damage from frequent power washing, traffic and the extreme Phoenix sun ultraviolet radiation resulted in accelerated deterioration of polyurethane joint sealants and building-expansion joint covers.

Each precast seating riser is supported at its ends by steel raker trusses or concrete raker beams/walls. Water leaking through these deteriorated joints corroded precast connections and the supporting structure. Threaded rebar anchors are directly below these joints, and gutters are located on each side of the concrete raker beams/walls. However, water drips down from the joint, onto the top of the beam/wall, into the precast bearing area, and down the face of the beam/wall, before being collected into the gutter (Fig. 2). Therefore, supporting member damage has occurred.

Precast Connections

Precast members are supported by typical embedded plates at bearings. Bearing plates embedded in precast members, steel shims, and bearing plates in supporting members all experienced various levels of corrosion. Building-expansion joints incorporating sliding bearing assemblies suffered even more deterioration. Repairs varied from simply sandblasting exposed surfaces of the bearings and epoxy coating, to full depth concrete removals in both precast and supporting members to replace bearing plates/pads, sandblast and epoxy coat exposed steel surfaces, and re-cast the section (Fig. 9 and 10).

To restrain seismic loading, a large steel embed plate was cast into the seating riser's horizontal portion directly adjacent to the transverse joints. These seismic connections experienced deterioration in many cases. Often, repairs encompassed both bearing and seismic areas on each row of seating (Fig. 9, 11 and 12).

To protect the repairs against future corrosion, all exposed steel embeds and rebar were epoxy coated, with the second coat also used as a bonding agent. Building expansion joints utilized pre-compressed, silicone-impregnated foam expansion material to provide a long-lasting waterproof joint, with walking surfaces suitable for high-heeled shoes without the need for metal cover plates.

To protect the concrete against moisture infiltration, a urethane deck coating was applied (Fig. 13). The deck coating primer was a super-low-viscosity healer-sealer epoxy, applied by flood coat with sand.

Precast joints have resulted in damage from moisture leaking onto raker trusses, concrete beams and walls, embeds, bearings, seismic connections, other structural connections, and threaded rebar anchors. Accordingly, repair of joints encompassed numerous repair steps, products, and methodologies to properly protect elements from repeated exposure/deterioration.

Prestressed Seating Riser Strand Corrosion

Concrete cracking and spalling was observed on the bottom

Fig. 7: Raker truss tieback anchor connection—completed repair with epoxy intumescent fireproofing to achieve 3 hour fire rating and provide corrosion protection to the beam and threaded rebar anchors.

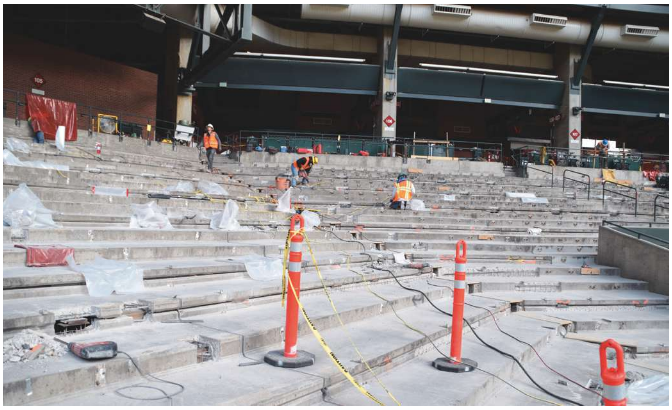

Fig. 8: Repairs to precast seating risers

Fig. 9: Typical precast joint repairs—seismic restraint plate (embed with bolt) and precast bearing seat assembly (below prestressing strands) after existing plates replaced, rebar welded back, and sandblasted prior to epoxy coating and pour back.

side of precast seating risers in two locations. Further investigation revealed corrosion of prestressing strands. Repairs consisted of:

- Installing an epoxy-coated full-length steel channel, bolted to the back side of the seating riser, supporting the weight;

Fig. 10: Concrete column repairs—due to placement logistics, the contractor elected to repair this column rather than replace it.

Fig. 11: Typical Precast Joint Repairs - Water leaking through building expansion joint between precast seating sections was absorbed by mineral wool fireproofing in the joint, resulting in severe deterioration. Large steel plates are seismic restraints.

- Chipping out concrete exposing corroded strands;
- Sandblasting;
- Epoxy coating exposed steel;
- Form and pour back; and
- Protection with a urethane deck coating.

Fortunately, no other seating risers have been discovered with similar deterioration. Ongoing repairs include deck coatings to prevent similar damage.

Other Repairs

Numerous other significant repairs have been performed over the last six years at Chase Field as a result of corrosion due to wash-down, and include the following:

- Hundreds of guardrails/handrails have been repaired due to corrosion at their base;
- Large steel columns (W14x311) which support the retractable roof were coated with a gypsum-based intumescent fireproofing which absorbed water, resulting in substantial corrosion of the columns at the floor line, where over ¼ in (6 mm) of the flange thickness was lost. Fortunately, this was detected early enough that structural repairs were not required; and
- Over 3300 bolts which support the seats required replacement in 2016/2017 due to section loss from corrosion.

Repairs are anticipated to continue in the upcoming years.

Cost Control

A very proactive approach in repairing the stadium was implemented. Through six years of repairs, the Owner has become knowledgeable and sophisticated. One aspect of this has been cost controls, which have been developed and improved each year to more accurately track the repairs, project costs vs. budgets, and add or delete scope of work to meet budget.

Repair drawings were developed with different variations for typical conditions which repeat throughout each year's repair program. Because much of the damage is concealed, it's impossible to accurately predict the level of deterioration for each location, and therefore the associated repair. Typical repair details were developed with two or three different scenarios corresponding to varying levels of deterioration. A typical connection had repair details for minor deterioration, moderate deterioration, and severe deterioration. Each location was identified with an anticipated quantity and level of deterioration. Unit costs were obtained for each item prior to construction. As the repairs progressed, and levels of deterioration were determined, most of the repair details had already been developed for construction and costs established, therefore, eliminating delays in waiting for design and their related costs, greatly streamlining the process.

The $4 million contract in 2016/2017 contained over 150 individual unit cost items. Each unit cost item was identified on the drawings, with careful attention paid to defining the work scope and avoiding overlap. An extensive spreadsheet tracked predicted quantities and locations for each unit cost repair item, actual quantities and locations, and automatically multiplied these out by the unit costs and projecting the actual total costs to compare with the anticipated budget. The Owner provided the spreadsheet template, and the contractor updated it with actual quantities, resulting in final cost updates weekly. This expedited the monthly payment applications, and identified overall project savings that were rolled into additional scope of work. Because this process streamlined and accurately predicted savings, additional work scope could be added early. Opening day for baseball season does not change, but because additional work scope was added early, the contractor was able to perform and complete it.

While unit costs are not new to concrete repairs, implementing them to this magnitude and sophistication is very unusual. It has been so successful that the general contractor, subcontractors, and engineer are each independently implementing it on other projects in varying degrees.

Fun Facts

Over six years, repairs at the stadium required approximately:

- 1030 gallons (3900 liters) epoxy;
- 1330 gallons (5035 liters) epoxy intumescent fireproofing;
- 5000 bags repair mortar;
- 3420 gallons (12,950 liters) urethane deck coating;
- 625 gallons (2365 liters) sealant; and
- 540,000 pounds (245,000 kg) sandblasting media.

The damage and resulting repairs at Chase Field should serve as a wake-up call to the sports venue industry, because similar conditions exist at other stadiums. ■

Fig. 12: Precast joint repairs—typical example of demolition required to repair the joints between the precast seating sections. Seismic restraint plates have been completely removed for replacement. Bearing repairs for stems have not started. Virtually every row was affected.

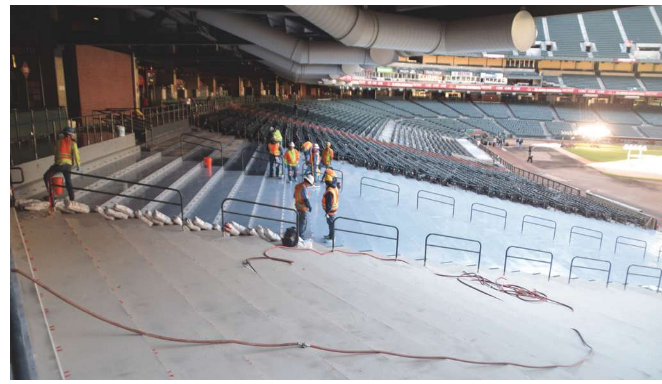
Fig. 13: Deck coating application at precast seating risers.

Chase Field Repairs
Phoenix, Arizona

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Phoenix, Arizona

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Phoenix, Arizona

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Tempe, Arizona
Jokake Construction
Phoenix, Arizona

CONCRETE REPAIR CONTRACTORS
Restruction Corporation
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Lyndhurst, New Jersey

Dennis Wipf, *P.E. is a Structural Forensic Engineer with Gervasio and Associates, a consulting engineering firm in Phoenix, Arizona. He began his 32-year career at Gervasio with the design of new buildings, and has since specialized exclusively in evaluations and repairs of concrete structures. He has received six awards from ICRI for outstanding concrete repair projects. He graduated from Utah State University with a Bachelor of Science in Civil Engineering in 1985. Wipf is a member of ACI and ICRI, is Co-Chair of the ICRI Evaluation Committee 210, and was instrumental in establishing the ICRI Arizona Chapter where he served as the President and on the Board of Directors. Dennis is also a Structural Specialist on the Phoenix Fire Department FEMA Urban Search and Rescue Team and served on deployments to New Orleans for Hurricane Katrina, and Houston and Galveston for Hurricane Ike.*