VOLUME 2: EXISTING CONDITIONS

aloha stadium PLANNING STUDY FINAL REPORT - 12.22.05

BSG
PCL CONSTRUCTION LEADERS
ARCHITECTS HAWAII
HOK SPORT
WJE ENGINEERS ARCHITECTS MATERIALS SCIENTISTS

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SECTION II: CONDITION SURVEY

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Introduction

For the purpose of gathering and organizing the information collected as part of the Aloha Stadium assessment, the stadium was divided into 20 components. Each element relates to a certain area of the building (i.e. seating bowl) or a certain system (i.e. electrical). The study team collected information on each component during several site visits to the stadium throughout the months of July, August and September 2005. Information was gathered by conducting visual inspections, reviewing previous studies and interviewing stadium operations personnel.

HOK Sport with the assistance of Architects Hawaii was primarily responsible for review of the stadium architectural and site components. PCL Construction, with the assistance of Continental Mechanical and A-1 A-lectrician, reviewed the mechanical, electrical, plumbing, and fire protection systems. WJE was primarily responsible for reviewing the condition of the structural systems, steel coating systems, and moveable stand transport systems.

The study team's collective observations, related comments and recommended actions are included in this section. For each component, recommended action items that have cost implications are identified numerically and its associated estimated repair/replacement cost is listed in the Capital Improvement Schedule contained in Section IV.

Aloha Stadium
Planning Study 2005

Architectural Condition Observations

HOK
SPORT

A. Site and Ancillary Structures

The majority of the site around Aloha Stadium is circular in shape around the outside of the stadium. There are 3 additional lots attached to this circular area. The Upper and Lower Halawa lots are to the south and the Kam lot is to the southwest. The site around the stadium is utilized more frequently for events than the stadium itself with the Swap Meet being held every Wednesday, Saturday and Sunday. There are 5 gates leading into the site from the surrounding roadways. The condition of the site is in generally good condition with the following observations being noted:

Pallets and rollaway trash cans are located against the fence in a parking area designated by the green signs next to the freeway. It is unsightly. Recommend removing pallets and storing in an area out of sight of the public.

A1. Steel 55 gallon trash drums in the parking lots are rusting and the bottoms are starting to rot. Need to be painted. Most of the trash drums are in this condition in the parking lot directly across from the main entrance. Recommend the use of a 44 gallon Rubbermaid trash receptacle that is easily transported and emptied.

A1. Steel 55 gallon drums used as trash can in parking lot near Gate 8 has the bottom rusted out. Recommend the use of a 44 gallon Rubbermaid trash receptacle that is easily transported and emptied.

A2. Transformer below the light pole no. 8 in the parking lot directly in front of the main entrance has the gate wide open within about 50 feet from this. Recommend some of protective enclosure to prevent access or damage caused by vehicle intrusion.

A2. Transformers near Gate 5 have no protection. Recommend a protective enclosure to prevent access or damage caused by vehicle intrusion.

A2. Transformer near Gate 8 is unprotected. Recommend a protective enclosure to prevent access or damage caused by vehicle intrusion.

A3. Light pole designated no. 7 in the parking lot showing signs of discoloration and graffiti is present. Light pole designated no. 4 across from main entrance is in the same condition. Pole is rusting and in need of painting. Recommend a regularly scheduled maintenance program to address the painting of light poles.

A4. The asphalt concourse next to Gate 1 has had the cracking repaired. Recommend the resurfacing of all asphalt paved areas.

A4. Evidence of cracking in the pavement and needs to be resurfaced. Recommend the resurfacing of all asphalt paved areas.

A4. Curbs need to be repainted.

A4. Access road across from Section 4 - asphalt needs to be repaired. Recommend the resurfacing of all asphalt paved areas.

A4. Asphalt is cracking outside Gate 4. Recommend the resurfacing of all asphalt paved areas.

A4. Asphalt on side of building near Sections 7 and 8 show the same wear pattern as parking lots.

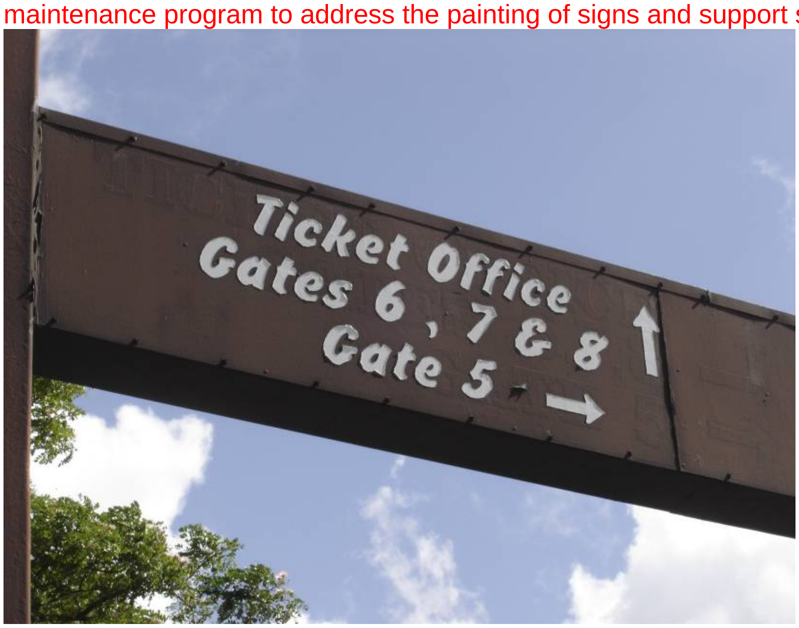
A5. Parking sign across from entrance off Salt Lake Road needs to be painted. Recommend a regularly scheduled maintenance program to address the painting of signs and support structures.

A5. Exit sign leaving property to Salt Lake Road is in good shape and does not show signs of rusting. However, sign end support structure should be painted consistent with all other site signs to establish uniform images and condition.

A5. Main entrance sign showing evidence of rusting and needs to be repainted. Recommend a regularly scheduled maintenance program to address the painting of signs and support structures.

A5. Gate 5 section sign in the parking lot across from entrance 5 - the paint is peeling off of the sign and support structure is rusting. Recommend a regularly scheduled maintenance program to address the painting of signs and support structures.

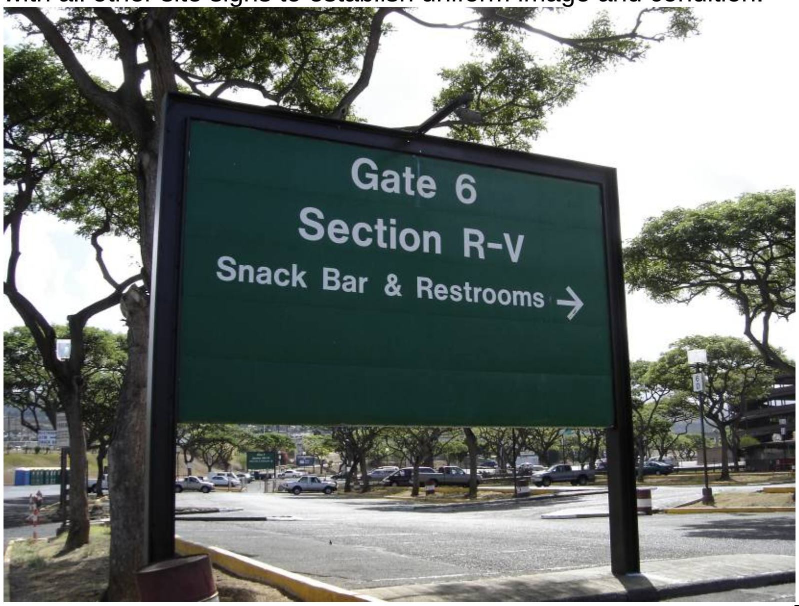
A5. Sign across from Gate 5 - needs to be repainted. Recommend a regularly scheduled maintenance program to address the painting of signs and support structures.



A5. Near Gate 5 - sign on light pole is faded and needs to be replaced. Most of the lot signs need to be repainted or replaced. Recommend a regularly scheduled maintenance program to address the painting of signs and support structures.

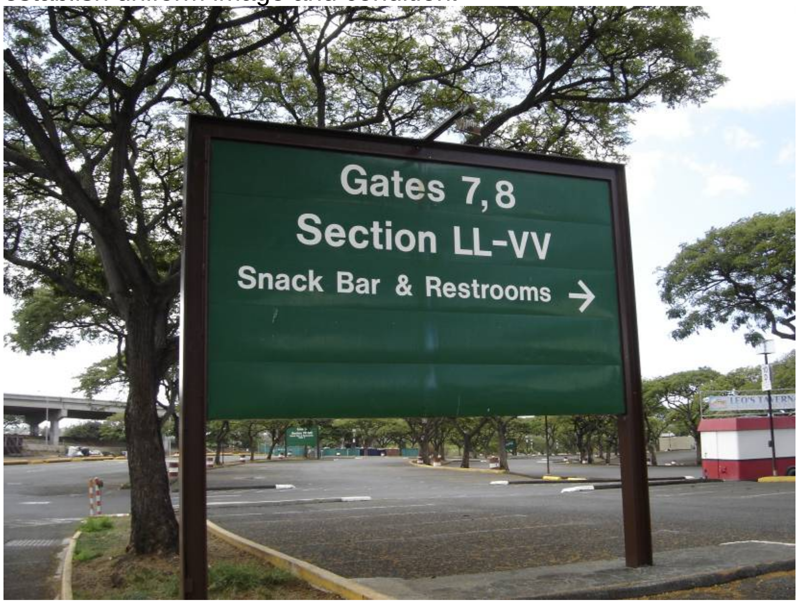
A5. Sign designating Gates 5 and 6 - discolored and masking tape on the sign. Recommend a regularly scheduled maintenance program to address the painting of signs and support structures.

A5. Gate 6 sign - the support frame and sign are in good shape and no need for repair except for some minor staining. However, sign end support structure should be painted consistent with all other site signs to establish uniform image and condition.



A5. Exit sign from parking lot near Gate 7 - sign has rusted and letters are peeling. Recommend a regularly scheduled maintenance program to address the painting of signs and support structures.

A5. Signs at Gates 7 and 8 - it appears that the support structure has been painted recently. However, sign end support structure should be painted consistent with all other site signs to establish uniform image and condition.



A5. Exit sign from stadium complex is peeling and significant staining. Recommend a regularly scheduled maintenance program to address the painting of signs and support structures.

A5. Directional signage at Gate 8 has minor rusting as well as the support structure. Recommend a regularly scheduled maintenance program to address the painting of signs and support structures.

A5. One way sign next to the light pole designated parking area 11 is faded. Recommend a regularly scheduled maintenance program to address the painting of signs and support structures.

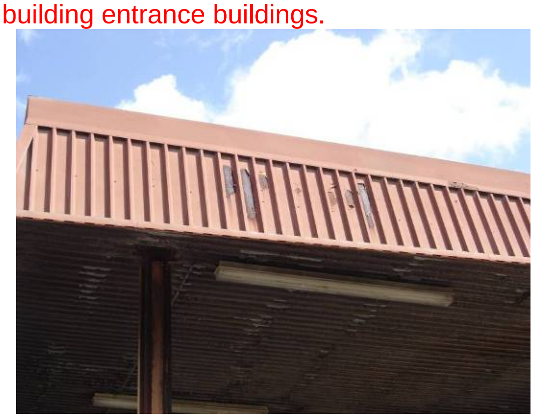
Sign for Gates 1 and 2 looks like it has been repainted recently. However, sign end support structure should be painted consistent with all other site signs to establish uniform image and condition.

A5. Exit sign from stadium area is rusting along with the support structure. Recommend a regularly scheduled maintenance program to address the painting of signs and support structures.

A5. Sign designating Gate 7 is in good shape with minor staining. However, sign end support structure should be painted consistent with all other site signs to establish uniform image and condition.

A6. Underneath the roof that is access point to the parking lot - all the paint is peeling and needs to be repainted. Recommend a regularly scheduled maintenance program to address the painting of roofs of parking overhangs.

A6. Entry building at parking lot entrance across from Gates 6 and 7 has a metal roof soffit with peeling paint. The roof canopy is peeling significantly. Recommend repainting all parking lot building entrance buildings.



A7. Gate 1 area parkway leading to gate has ample vehicle intrusion bollards. Bollards need repainting.

A7. Parking lot next to entrance no. 5 - bollards have been chipped and worn and need to be repainted. Recommend a regularly scheduled maintenance program to address the painting and refurbishment of bollards.

A8. The concession stand next to Gate 4 has peeling paint on the soffit. Recommend a regularly scheduled maintenance program to address the painting of exterior building structures.

Note: Chain link fencing surrounding the stadium is generally in good condition with minor incidents of rusting on the chain link.

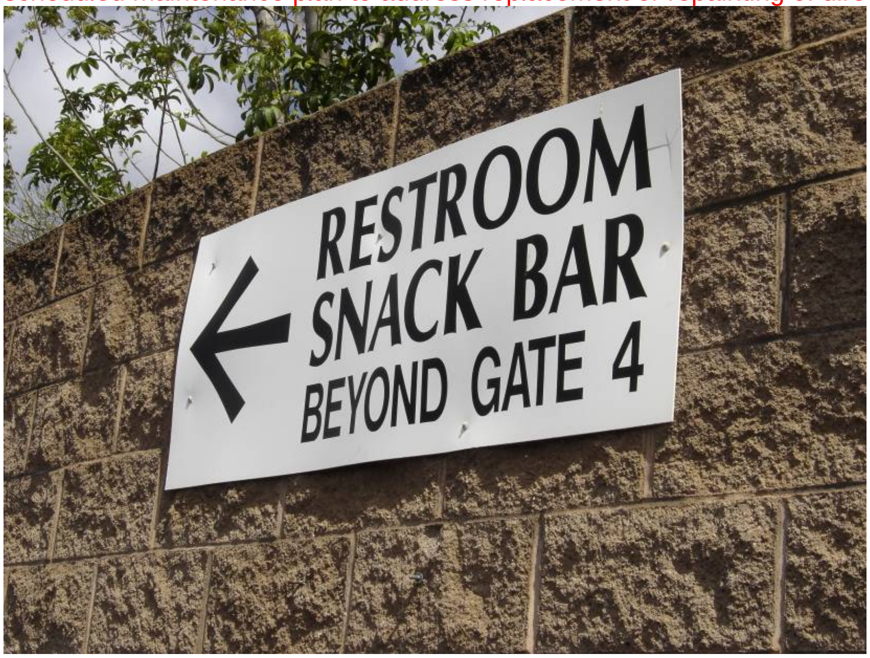
A9. Sign designated parking lot 12D is faded. Recommend a regularly scheduled maintenance program to address the painting of signs and support structures.

A10. Sign at Gate 2 is bent and in need of repair. Recommend replacing sign as part of overall site signage refurbishment.

A10. Telephone sign appears to have been remounted and previous holes were not filled in. Recommend replacing sign as part of overall site signage refurbishment.

A10. Gate 3 signage is clear and concise, however should be replaced as part of overall site signage refurbishment.

A10. Sign on the wall next to Gate 4 is bent and in need of replacing. Recommend a regularly scheduled maintenance plan to address replacement or repainting of directional signage.



A10. Gate 4 prohibited items signage exhibiting signs of rusting at the bottom. Recommend a regularly scheduled maintenance plan to address replacement or repainting of exterior signage.

A11. Gate 2 and Gate 6 steel posts exhibiting signs of corrosion. Recommend a regularly scheduled maintenance plan to address painting of steel posts and signs at entry gates.

A12. Gate 5 approach has one level of vehicle intrusion protection. Recommend increasing the level of vehicle intrusion protection at Gates 5 & 8 possibly with concrete planters.

A12. As was the case with Gate 5, Gate 8 has one line of vehicle intrusion protection. Recommend increasing the level of vehicle intrusion protection at Gates 5 & 8 possibly with concrete planters.

A12. Gate 6 vehicle intrusion protection. Recommend larger concrete bollards at entry points.

A13.

A13. The block wall to the outside Gate 5 is discolored, probably by water from irrigation system. The wall also shows signs of efflorescence. Recommend cleaning and sealing the entire wall. A coating system may also be worth exploring for all stained walls.

A13. Wall next to Gate 4 shows signs of rust.

A13. Between Gates 6 and 7 it appears that somebody has tried clean the block wall. Recommend sandblasting or power washing the entire wall followed by application of a sealer.

A13. Outside Gate 8 again the wall on the back side it appears the wall has been painted to cover staining from efflorescence. Recommend painting the entire wall although it may not prevent efflorescence from continuing.

A14. The light fixtures at Gate 6 show signs of peeling paint. Recommend a regularly scheduled maintenance program for the stripping and repainting of light fixtures on steel beams next to entry gates.

A15. Primary trash can on main lower level concourse. Trash cans with spring hinged doors are not considered as a "best practice." Recommend replacing trash can top with a top that has sides that are "open."

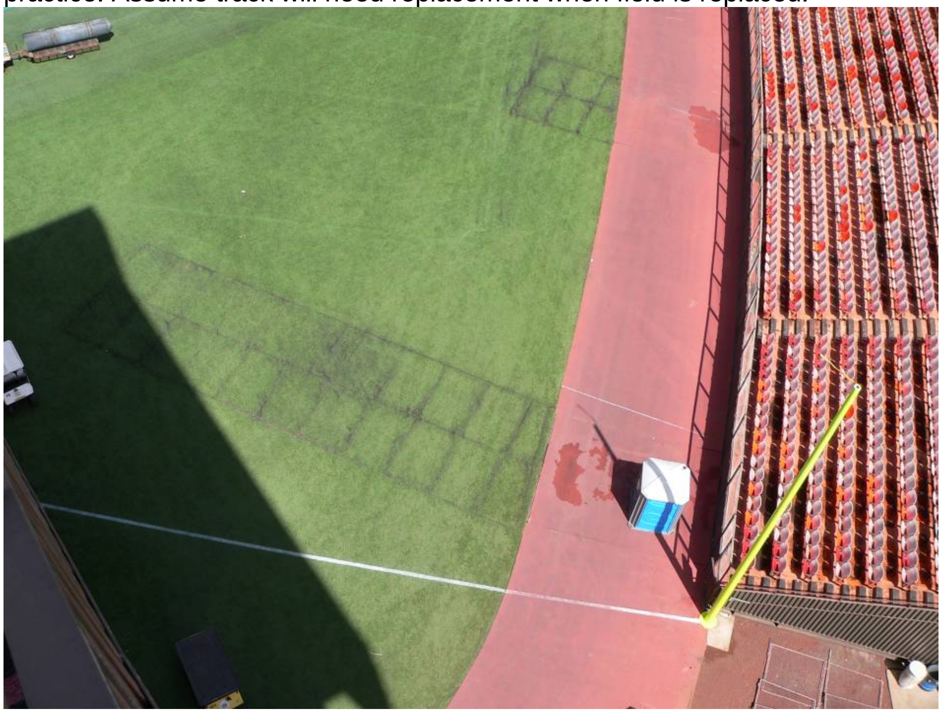
A16. Power cables emanating from show power building exposed to the elements. Recommend encasing exposed power cables in underground conduit to prevent degradation due to weather.

B. Playing Field

The turf is a synthetic infilled turf system manufactured and installed by Field Turf in 2003. The system employs long synthetic fibers infilled with a mixture of sand and rubber granules. The perimeter of the playing field is bordered by a rubberized warning track that is in reasonable condition. At the time of the site visit, the infilled system appeared to be excessively consolidated and in need of grooming. Conditions resulting from the conversion from football to baseball created two observed areas of concern. First, the seams between the homeplate and pitchers mound trays were not adequately flush. Significant depressions occur at the seams and could cause injury and invite player complaints. The warrantied lifespan of this turf system is 8 years. In most parts of the country, this system can last about 10 years, but with the intense sun of Hawaii, it is only anticipated to last for 8 years. The perimeter track will probably need to be replaced at the same time.

B.1 View of seam depression. Recommend reviewing grooming procedures and tray installation procedures with manufacturer's representative to implement their recommended practice.

B2. The second area of concern is the visible track area of the moveable stands exposed in the baseball configuration. This condition doesn't appear to be a performance issue, but does have minimal negative appearance. Recommendation: The condition of the track area should be monitored for potential deterioration. Review dressing procedures and tray installation procedures with manufacturer's representative to obtain their recommended practice. Assume track will need replacement when field is replaced.



Field vehicle access is adequate through the north tunnel.

Field walls are convertible for higher baseball fence condition. Field wall pads for football events were not observed due to the conversion that was in progress.

C. Event Level

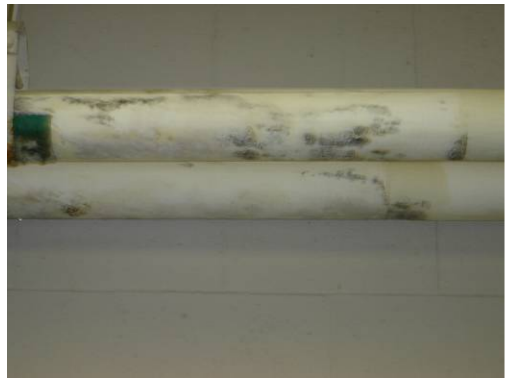
The event level of the building is primarily located at the north and south fixed portions of the stadium. At the north endzone the event level contains the concessionaire spaces, some building maintenance spaces, the loading dock, and the truck ramp. At the south endzone there are two floors that are part of the event level. The upper floor or team office level contains the building operation offices, security and ticketing offices, staff dressing rooms, as well as some multipurpose meeting spaces. The lower floor or the team locker level contains locker rooms and support spaces for the teams, coaches, and officials.

General building storage – There is very little general building storage. What storage space that does exist is in small pieces scattered throughout the different levels of the stadium. There are several large areas that could be used for storage if the decision was made to no longer convert the stadium into baseball configuration. These include the bridge storage areas in each corner as well as the large spaces under the movable stands themselves.

Employee entrance / locker rooms – The employee entrance is at the team office level at the south endzone. There is a large men's and women's changing area and toilet at this level for use by the staff.

C1. Team locker facilities – There are two large locker rooms at the event level of the stadium. Both locker rooms have toilets, showers, and coaches offices associated with each. The condition of the visitor locker room (on east side of level) is in poor condition. Water has leaked through the precast seating bowl above and has damaged the rubber flooring, pipe insulation, paint, and several other items. It appears this water is also causing mold to grow in certain places which could become a serious health concern if not corrected. Leaking pipes are damaging pipe insulation. Recommendation – Stop water from entering space by replacing the sealant joints in the precast seating areas above, adding a subroof system, and removing the old coating system on concrete treads and risers and replacing with elastomeric waterproof traffic coating. Traffic coating and precast joint replacement is also necessary to protect the condition of the bowl and is discussed in greater detail in Section D, Seating Bowl. Hire an industrial hygienist to confirm the presence of mold and offer advice of how to eliminate it.

C2. Remove and repair any finishes including painting of walls and ceilings damaged by water or showing signs of mold.

C-3 The condition of the Makai locker room to the west is in better shape as there appears to have been much less water infiltration from the seating bowl above. Recommend budgeting money for normal repainting of wall and ceiling surfaces on a five year basis. replace flooring on ten year basis.

Media – There is very little space dedicated to the media at the event level of the building. The majority of their space is at the press box level of the building

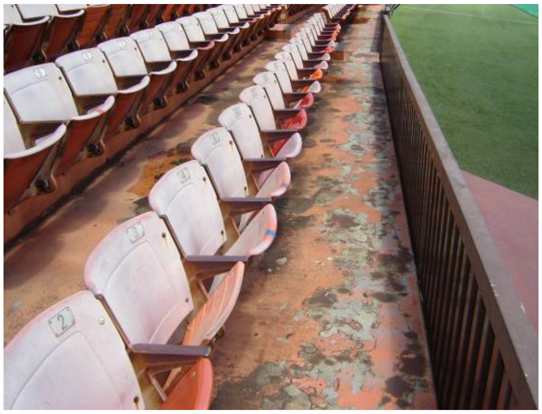
C-4 Officials locker room - There is a single official's locker room located at the event level off the service corridor. The condition of this space is generally in good condition. Recommend budgeting money for normal repainting of painted surfaces on a five year basis. Replace carpeting and other flooring materials on ten year basis.

C-5 Offices - The condition of the offices at the Event office level appear to be in good shape. Some of the finishes in these offices are beginning to show signs of wear and tear. Recommend budgeting money for normal repainting of painted surfaces on a five year basis. Replace carpeting and other flooring materials on ten year basis.

D. Seating Bowl

Lower Bowl

D1. Treads / Risers condition – The lower field seating bowl area (orange seating area) is constructed of precast concrete units on the north and south fixed sides and steel plate on the east and west movable sides. The depth of the seating bowl treads is 2'-11 3/8" and the height of the risers ranges between 1'-0" to 1'-3". The upper field seating bowl area (blue seating area) is steel plate and riser in all areas. The depth of these seating treads is 2'-9" and the height of the risers is 1'-3". A coating system has been applied to all treads and risers and cross aisles in both seating areas. The overall condition of this coating system is very poor particularly in the lower field seating areas. There are several areas where the coating system is missing completely and bare steel or concrete is exposed. The coating on the upper field seating areas treads and risers is also in need of replacement for the same reasons. In the north and south lower field seating bowl areas there are sealant joints installed between the pieces of the precast seating units. These joints are in poor condition and allow water to enter the finished spaces below which has caused damage. Recommendation – Replace entire coating system on treads and risers with the highest priority being given to the lower field seating areas. A replacement of the sealant joints in the precast seating areas should also be done at the time that the coating is replaced to prevent further damage to the interior spaces below. This work should be sequenced with other improvements such as seat replacement and overhead painting to avoid damage caused by other trades.



D1. Section R row 18 seat 19 - concrete joints are delaminating. There are several areas where this is evident. Recommend a review of maintenance procedures to address broken concrete in fixed seating. Repair concrete prior to elastomeric waterproof traffic topping replacement.

D2. Replacement seat bottoms in Section S have been painted blue and the paint is worn away revealing an original red seat. Recommendation – replacement of all seats throughout the stadium.

Loge Seating Deck

Treads and Risers are steel plate with an elastomeric waterproof membrane traffic coating similar to the upper field seating bowl. The membrane is in its best condition on this level, probably due the greater protection offered by the upper deck and canopy. The membrane, however, is showing signs of deterioration. Recommended action: Reapply membrane in conjunction with seat replacement.

D1. Section U seat 21 row 3 – floor coating at the base has come up and has exposed the concrete and is beginning to weather. This photo illustrates a common condition on the Loge Level requiring reapplication of the elastomeric waterproof traffic coating.

D2. Seats are in better condition on this level than in most areas of the stadium, however, they still need to be replaced due to extent of corrosion on seat standards, fading of seats and backs and loss of spring action on seats. Recommendation: Replace all seats on this level.

D3. Section S row 31. The paint has come off the vomitory bulkhead wall and is in need of repainting. Recommendation: Recoat utilities and other nonstructural components at the same time structural steel is recoated. (Refer to Plumbing section of report which addresses the condition of the piping.) Piping will need to be cleaned and repainted.

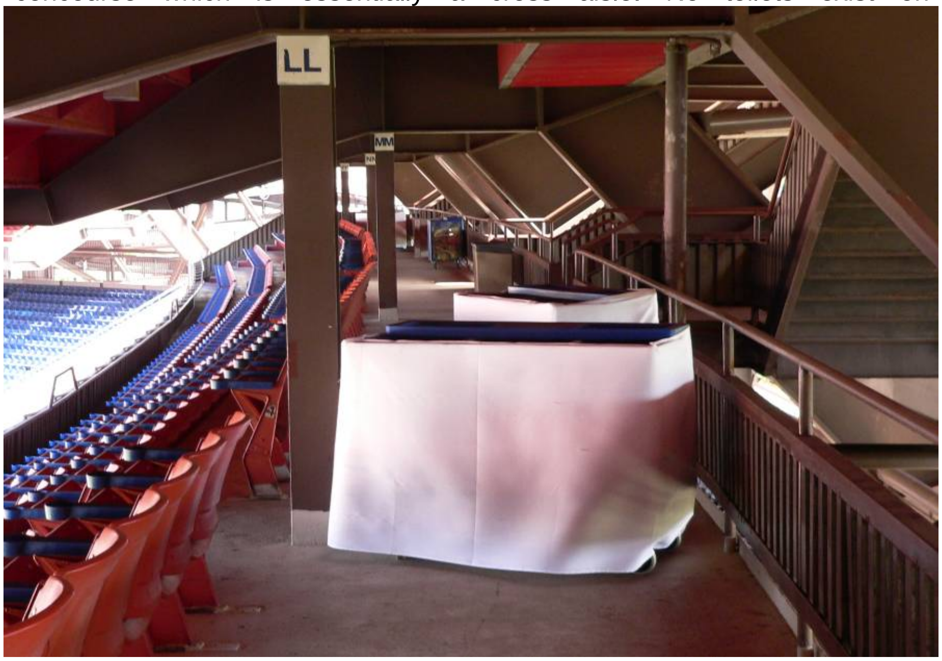
Roof drain leaders show signs of corrosion.

Fittings on plumbing lines are heavily corroded.

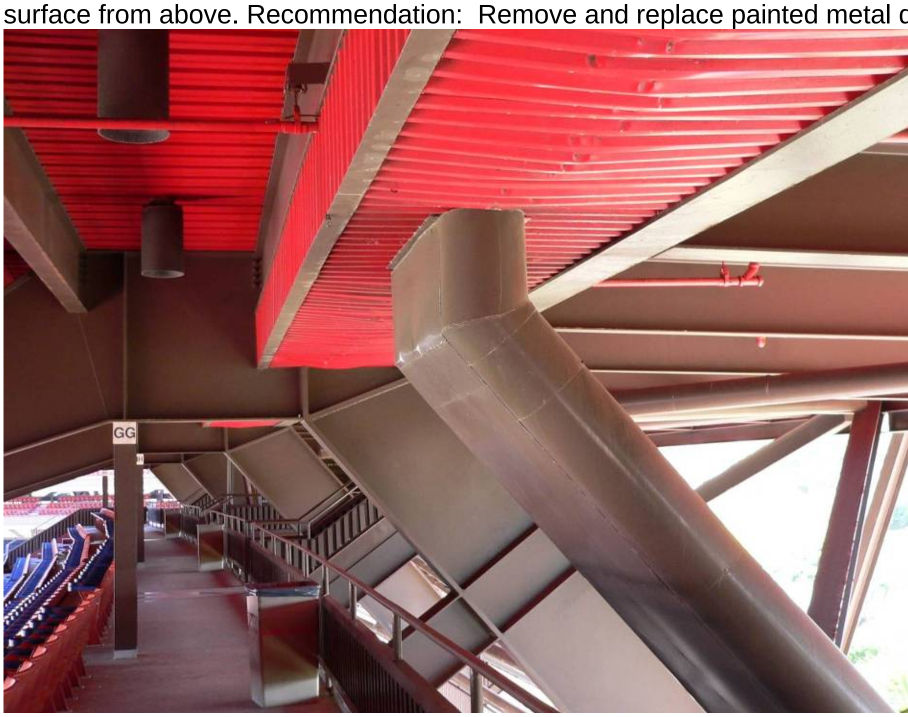
Section S, Row 46 – railings showing evidence of oxidation.

D2. Section T row there are several instances where wooden slat bottoms have been utilized as replacements for plastic bottoms.

Concessions/Toilets – The Loge Level is served only by portable concession stands on a very narrow concourse which is essentially a cross aisle. No toilets exist on this level.



D4. A utility chase runs above the cross aisle and is enclosed with painted metal deck. In several areas, particularly the northeast moveable stands, the horizontal deck is significantly dented apparently due to damage caused by workers bearing weight on the surface from above. Recommendation: Remove and replace painted metal deck.

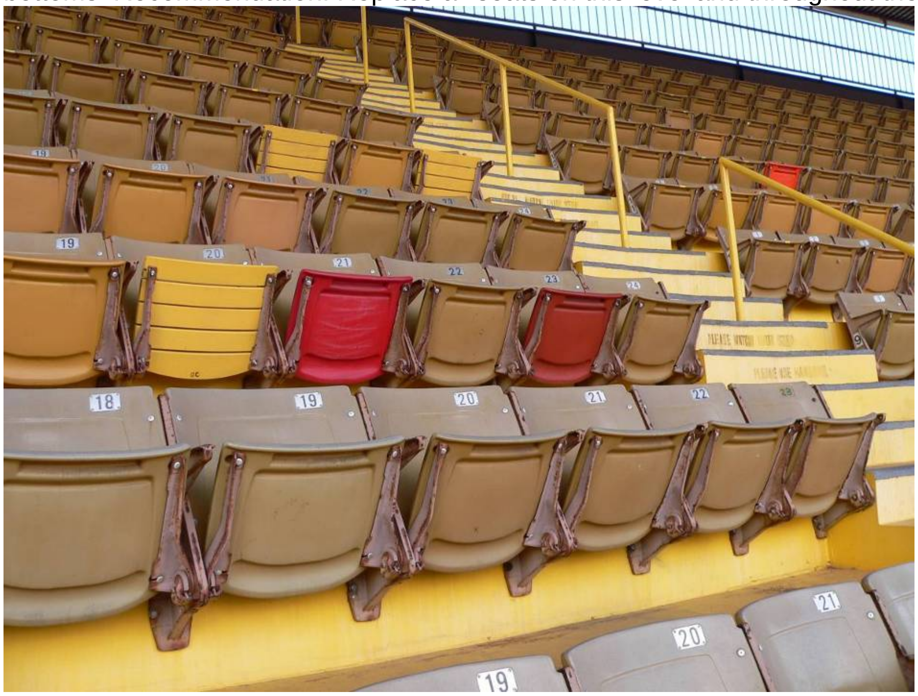


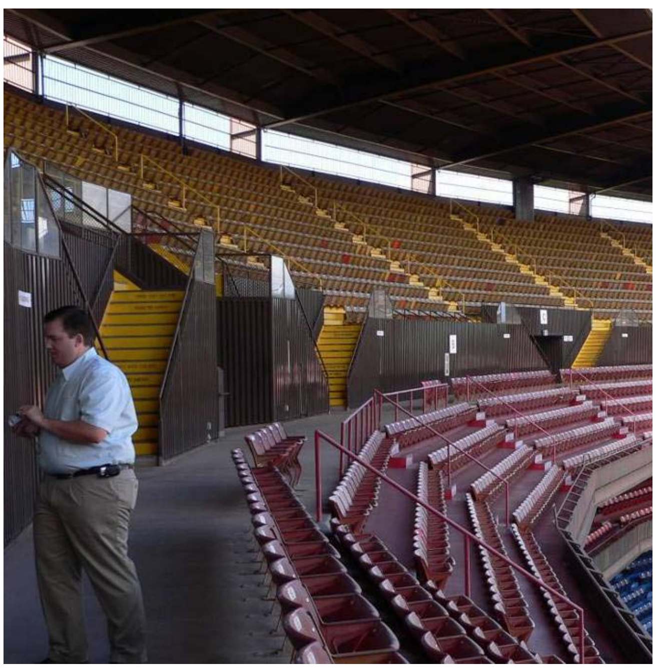
Upper Seating Bowl

D1. Treads and Risers are steel plate with elastomeric waterproof membrane traffic coating. The membrane is failing, particularly in the more exposed rows due to greater sun exposure. Photo below shows delamination of the last membrane from what is assumed to be the original coating. Recommendation: Remove existing coating and reapply new elastomeric waterproof membrane in conjunction with seat replacement.

Lower section below cross aisle has small amounts of exposed bare steel. Balance of topping is very thin and needs recoating.

D2. Seats are in the middle range of deterioration on this level and need to be replaced due to extent of corrosion on seat standards, fading of seats and backs, and loss of spring action on seats. Several seat bottoms have been replaced with an ad-hoc supply of “found” seat bottoms. Recommendation: Replace all seats on this level and throughout the stadium.



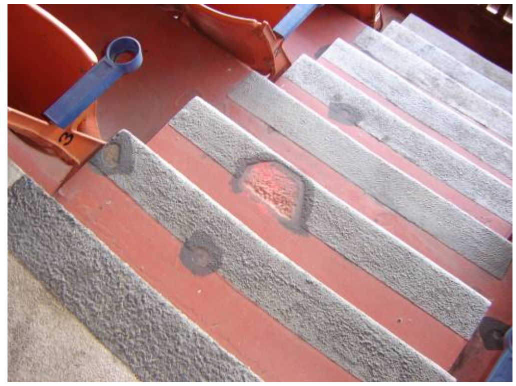


D6. Cross Aisles – The metal siding forming the bulkhead in front of the upper bowl and forming one side of the cross aisle has some corrosion and in the north east moveable stands section is significantly dented. Recommendation: Replace damaged wall panels. Recoat all wall panels.

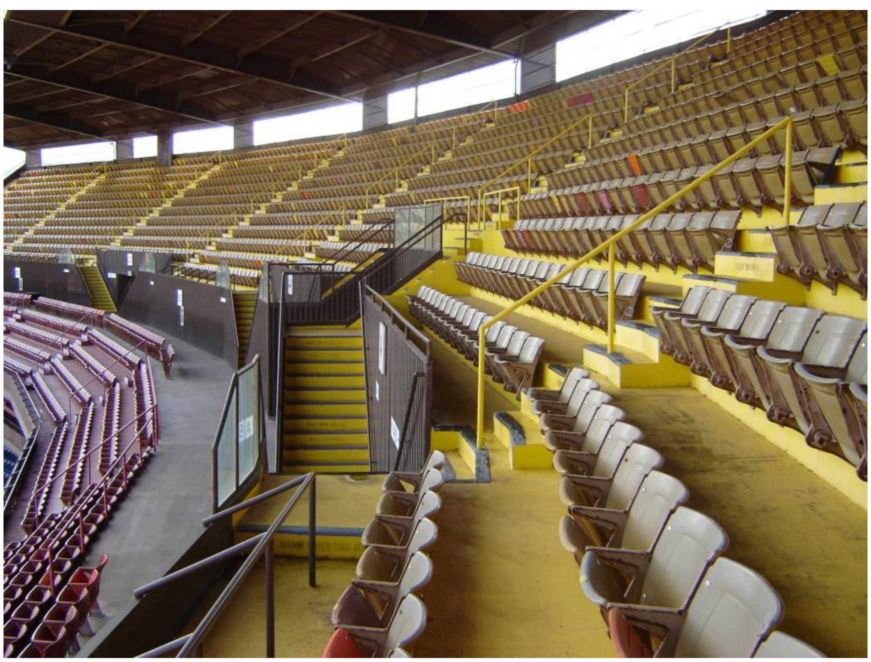
Drainage – The upper bowl is drained by floor drains located in the lower tub at the front of the bowl. Due to its cantilevered position, the drains are collected by horizontal piping following the bowl fascia and leading to a pump which collects the bowl storm drainage and pumps it up to rain leaders located at the back of the loge level. The condition of this system is assessed in the plumbing section of the report.

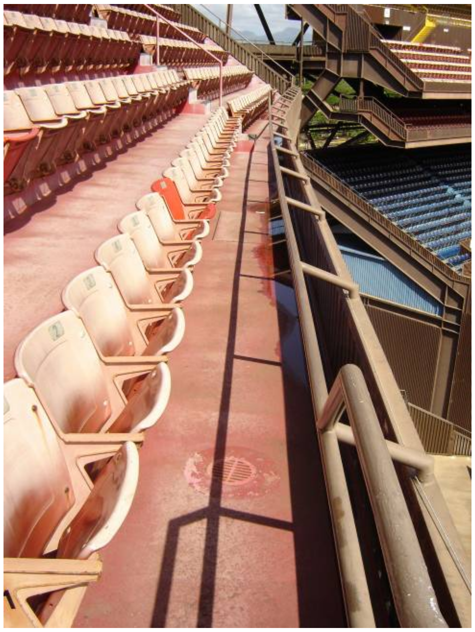
D7. Floor drain at Section M, Row P, as well as other areas within the moveable seating sections, show signs of significant corrosion. Replace corroded drain bodies prior to installing traffic coating.

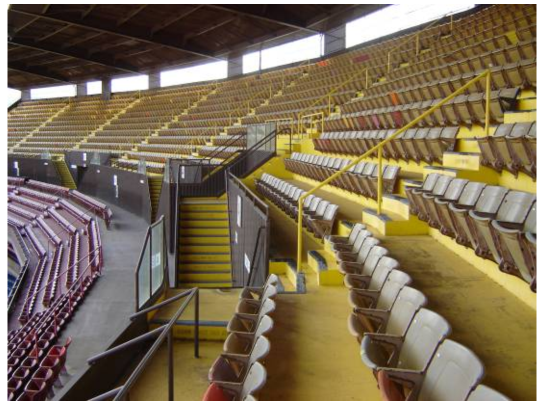
D1. Stairs – In both the lower and upper field seating areas there are aisle steps located between sections. In the lower field seating bowl the width of the aisle steps vary from 4'-7" wide at the top of the section to 3'-6" wide at the bottom of the section. In the upper field seating bowl, the width of the aisle steps vary from 3'-6" wide at the top of the section to 4'-3" wide at the bottom of the section. This change in width relates to the increased capacity of the aisle steps as they get closer to the lower level concourse. There are also 5'-0" wide accelerated aisle steps leading from the cross aisle up to each aisle of the upper field seating areas. The aisle steps in the lower bowl seating areas match the same construction as the treads and risers that they are located in, so the overall condition of them is very similar to the tread and riser condition. The failure of the coating system is the biggest issue at this time and is consistent with the type of failures occurring on the seating bowl treads and risers. The condition of the stair nosing material on the aisle steps in the lower seating bowl however is still in good condition in most locations. There are a few isolated locations where the coating has been chipped or damaged. Recommendation – Removing existing coating system and replacing with elastomeric waterproof traffic coating system on the aisle steps throughout the stadium when the rest of the coating system on the seating bowl is replaced. Continue to spot repair stair nosing material where necessary.



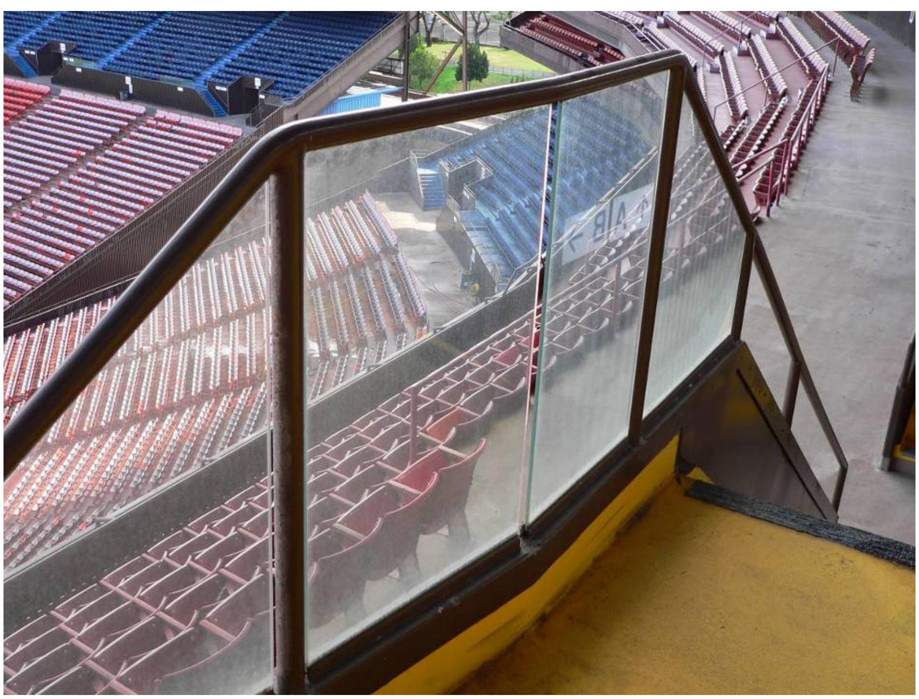
D8. Railings – Most of the railings in the seating bowl appear to comply with current code requirements. All of the rails are painted steel. The coating is currently acceptable however these rails will need to be repainted in the near future. There is some glass infill on the guardrails around the vomitories at the upper tier seating and upper field level seating sections. In the upper tier seating sections of the upper deck the height of the guardrails at the landings is 3'-5" instead of the required 3'-6". Also, the guardrails are not as long as the width of the aisle steps above. They begin to slope down with the stairs 2 to 3 inches before they should. This condition also occurs at the upper field seating vomitories. At the vomitories at the upper tier and upper field level seating sections there is no railing at guardrail height (3'-6") down the side of the stair adjacent to the cross aisle. The single rail that is mounted there is at handrail height (2'-10") and does not meet guardrail code requirements. At the front of all of the seating decks the rails that are installed appear to meet current code requirements however some of them have a very strange configuration for sightline reasons. Only the seating in the upper deck (lower and upper tier seating sections) has a center aisle rail installed. We would recommend installing a center aisle rail at the other seating bowls for safety. The center aisle rails that are installed do not have a second horizontal rail 12" below the top rail. Recommendation – Correct heights of rails where they are low or not long enough to meet current codes. Install guard rail on sides of accelerated stairs next to cross aisles. Install center aisle rails at lower and upper field level sections as well as box seat sections. Recoat railings at all locations when seating bowl is recoated.



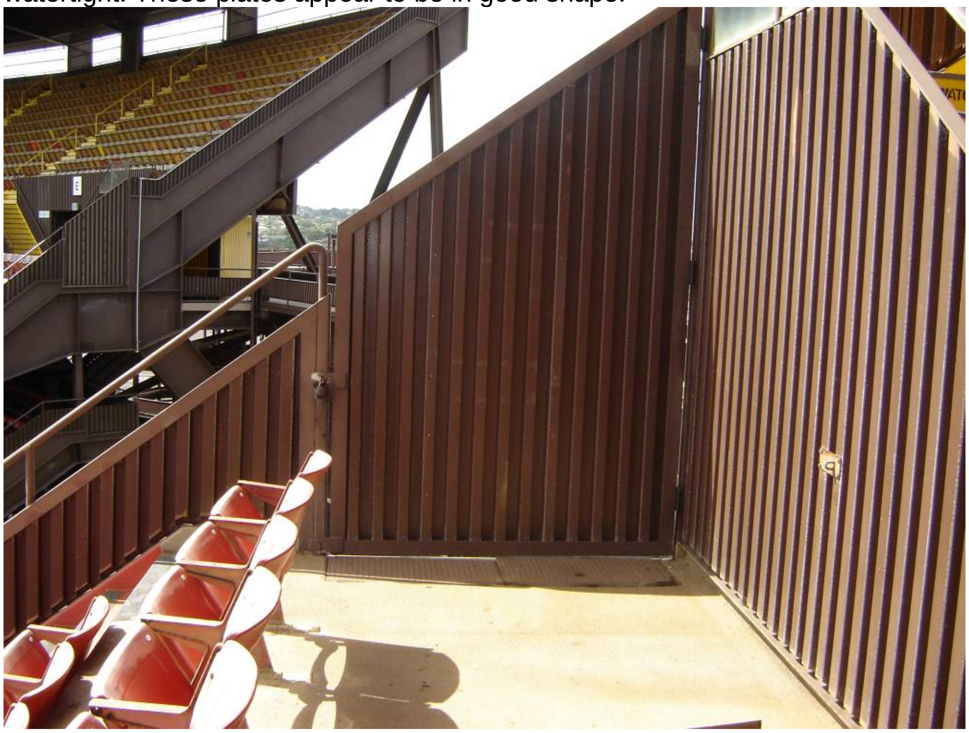




D8. Railings – Stair landings utilize glass panels. Panels are approximately 42" in height at landings, but open side of stair does not meet 42" high guardrail code requirement. Glass should be confirmed that it is tempered or laminated for safety reasons. All railings should be recoated. Side railings should be corrected to provide required guardrail protection.

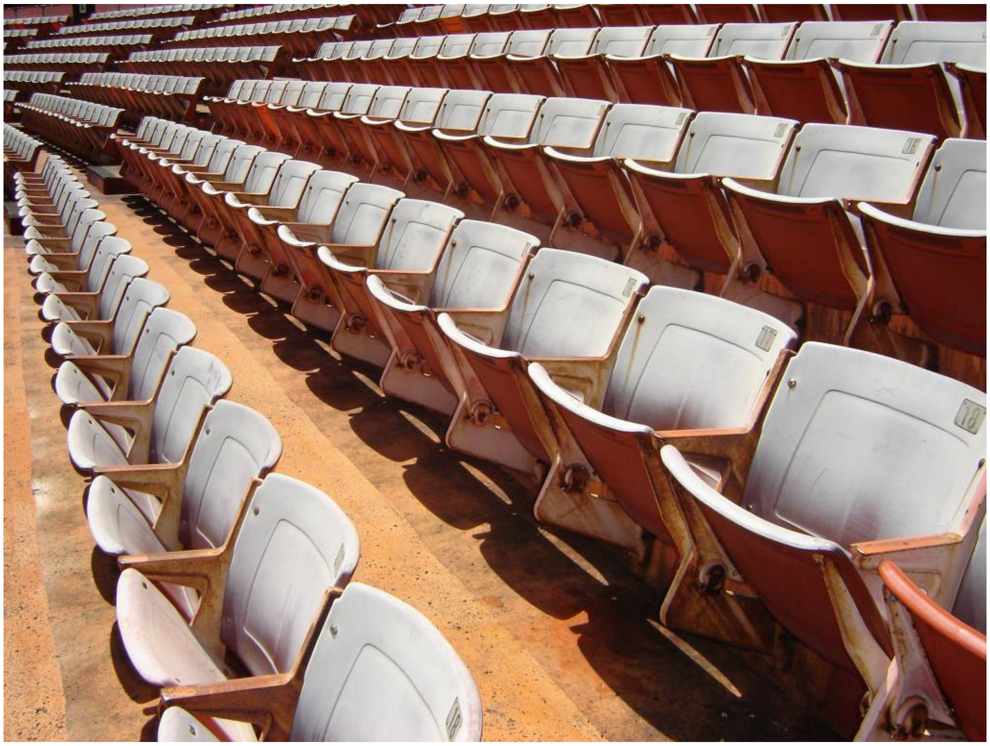


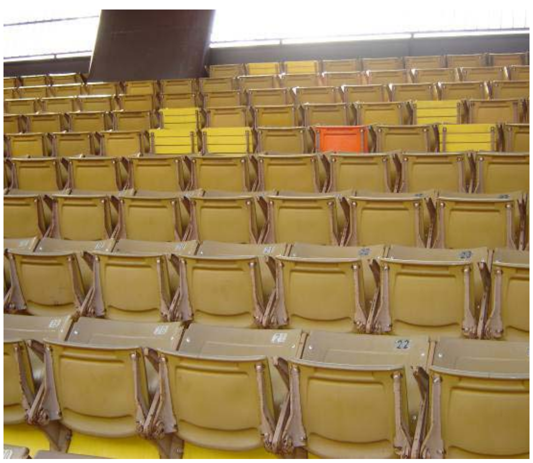
D8. Expansion joints – Due to the seating bowl being divided into fixed and movable sections there are no expansion joints that fall within the seating bowl. There are, however, cover plates that are extended between the fixed and movable seating sections that bridge the gap between them. These function similar to an expansion joint cover but are not watertight. These plates appear to be in good shape.



D8. Drainage - The intent of the original seating bowl drainage system was for the treads and risers (both concrete and steel) to be sloped towards the front row of each seating section where drains are located. This drainage system appears to work well in the north and south areas of the lower field seating sections where the seating bowl is precast concrete. The only problem observed at these locations were the drains being filled with trash and other debris. At the east and west lower field seating sections as well as the entire upper field seating bowl the drainage system does not work as well. At all of these locations the seating bowl is constructed of steel treads and risers. There were many locations observed where the water ponds on the seating bowl treads instead of running down to the next row. It appears that this ponding of water has accelerated the deterioration of the steel coating system in those areas. It is evident that this has been a problem for some time as additional drains have been added in random locations to provide spot drainage for ponding water. While this does solve the problem at an individual location we believe it is a costly solution to try to do this everywhere. Recommendation – Eliminate areas in seating bowl where water ponds and does not drain properly prior to applying traffic coating. Clean out trash and debris from existing drains.

D2. Seats / bleachers – The seating at all locations of the stadium is in poor shape and in need of replacement. The majority of the seating standards and hinge arm assemblies are showing significant rust. Most of the anchorage into the seating treads and risers appeared sturdy and most of the hinge arm assemblies appear to still function properly. The plastic seat backs and bottoms are severely faded and there are many locations where they have been replaced with a piece that is a different color, been painted to match, or a piece that is wooden instead of plastic. The seating in the lower and upper field seating areas are 21 inches wide which is wider than the current standard of 19" in most modern stadium general seating areas. Recommendation – Replace entire seating system.

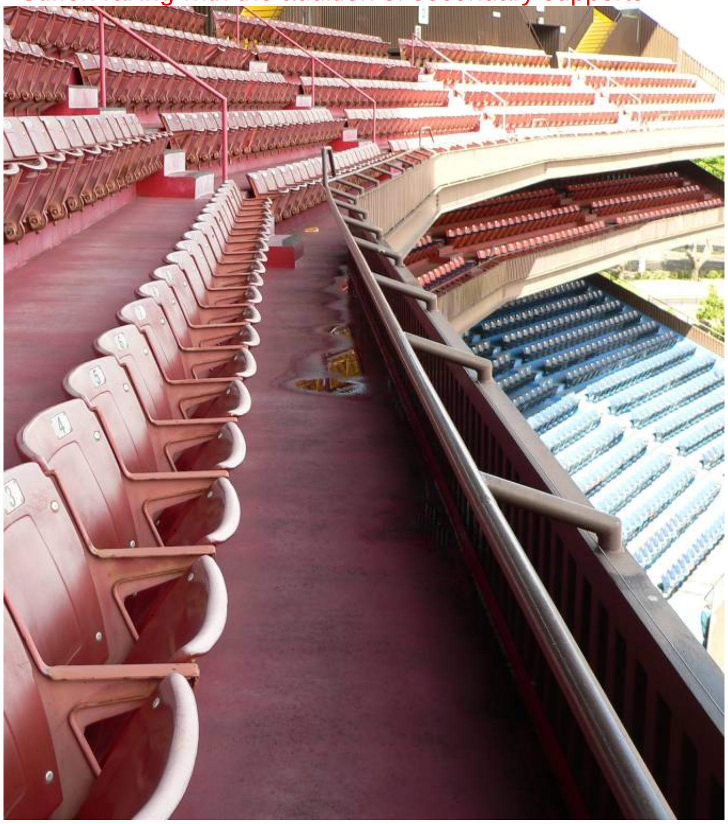




D6. Television camera locations – There are three fixed television camera locations located at the top of the lower field seating bowl. One is located at the center of the north endzone and the other two are at the southeast and southwest corners of the stadium. The platforms are sized for a single camera position and there is an A/V and power connection at each location. At the upper deck there are a few movable wooden platforms at the cross aisles that are used as camera platforms. There does not appear to be any dedicated power or A/V connection boxes for the moveable platforms. There are two additional camera platforms at the west side in front of the football press box. Recommendation – Install additional permanent camera platforms with dedicated power and A/V connections to accommodate television and coaching staff needs.

Graphics / signage – There is very little graphics/signage in the seating bowl, but it appears sufficient.

D9. Railings – The railings at the front of the upper bowl and loge flex substantially when leaned on. This increases the perception of structural instability. Filler between moveable stands when they are in the football position are painted plywood panels. Recommendation - Stiffen railing with the addition of secondary supports.



E. Roof Canopy

Roof gutter and canopy has significant corrosion. Roof access ladder needs repair. Ceiling at the back of the bowl is corroded.

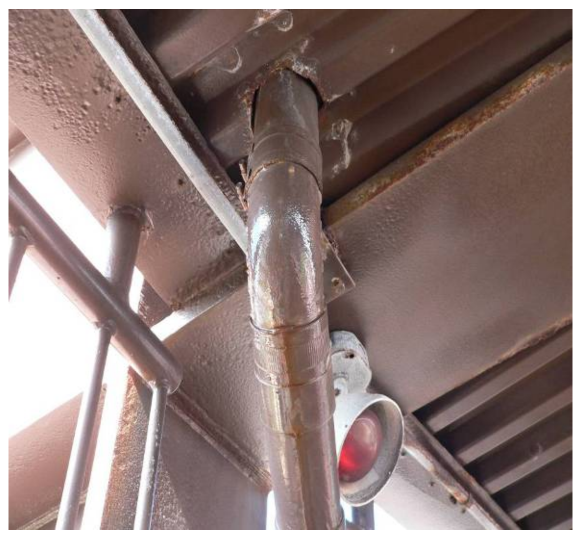
Roof canopy above the southeast moveable section (right side of photo below) shows greatest signs of corrosion. Steel roof beams are corroding in several areas of the roof.

Railing at back of bowl is corroded along with gutter framing.

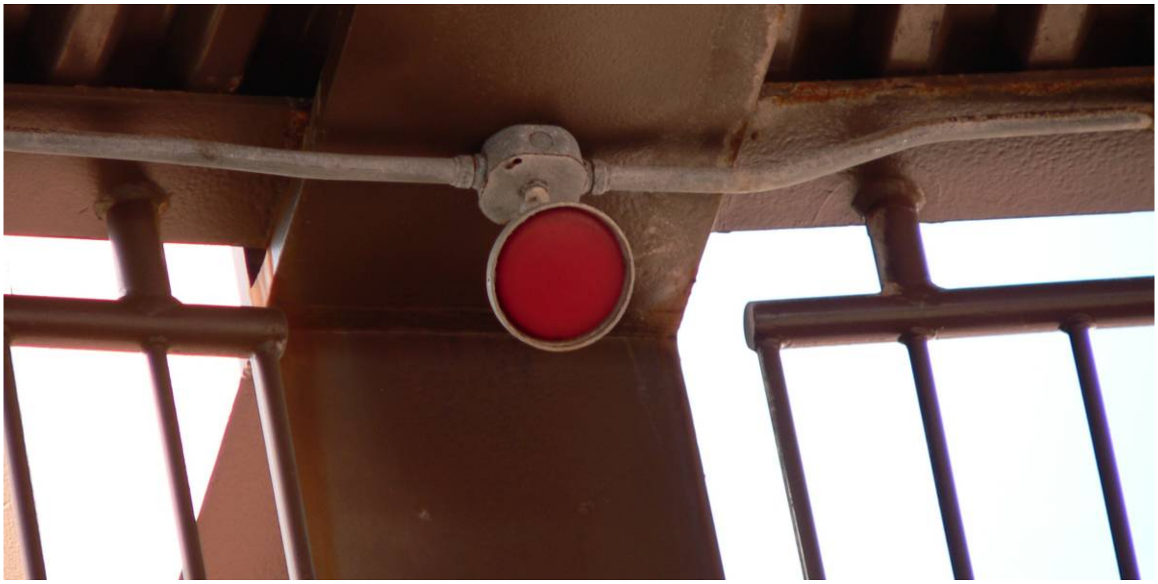
E1. Replace steel decking at canopy. Recommendation – Recoat all exposed steel structural members including girders, gutter decking and railing at the back of the bowl.

E2. At the South end of the upper bowl there is a hole in the metal roof panel.

E3. Roof drain bodies, piping and adjacent vents are corroded with surrounding decking severely corroded. Recommendation: Replace all roof drains and piping. Repair metal decking with steel plate around drains. Recoat all exposed steel including railings.



Emergency exit red lights are located above the aisles in the seating bowl which is not a typical requirement in outdoor seating bowls.



Upper level South end – roof paneling at the top row of seating area showing extreme evidence of oxidation.

F. Concourses

Main Concourse

F1. Concrete slab condition – The lower concourse slab and coating system appears to be in good condition unlike the seating bowl. There are some areas where cracks have appeared that need to be addressed. There are no concourse drains so all drainage is accomplished by sheet draining the water to the outside edge of the concourse. There is minimal slope on this concourse slab to accomplish this. Recommendation –Repair cracks in concrete in concourse with epoxy non-shrink grout. These repairs should be made prior to replacing the traffic coating system on all concourse slabs.

F2. Vomitories – The vomitories are in good condition along with the gates that are used to block access to the seating bowl. The metal decking on the walls need repainting. Recommendation –Repaint metal decking on vomitory walls where needed.

F2. Vomitory walls and railings show advanced weathering. Walls on the windward side of the stadium are particularly corroded due to the prevailing salt laden winds. Recommendation - Recoat Vomitory walls and railings.

F3. Railings – There are steel railings around the outside of the lower concourse at the four movable stadium sections. The condition of these appears to be acceptable. These guardrails are 3'-6" tall and have a top opening between the top rail and the ribbed metal siding infill of approximately 9" clear. There is another 9" clear opening between the bottom rail and the top of the stair landing. Neither of these openings meet current code requirements. Recommendation –Add additional infill rails or cabling to reduce size of gaps in guardrail system.

F4. Graphics / Signage – There is very minimal signage on the lower level concourse. What signage does exist is small and plain. Recommendation –Add additional wayfinding and informational graphics. Also consider additional sponsorship graphics as a way to increase stadium revenue.

Example of wayfinding signage at the entry point to Gate 5. Signage is clear and concise.

Main concourse outside Section J is clear and concise.

Outside Section J picture of directional signage is clear and concise.

Outside Section M picture of wayfinding signage is dull, dirty and in need of enhancement.

Lighting – The majority of the lighting at the lower level concourse is very utilitarian florescent lights mounted above the concession and toilet openings. (See electrical portion of report for condition of lights.) Suggest study lighting upgrade in conjunction with signage upgrade designs.

Other spectator conveniences / facilities (ticket sales, telephones, first aid, information, etc.) – There are two novelty stands, a first aid station, ticket booths, and a security room at the lower level concourse at the south end.

F4. First aid room on main concourse with a folded paper sign welcoming guests. Recommend replacing broken and outdated signage on doors.

Trash can inside bowl off main concourse South end. This type of trash can is better suited than the one currently being used on the concourses.

Main concourse outside of the Hawaiian Isle concession stand has significant staining and should be power washed. Recoat over any stains that normal washing and cleaning will not remove.

F5. Main concourse outside Women's restroom, Section A - water fountain has a missing push button. Recommend a regularly scheduled maintenance program to address replacing hardware on water fountains.

F5. Water fountains outside section SS missing push buttons. Recommend a regularly scheduled maintenance program to address replacing hardware on water fountains.

F6. Counter to information booth on the main concourse is in need of repair. Exposed exterior conditions create a harsh environment for what is traditionally interior materials. Recommend a regularly scheduled maintenance program to address replacement of delaminated counters.

F7. The “usher phone” is missing from box on main concourse. Recommend a regularly scheduled maintenance program to address the replacement of missing and damaged equipment.

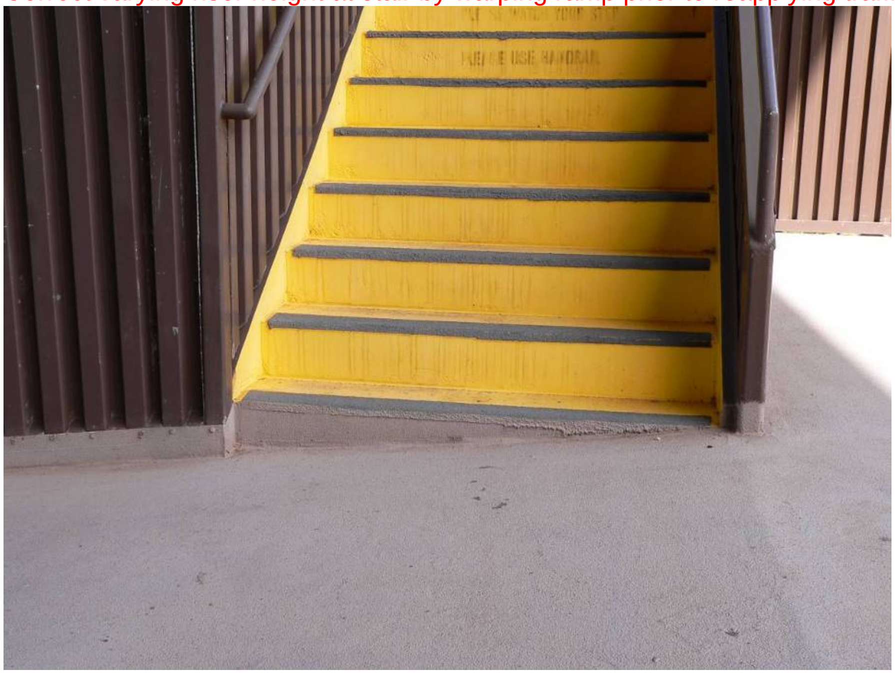
Vomitories through out the facility have graphics detailing the rich tradition of events at aloha stadium creating a nice touch. Similar graphic themes can be used to enliven the concourses and attract advertising or sponsorships.

Upper Concourse

F8. Concrete fill on steel deck is protected by an elastomeric waterproof membrane which is nearing the end of its useful life. Recommendation – Remove old coating and apply new elastomeric waterproof traffic coating over concourse.

F9. Upper concourse outside section DD - noticed some discoloration of the upper bowl metal raker beams. Recommend a regularly scheduled cleaning program to address dirt build up on the rakers .

F9. Vomitories – The sloped condition at the upper bowl vomitories creates an unsafe condition in front of the aisle steps leading to the upper level seats. The slope also exceeds the maximum allowable slope of 1:12 stipulated in the ADA guidelines. Recommendation – Correct varying riser height at stair by warping ramp prior to reapplying traffic coating.

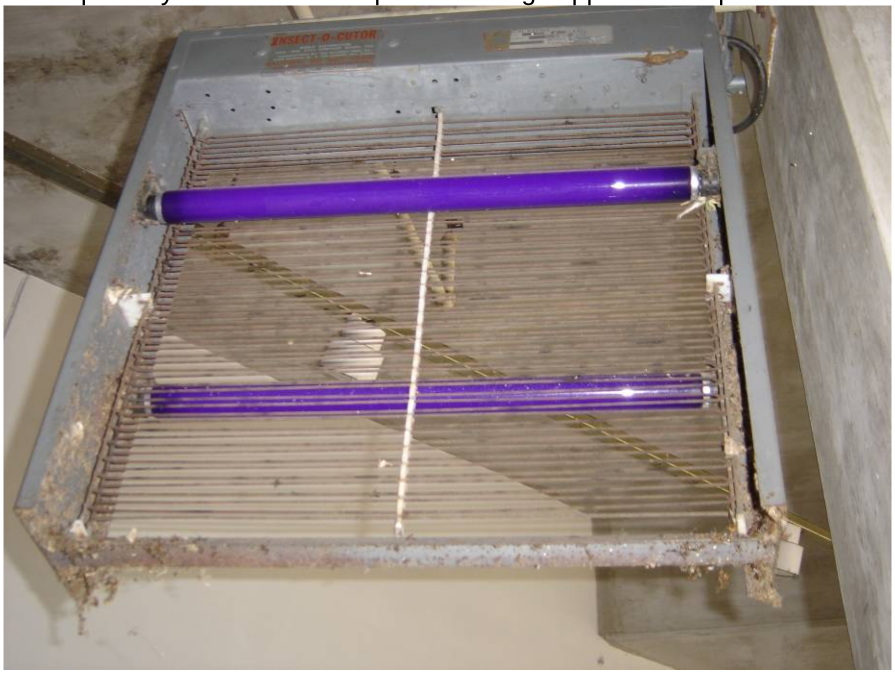


F10. Main and Upper Concourse Corner Bridges – The width of the bridges constrict travel and they are very bouncy when walked on. The railings flex excessively when leaned on. Although the current design may be adequate for safety, it likely contributes to a perception of instability for patrons. Recommendation: Perform additional structural analysis on bridges and rails to confirm they are safe. Also stiffen bridge guardrailing with the use of secondary support members.

F4. Lighting – Light fixtures are utilitarian with uplighting at each vomitory entrance. More dramatic uplighting could greatly improve the image of the stadium at nighttime. Study lighting upgrade in conjunction with signage upgrade design.

F4. Signage – Sections are indicated with minimal signage. New signage could help activate the concourse. Very minimal amount of advertising signage is present in the stadium. The opportunity to increase advertising with associated revenues is apparent.

Security checkpoint by main entrance - picture of bug zapper in disrepair.



Trash can outside with open lid. Housekeeping manager said they are doing away with this kind - it is 10 years old.

Storage area across from the freight elevator on the main concourse. Cramped storage areas are inefficient due to lack of available storage space.

Return air vent on the service level outside the freight elevator is dirty. Recommend a review of cleaning procedures to address dust and dirt on return air vents on a regular basis. Refer to Mechanical Report for detailed related recommendations.

F11. Fire extinguisher in the box - the glass has been broken, it is dirty. Recommend a review of maintenance procedures to address missing glass and cleaning procedures for build up dirt on the box.

F12. Light on upper deck has a significant amount of dirt buildup. Recommend a review of cleaning procedures to address dirt and cobweb build up on light fixtures.

F13. Sign outside section M. It should be noted that this is a rated exit and there is no illuminated exit sign at this location. Recommendation – Add illuminated exit signs meeting current life safety code requirements.

F14. The south concourse areas over the offices show cracks in the asphalt and unsealed penetrations near the steel columns both of which are causing leaking below. Recommendation – Remove existing asphalt and waterproofing membrane over offices, reapply a new fluid applied membrane system and seal around all penetrations, and reapply new asphalt in this area.

G. Toilets

Men's restroom outside of Section AA is in good condition. Recommend a review of the floor coating system and repair any damaged areas and unsealed penetrations. Increase normal maintenance program to make these repairs.

Women's restroom outside section SS in very good condition - no issues.

G2. Men's restroom outside section SS - mirror has been damaged by water. Recommend a regularly scheduled maintenance program to address replacing equipment in rest rooms.

Toilet fixture count and distribution – The current toilet count for the stadium are as follows:

Lower Concourse

8 Men's Toilet Rooms (4 Fixed, 4 Movable)
80 lavatories
40 toilets
260 lineal feet of urinal trough = 104 spots @ 30'' O.C.

8 Women's Toilet Rooms (4 Fixed, 4 Movable)
48 lavatories
80 toilets

32 drinking fountains

Upper Concourse

8 Men's Toilet Rooms (4 Fixed, 4 Movable)
40 lavatories
24 toilets
144 lineal feet of urinal trough = 58 spots @ 30" O.C.

8 Women's Toilet Rooms (4 Fixed, 4 Movable)
32 lavatories
48 toilets

16 drinking fountains

Total Stadium

16 Men's Toilet Rooms (8 Fixed, 8 Movable)
120 lavatories
64 toilets
404 lineal feet of urinal trough = 162 spots @ 30" O.C.

16 Women's Toilet Rooms (8 Fixed, 8 Movable)
80 lavatories
128 toilets

48 drinking fountains

Current 2003 IBC Requirements for 50,000 seat stadium

Men's Toilet Rooms
125 lavatories
72 toilets
144 urinals

Women's Toilet Rooms
167 lavatories
430 toilets

50 drinking fountains

The current code requirements for a stadium of this size require a number of drinking fountains men's lavatories, toilets, and urinals that are very close to the number provided. The required versus provided number of women's toilets and lavatories are 302 and 87 deficient respectively. This shortage of women's fixtures is very concerning and we recommend increasing the quantity of women's fixtures. Typical current best practice in stadium design today would be to shoot for a toilet ratio number that is around 1:60 for women and 1:75 for men. This is done to alleviate long lines during halftime or other breaks during an event when the toilet demand is at it's greatest. Recommend finding additional locations to locate women's restrooms on both stadium concourse levels.

H. Concessions

The concessions are generally in a well maintained condition. The central kitchen and commissary areas are in the greatest need for maintenance. The concession stands inside the stadium have no cooking capabilities and serve a very limited offering. The fixed points of sales are fairly minimal in the stadium, but the food service operator supplements the fixed concession stands with portable stands as necessary to maintain a 1 POS (point of sale):180 patrons ratio, which is normally a reasonable ratio as long as the points of sale are adequately distributed. According to the food service operator, beer sales make up the large share of their sales revenues. Reportedly, the food and beverage lines in the stadium are excessive and possibly restrict some potential sales. No fixed concessions are located on the loge level. This level is served by portables which constrict circulation or patrons are forced to walk up to the upper concourse to purchase concessions.

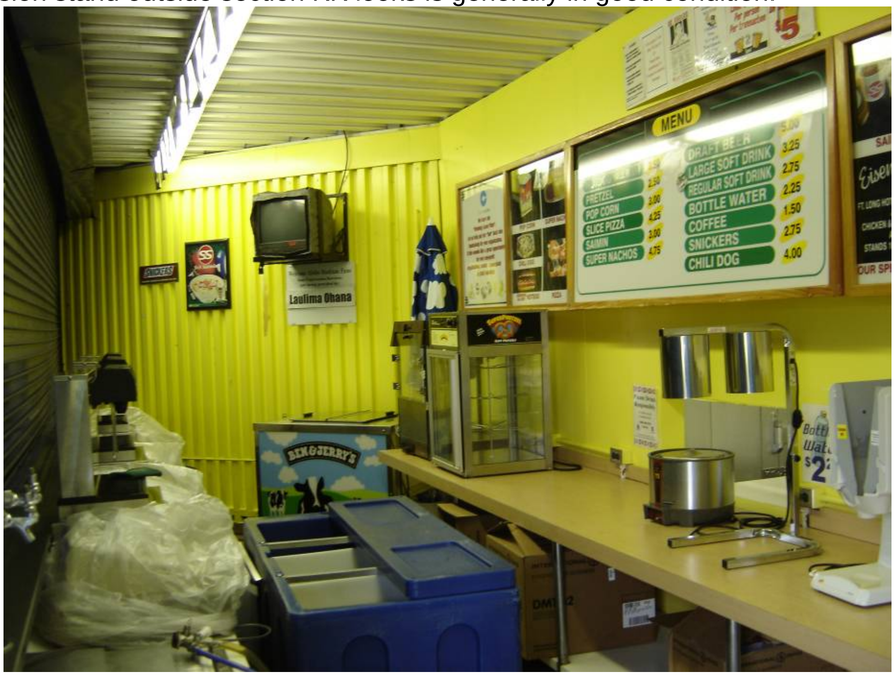
Concession stand next to Gate 1 with outdated use of graphics. Recommend replacement of concession signage as part of F4 or as part of Food Service operator contract requirement.

H1. Concession stand next to Gate 1 with peeling paint on soffit. Recommend a regularly scheduled maintenance program to address the painting of exterior building structures.

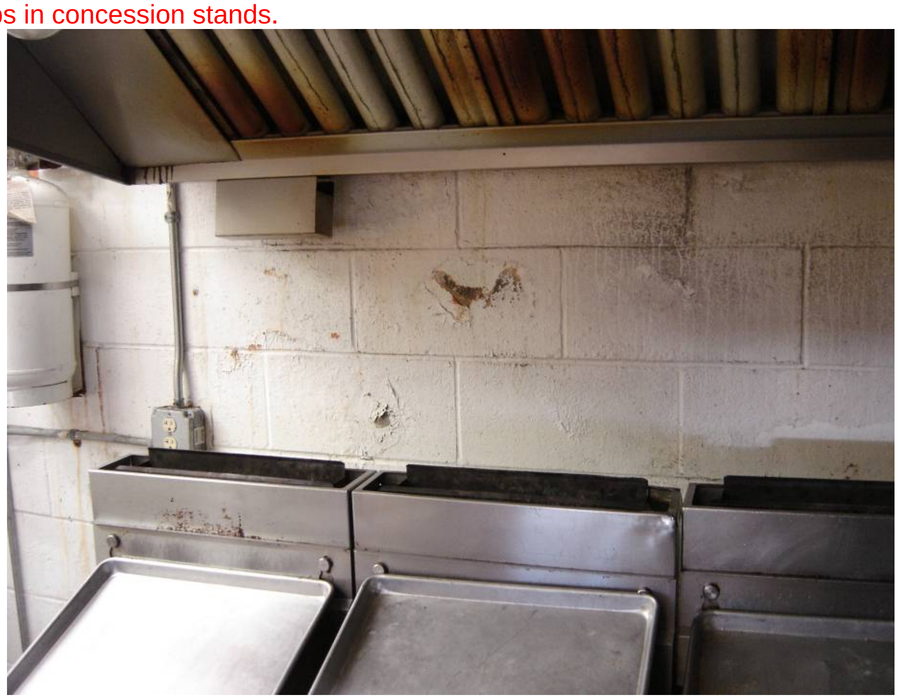
H2. Concession stand on the main concourse across from Gate 1 has a floor drain not flush with the floor so water cannot drain. This condition may possibly violate a state health code. Recommend lowering floor drain to allow flow to the drain.

Subway concession stand on main concourse by section KK is in good condition.

Concession stand outside section KK looks is generally in good condition.



Concession stand Gordon Birsch main concourse across from section AA needs general cleaning and maintenance. Recommend a regularly scheduled cleaning program to address dust and cobwebs in concession stands.

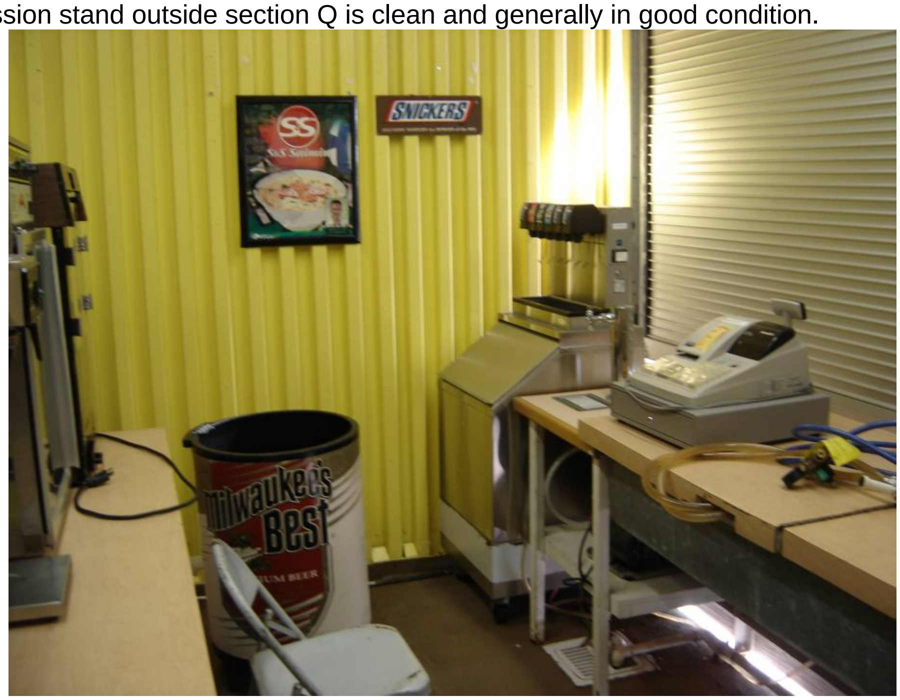


Isle Cone and Coffee stand is in good condition.

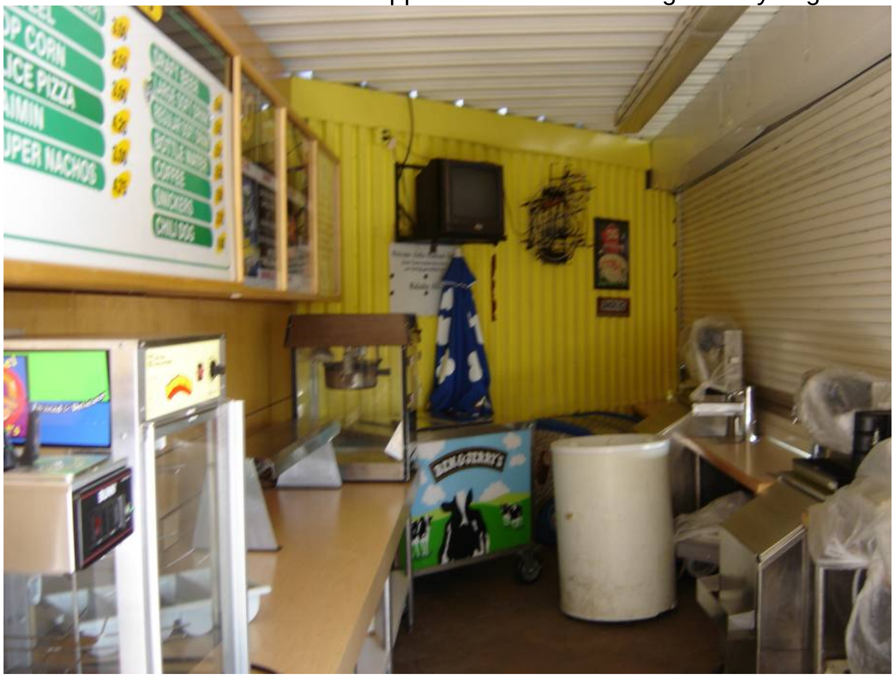
Concession stand outside section J main concourse is clean and generally in good condition.

Concession stand outside section K is clean and generally in good condition.

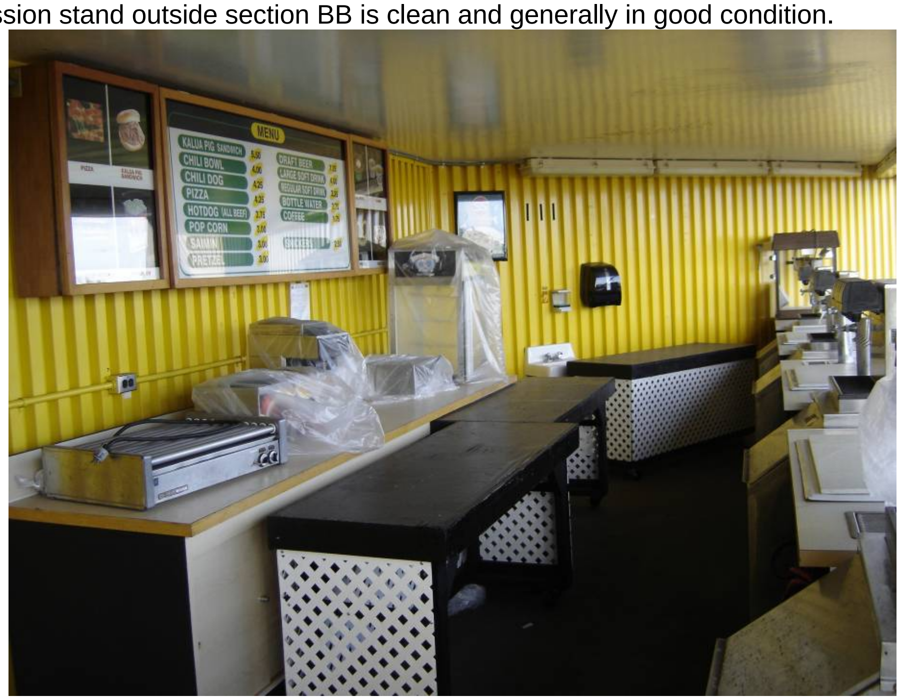
Concession stand outside section Q is clean and generally in good condition.



Concession stand outside section B on upper level is clean and generally in good condition.



Concession stand outside section BB is clean and generally in good condition.

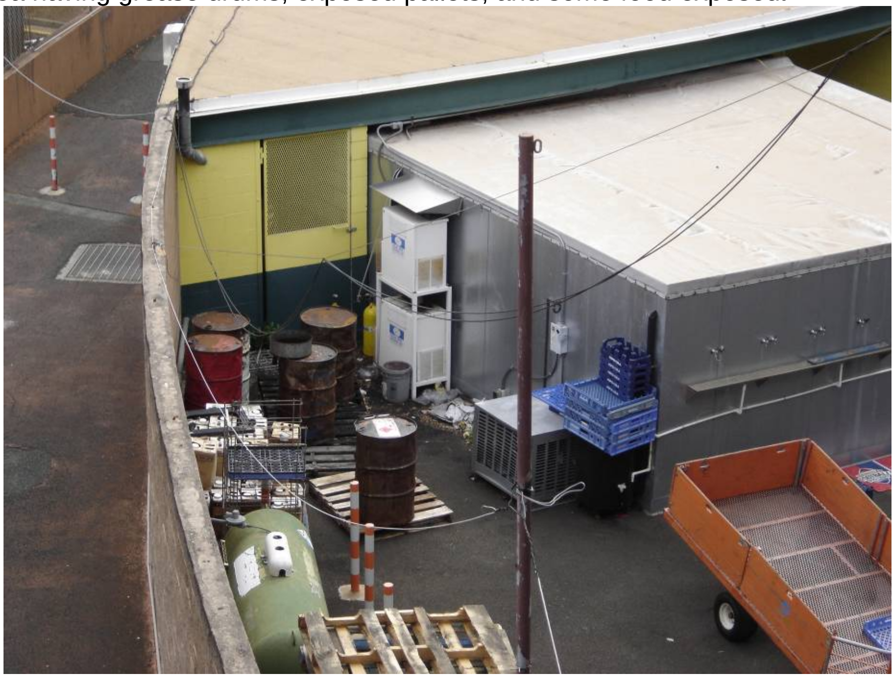


Concession stand outside section JJ is clean and generally in good condition.

Ice maker outside the Centerplate offices on the service level appears to be in working order.

Main commissary on the main concourse next to the Eisenberg Gourmet Foods concession stand across from section U. Recommend a review of cleaning procedures to address spills, dust and cobwebs in the kitchen areas.

Photo of the area outside the main kitchen for Centerplate, the food service operator, shows the back area having grease drums, exposed pallets, and some food exposed.



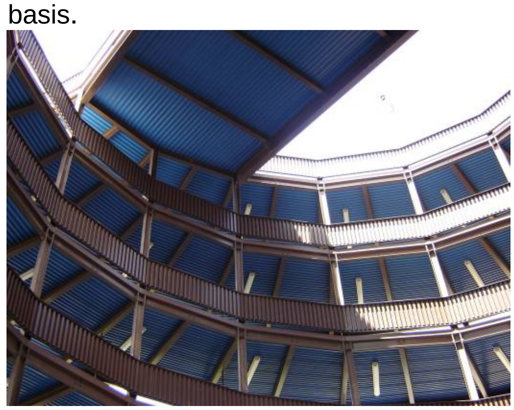
I. Ramps

Configuration / Stadium location – There are 4 double spiral pedestrian ramps in the stadium. One is located at each corner of the fixed north and south seating sections. These ramps tie into the 4 main stadium entries at ground level. Their location makes them accessible in both the baseball and football configurations.

I1. Walkway ramp A - area where floor surface has cracked and is pulling away. Recommend a review of maintenance procedures to address tears and cuts in rubberized floors surface.

Concrete and steel surface conditions – The concrete and steel on the ramps appear to be in good condition. The coating system also appears to be in good condition except for a few areas near the bottom of the ramps where it has be cut and damaged. This is probably due to a heavy amount of vehicle traffic using these ramps. The structural steel surfaces are showing some chalking and fading of the paint system used on them. This will become worse over time if they are not repainted. Recommendation – Repair coating system on ramp concrete surface.

I2. Repaint steel surfaces as needed on a regular basis.



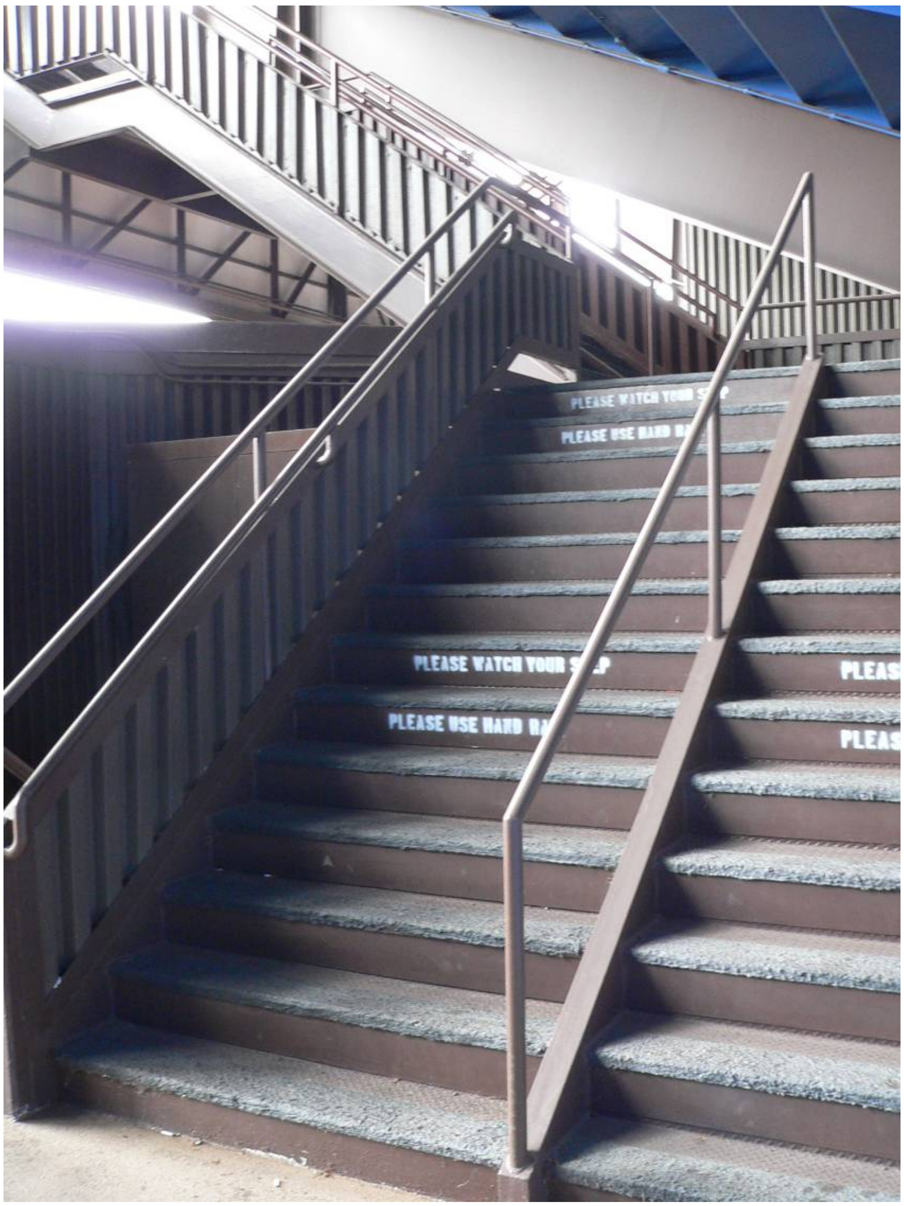
Railings – The ramps have a 3'-6" high solid metal siding guardrail mounted on each side with a handrail mounted to the inside of it. There is also a handrail mounted down the center of all of the ramps.

Graphics / signage – There is no graphics or signage installed on the ramps. Directional signage should be added as part of Item F4.

Lighting – All lighting at the ramps is very utilitarian florescent lights mounted above the concession and toilet openings. (See electrical portion of report for condition of lights.)

J. Stairs

J1. The main stadium exit stairs (1, 2, 3 and 4) connect the field level, main concourse and upper concourse and are located in the middle of each moveable seating section. Although an exit analysis is beyond the scope of this study, the size and distribution of exit stairs and ramps appear adequate. The stairs reportedly are not used heavily during football events. Most patrons circulate along the concourse to the ramp closest to their destination. Enhanced lighting, lighter paint color selection and graphics could increase their utilization. The stairs are generally in good condition. Recommendation: Recoat exposed steel railings and risers. Suggest lighter color for railings. Upgrade lighting and graphics. Nosings are in good condition.

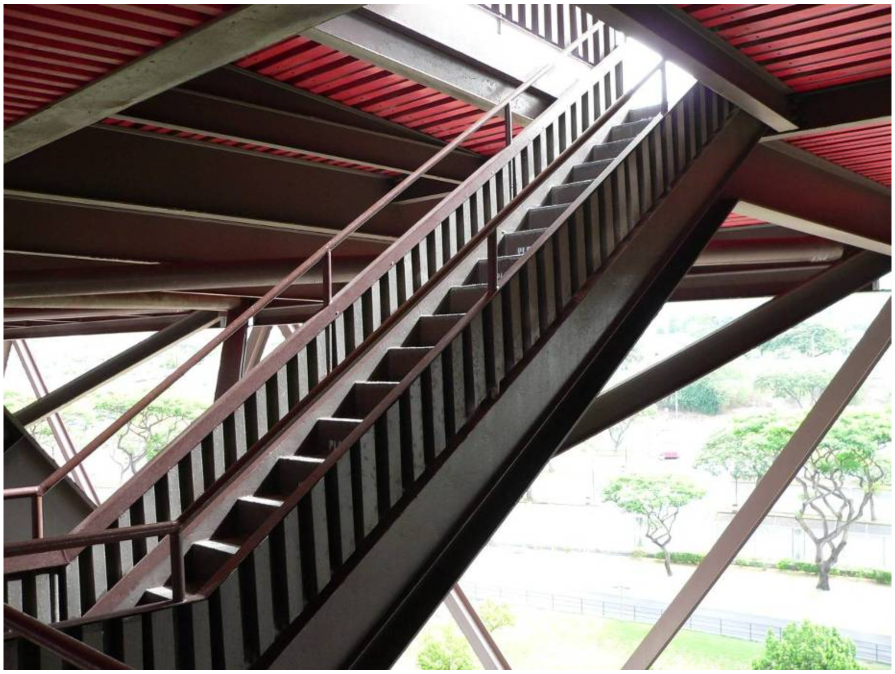


J2. Stair header beam needs a brighter color on flange to prevent guests from accidentally hitting their head. Recommend a comprehensive safety review of the facility to address areas for potential venue safety issues for guests.

Stair railings for the main stadium stairs (1, 2, 3, & 4) there are steel guard rails and handrails on each side of them. The guardrails are typically 3'-6" high and the handrails are 2'-10" high. Both of these heights are acceptable. The length of the handrails at the bottom of each stair run currently stop even with the last riser location. Per current code requirements these should extend 1'-11" past this point. The length of the stair handrails at the top are also too short. Currently they stop even with the top riser and should extend 12" past it. The guardrails have a top opening between the top rail and the ribbed metal siding infill of approximately 9" clear. There is another 9" clear opening between the bottom rail and the top of the stair landing. Neither of these openings meet current code requirements.

J3. For the back of house stairs (5, 6, 7, & 8) there is a center guardrail / handrail that is 2'-8" tall. Again this height does not meet the current code requirements. Recommendation – Lengthen the handrails at the top and bottom of the stair runs to meet current code requirements. Add additional infill rails or cabling to reduce size of gaps in guardrail system.

J4. Stairs between upper concourse and loge level concourse are open straight runs that occur at each seating section. These stairs, along with the bridges accessing the elevators in the endzones, are the only access points to the loge level. Recommendation: The side rails do not meet code and should be increased to the required 42" guardrail height to meet the code and provide a more secure feeling for patrons.



K. Elevators

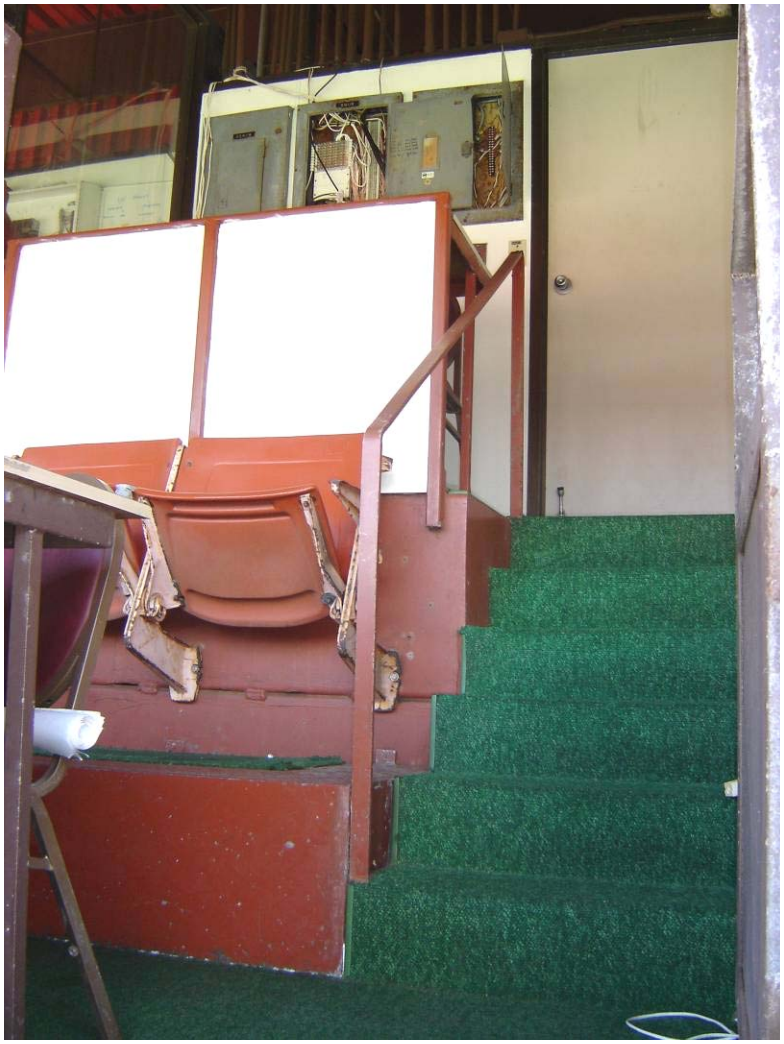
K1. Two freight elevators serve the stadium. These are utilized for passengers on game day and serve medical staff, VIP's, media and food service staff and supplies. The south elevator provides access for disabled patrons to various concourses. The cabs are in good condition for freight elevators, but do not project a positive image for passenger use. Recent inspection reports indicated they are in good working order. Recommendation – Add one bank of two passenger elevators to each quadrant serving the Loge Level at minimum and preferably, the Main and Upper Concourses for disabled patron and premium seating patron access.

L. Escalators

L1. One escalator is located on each sideline connecting the ground level to the main concourse. Reportedly, the west, makai, escalator in particular is shut down frequently during events due to water presence and other safety shut-off features triggered by overloading or rail pressure. The escalators are open to the sky, which is not permitted under current code regulations. Recommendation: Provide escalator canopy with sufficient overhang to prevent wind driven rain from entering the escalators. Canopy could provide advertising signage opportunity and could reduce some of the shutdowns of the west escalator.

M. Pressbox

M1. Stadium location – There are two separate press box locations at the stadium. One is for baseball and the other is for football. Both are located at the box seating level between the upper and lower concourses. The baseball press box is at the south end of the stadium. It has an open three-tier writing press area that seats approximately 50 people and 5 small booths. There is no front enclosure to the seating bowl in this press box. Because of this the finishes in this space are minimal and utilitarian. The football press box is on the west side of the stadium. It is split in half between the two moveable sections. It is also an open three-tier writing press area with nine enclosed small booths next to it. The finishes in the football press box are very similar to the baseball press box finishes. Size is minimal and there is not sufficient work area and break area for the press. Recommendation: Repaint painted surfaces on a five year basis and replace carpeting on a ten year basis.



M2. Media building access – The majority of the media access into the stadium on game day is through the south endzone security area where the rest of the stadium staff enters through. This is at the opposite end of the stadium from where the television truck compound is located. Once the media personal do enter the stadium they use the single freight elevator to go up to the press box level. This elevator is shared between the press, the concessionaire staff, building staff, and people using the elevator for ADA access to other levels. Typically most stadiums will congregate all press and media type functions and entry points to a single location. They will also usually be a dedicated elevator for the press to use before, during, and after the event to provide quick access between the press box and field levels. Recommend creating a single media entry location and adding a dedicated elevator between the press box and field level. This entry and elevator should be on the same side of the stadium as the football press box and should be as close as possible to the television truck compound.

M2. Vertical circulation to press box – The only vertical circulation to the press boxes is by the single freight elevator or by stairs to the press box level. Recommend adding a dedicated press elevator to be used by the press during events.

Interview space – There is a small interview space at the event level near the locker rooms. The condition of this space is similar to the rest of the spaces at that level. There is larger space to have interviews and press conferences in the large multipurpose hospitality space at the office level of the stadium.

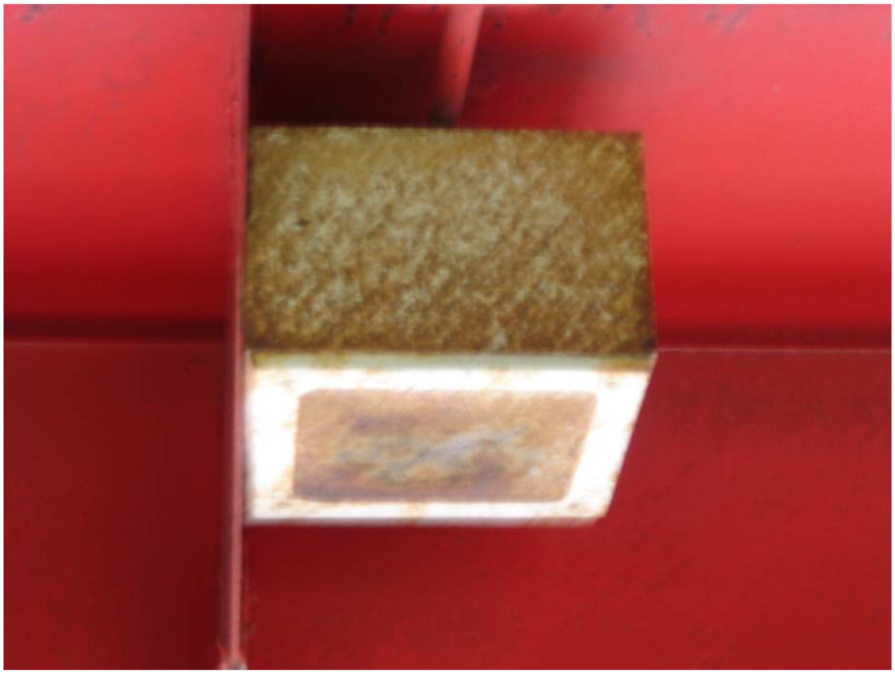
M3. Work room / food service – At both press box locations there is an open area where it appears catered food is located during an event to serve these spaces. There is not a large workroom at either press box. Recommend adding additional space at the press box for work space and additional break area for the press during or after an event.

M4. Toilets – There is a set of small individual toilets at both press boxes. These toilets are not sized sufficient to handle to the rush before or at halftime of a game. Recommend adding additional toilets for the press in or near the current press box location.

Sound control room – This space was not accessible during the site visit.

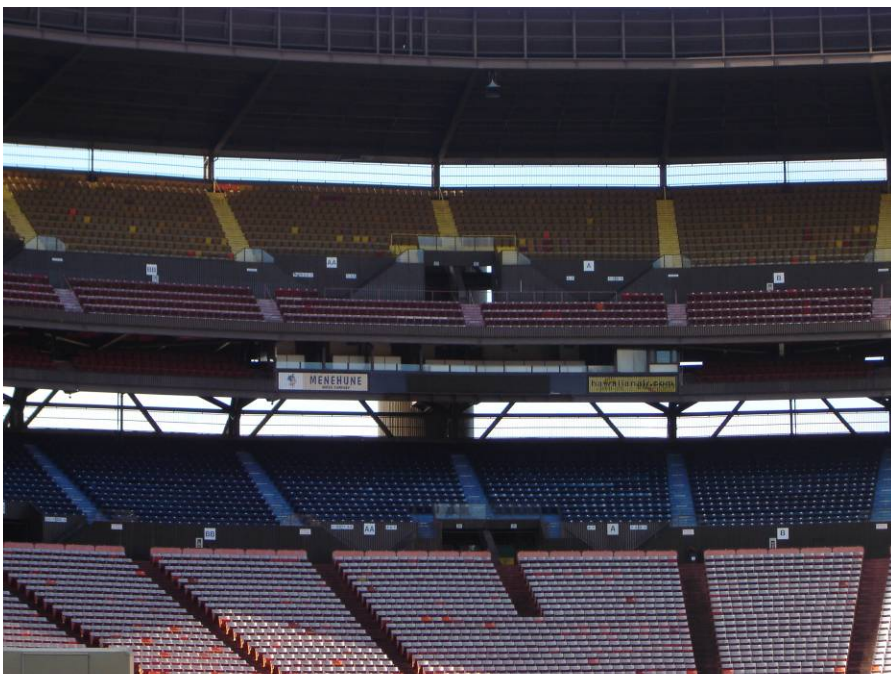
N. Scoreboard/Video/Audio
The sound system is in reportedly good functional condition. It is checked out and serviced annually.

N1. Section KK - speaker box is rusted and discolored and is representative of the exterior speaker boxes throughout the Loge Level. Housing needs to be replaced. Recommend a regularly scheduled maintenance program to address replacing or cleaning speaker enclosures.



N2. Systems function – The scoreboard system consists of a large matrix board and video board display at the north endzone in front of the box seats and lower tier seating sections. At the south endzone there is a small matrix display in front of the baseball press box. It appears the video board was manufactured by Sony and the matrix boards were manufactured by Daktonics. The boards and control system were installed in 1991 and are nearing the end of their useful life. Recommendation – Replace boards and control system with current technology. Incorporate increased advertising components to help fund costs.


Join the
MIDAS
OIL CLUB
PEPSI
GENTRY HOMES
SONY
THE power of yes.
verizon Hawaii
Just Say
NOH
Foods!
PRICE BUSTERS
Say Hello To Good Buys
NORTH


MENEHUNE

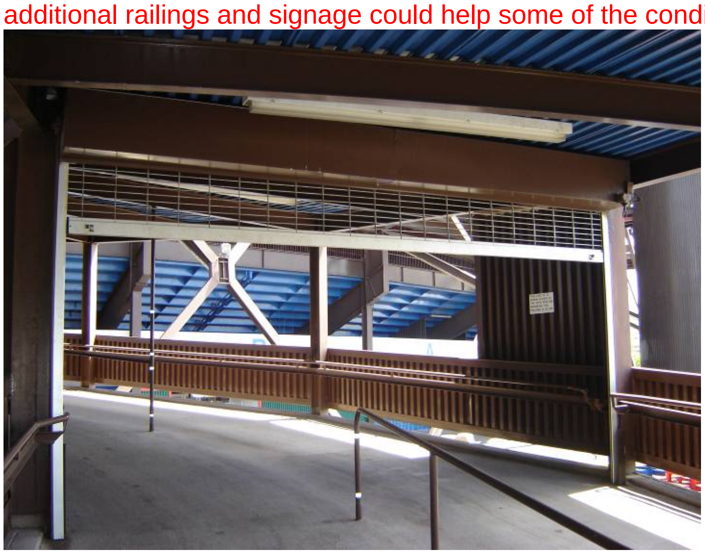
Control room condition - The location of the control room is at the box seats cross aisle / press box level and is inside the south scoreboard. The room is small and filled to capacity with scoreboard control equipment. There is a main level with a small front lower level that is accessed by a ships ladder. There are two windows with a view out to the playing field in front of this lower section. Since the control room is located inside the scoreboard itself there is no direct view of the scoreboard display. Instead, the operators must rely on a video camera mounted at the front of the football press box which is aimed towards the scoreboard which provides a view of what is being displayed. This is not an ideal situation but appears to serve the operators needs and has been done in some other older stadiums.

O. ADA Accommodation

As expected, given the age of the stadium, it does not comply with all measures of current ADA guidelines. An ADA compliance self assessment was completed after ADAAG was established. A consultant submitted reports to the State and reasonable accommodations were incorporated to comply with the new statutory provisions. The local ADA commission reviewed the proposed accommodations and reportedly approved the extent of modifications. The cost to bring the entire stadium into compliance could be prohibitive. Each non complying element should be assessed from a priority standpoint when other upgrades or improvements are made to the stadium to determine feasibility of incorporating accommodations into other improvements.

O1. Seating –There is ADA seating positions located at the top of the lower field seating sections and at the cross aisle between the lower and upper tier seating sections. There are no permanent companion chairs. Reportedly, temporary folding chairs are brought out for each event. The stadium seating manifest lists that there is a total of 418 wheel chair spaces in the stadium which does not comply with a 1% requirement. Based on the seating capacity of 49,583 there should be a minimum of 496 wheel chair spaces. Also the distribution of spaces is not equal throughout all of the seating areas as required. There are no ADA seating locations at the Loge box seating areas. The south endzone loge level is the only loge section accessible from the south elevator. The rest of the loge areas are not accessible. Recommendation – Add additional ADA seating locations at box seating areas. Add ADA access to this level.

O2. Circulation – The only vertical circulation through the building is from the ramps, four main stairs, or the south freight elevator. The ramps as constructed do not meet the current ADA requirements as they do not have a flat landing after every 30” of rise. The south freight elevator is one of only 2 elevators in the building and is the only one that stops at all levels of the building. This elevator does not have the capacity to handle all of the ADA and other (concessionaire, stadium staff, press, first aid, etc.) traffic during an event. Nor is it an inviting mode of transportation for disabled patrons. At the upper concourse there are ramps in the vomitories that lead from the concourse to the cross aisle between the upper and lower tier seating sections. The slope of these ramps are over the maximum allowed by the ADA nor do they have the required handrails mounted on the sides of them. This condition also occurs at the lower level vomitories where there are ramps from the concourse to the cross aisle. Recommendation – Correcting the above items will be a major undertaking. We recommend determining what level of improvements can be made to accommodate the highest priority ADA provisions. Minor improvements like adding additional railings and signage could help some of the conditions.



Other stadium functions and spaces – For most of the public spaces some level of provisions have been made to make them ADA accessible. There is at least 1 point of sale at every concession counter at an accessible height, in the restrooms there is at least one stall and lavatory that is accessible. Inside the stadium there is very little signage helping to instruct people to where ADA accessible provisions have been made. As for the back of house areas and the employee areas, there are some provisions made but less than in the public spaces. One example of this is the ramp between the stadium office level and the team locker room level. The slope of this ramp is over 12% and there are no hand rails mounted on either side of it.

O3. Ticket windows between Gates 1 and 2 are not ADA compliant. Recommend a renovation of exterior ticket booths next to gates as well as main box office area to conform to the ADA guidelines.

O2. Main Box Office windows are not ADA compliant. Recommend modification of one window to comply with ADA guidelines.

Aloha Stadium
Planning Study 2005

Mechanical/Plumbing/Fire Protection and Electrical Condition Observations

P. Mechanical, Plumbing & Fire Protection

The evaluation of the mechanical, plumbing, and fire protection systems is based on several visits made to the stadium as well as interviews with maintenance personnel.

P1. The fiberglass insulation throughout the stadium show that the vapor barrier jacket has water stains along with growth of mold and mildew in various areas. Our visual inspection shows that the chilled water, condensate drain, and hot water pipe and duct insulation should be changed. We recommend that the insulation for the pipes be changed to close cellular foam insulation. For the ducts, removed and reinstall new fiberglass insulation with VINYL FACED vapor barrier jacketing. The following are the areas the insulation should be changed:

P1a. Team locker rooms - piping only
P1b. Team Management Office $ Locker - piping only
P1c. Stadium Management & Ticket Sales - piping only
P1d. Mechanical Equipment room - piping, pumps, ducts and packaged AC unit
P1e. Sound booth @ Press Box area - ducts only

P2. HVAC systems are generally in good condition. Various areas require immediate attention. Built up chiller system appears to be providing the proper chilled water needed for the air conditioning system. Consideration should be made to reduce the chilled water supply temperature to assist in the deterring the growth of mold on pipes and in ducts. Except for units as listed below, it appears that the air conditioning units and exhaust fans could have another 5 to 10 years life span. Proper maintenance must continue.

P2a. Jumbotron AC unit is a 10 ton split system. This unit should be changed immediately. We recommend the use of two each 7 1/2 ton packaged units

P2b. First Aid room AC unit is a 2.5 ton roof top package unit. This unit should be replaced with new, of equal size.

P2c. Baseball Announcer room AC unit is a 1 ton packaged unit. This unit should be replaced with a new 1 ton split system unit.

P2d. North End Zone Maintenance Office AC unit appears to be approximately 2 1/2 ton water cooled unit. This unit should be changed to a 3 ton unit either split or packaged unit.

P3. General condition of the plumbing systems is favorable. Piping appears to be in very good condition. Water heaters and pumps, appear to be working well. Most of the plumbing fixtures operate as intended. There are areas where plumbing pipes show signs of exterior rusting. We recommend painting of the pipes.

P3a. Showers in both men and women's locker room require repairs and replacement. In various areas, water is continually leaking. In most cases new washers are all that's needed and should be changed in its entirety. Estimated cost to repair 75% of the shower valves and replace 25% with similar shower valves.

P3b. Various water closets and lavatories have running water problems throughout, but none seem major. Maintenance, service and repair can get all fixtures to operate properly.

P3c. Various water closets and lavatories have running water problems throughout, but none seem major. Maintenance, service and repair can get all fixtures to operate properly.

P4. Overall Fire Protection Systems appear to be in good condition. The piping appears to be in good condition and recently painted. The painting of the piping is good, but many heads had paint on them. Annual fire sprinkler testing must continue.

P4a. Sprinkler heads were found to have paint on it. All of which must be changed.

Q. Electrical

The below recommendations and replacement reflect, at this time without benefit of an electrical integrity study, the overall condition of Aloha Stadium based on our visual inspection and discussions with the Stadium's personnel on the worthiness of their electrical systems. Scheduled electrical integrity studies on Aloha Stadiums existing aged electrical systems would determine its ongoing worthiness. These scheduled studies would expose any existing but undetected, by visual inspection, any loose, overloaded, arcing over current devices and/or terminations.

Q1 Replace field sporting event lights.

Q2 Replace field lighting transformers.

Q3 Recommend existing hard wired fire alarm system be upgraded to current NFPA and ADA code compliant new addressable fire alarm system.

Q4 Recommend existing field sports event lighting controls be replaced with new mechanically held lighting contactors and control devices. Current equipment is obsolete and no longer readily available per stadiums' maintenance personnel.

Q5 Recommend electrical integrity study be performed to determine worthiness of the stadiums' electrical distribution system.
Electrical integrity study should consist of:

1. strip chart recording of various loads.
2. visual and thermal graphic inspection of secondary distribution.
3. visual and ultrasonic inspection of the primary distribution.

Q6 Aloha stadiums' personnel have concerns of circuit breakers tripping at concession stands. Recommend providing new distribution for concession stands. As stated in THE 1997 ALOHA STADIUM ELECTRICAL POWER DISTRIBUTION SYSTEM ASSESSMENT REPORT DAGS JOB NO. 22-10-0014 "..transformers are relatively lightly loaded." Pg 28. This statement would allow for this electrical expansion.

Q7 Aloha stadiums' personnel have concerns of parking lot lighting transformers reliability. Recommend electrical integrity study and replacement.

Q8 Aloha stadiums' personnel have concerns of needed additional parking lot lighting. Foot lighting calculations need to be done and compare to IES minimum. As stated in THE 1997 ALOHA STADIUM ELECTRICAL POWER DISTRIBUTION SYSTEM ASSESSMENT REPORT DAGS JOB NO. 22-10-0014 "..transformers are relatively lightly loaded." Pg 28. This statement would allow for this electrical expansion. Recommend extending required lighting from existing lighting infrastructure.

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Structural Conditions Observations

ENGINEERS
ARCHITECTS
MATERIALS SCIENTISTS

Part II – Condition Survey

Section R - Protective Coatings Systems

R.1. General Background on Corrosion at Aloha Stadium

R.1.1 Weathering Steel Framing

The original main structural steel framing of Aloha Stadium was fabricated with a high strength, low alloy steel known as "weathering steel" (ASTM A588), partly for its aesthetic characteristics and apparent "low maintenance". Weathering steel was produced by the major steel manufacturers in the U.S. with trade names of *Cor-Ten* (US Steel) and *Mayari R* (Bethlehem Steel). Weathering steel is intended to corrode after installation to form a dense, rust-colored patina. This dense, tightly adhered, relatively impermeable barrier layer (a relatively thick layer of corrosion product or 'rust') is intended to protect the underlying steel and reduce its atmospheric corrosion to a very slow or mitigating rate. Historically, weathering steel has been advertised as a material that stops corroding after the patina has formed and touted as "maintenance free" with no need to paint.

Weathering steel usage and performance is highly dependent on the environment to which it is exposed, and a less than suitable environment can cause ongoing or advanced corrosion, rendering the dense patina formation useless in mitigating the steel's own corrosion. Aloha Stadium is situated in a less than suitable environment that includes high humidity and exposure to a high level of airborne chlorides inherent in a marine environment. These conditions served to disrupt the "protective" mechanism of the patina and compromise the design intent of the weathering steel.

Consequently, the weathering steel at Aloha Stadium has not performed as intended, as evidenced by the past work at the stadium to address the corrosion issues. The weathering steel showed signs of corrosion issues initially in 1979, four (4) years after the structure was opened. Until a coordinated corrosion abatement program was undertaken in the mid-1980s, the corrosion had continued unchecked. The October 1995 structural certification report from Robert Englekirk Incorporated (REI) provides a good chronological history of the corrosion abatement program at the stadium from 1980 to 1995. As noted in the REI report, the past studies of corrosion of the weathering steel determined that the:

- The weathering steel was not performing as per the original design intent
- Significant corrosion was occurring above and beyond that of the protective patina layer formation

- Consequences of the advanced corrosion include section loss that could be compromising structural integrity
- Several inherent design conditions were conducive to promoting and accelerating the corrosion process. These conditions included debris and moisture collection points, such as stiffener pockets, connections, flat-laid members, and box-type member intersections (hubs).

As a result of these past studies, corrosion mitigation efforts – primarily in the form of painting and water shedding repairs – were conducted to extend the stadium's service life. In addition, a number of structural strengthening measures were implemented as a result of these studies and the discovery of section losses compromising structural integrity.

R.1.2 Coating System in General

Prior to discussing our observations of the coating system at Aloha Stadium, it is helpful to review typical coating systems and some of the various challenges typically encountered with the coating of weathering steel. A typical coating system for structural steel exposed to the exterior elements consists of a three-coat system having the layering sequence and typical thicknesses summarized in Table R1.

Table R1 - Typical Coating System Thicknesses

Coat or Layer	Typical thicknesses for this type of system (per coat, in mils)
Organic zinc-rich primer	2.0 – 3.5
Epoxy intermediate coat	3.0 – 5.0
Aliphatic urethane topcoat	2.0 – 3.0
Total system thickness	**7.0 – 11.5**

This system is typical for highway bridges and was specified for use at Aloha Stadium. The base coat in direct contact with the steel is a zinc-rich paint material that provides galvanic protection to the steel; in other words, it anodically protects the underlying steel. Galvanic action is addressed in Paragraph R.1.4. The epoxy intermediate coat provides barrier protection from moisture intrusion. By itself, it is capable of good abrasion, impact, and chemical resistance; however, because epoxy is not UV stable, it will chalk and discolor. Therefore, a urethane top-coat is used to provide UV resistance. It also provides an aesthetically pleasing surface, as well as added thickness for wear and to resist moisture penetration.

The weathering steel at Aloha Stadium was exposed to the elements for a number of years prior to receiving its first paint coating. As such, the steel surface became pitted due to corrosion caused by exposure to chloride-rich (salty), humid atmospheric conditions. Corrosive pitting of the steel surface makes the extent of steel section loss difficult to evaluate. Additionally, it makes

Figure R-1. View of a pitted weathering steel surface that was coated.

Figure R-2. Close-up view of recent weathering steel corrosion.

surface preparation and painting difficult. Figure R-1 shows a representative example of a heavily pitted surface that was coated. Figure R-2 shows an example of the nature of weathering steel corrosion, where heavy corrosion pitting and laminar corrosion planes are created.

Given the Hawaiian marine environment and the micro-climate at the stadium, salt becomes trapped in the depth of pits and coatings do not always penetrate the full depth. Consequently, the selection of coating products and methods of cleaning the steel must be very particular, as not all products and cleaning methods are suitable or equivalent in their performance.

Chloride is an issue for proper coating performance. Chloride deposition on the steel substrate prior to coating application will have adverse effects and can promote the following problems:

- Coating system blistering
- Adhesive failure
- Under-film corrosion
- Accelerated consumption of zinc (zinc-rich primers or galvanizing), as it anodically protects the steel.

When the steel was originally painted at Aloha Stadium, the chloride concentration on the steel surface was likely a design consideration. Some of the conditions we observed in the present study may be the result of the past painting efforts themselves or resulted from coating breeches that have allowed intrusion of salt-laden moisture.

R.1.3 Adhesion of Coating Systems

Layers of multi-coat systems, such as those applied to Aloha Stadium, are joined by adhesive forces to form a composite. The integrity of the individual layers is maintained by their internal cohesive forces. Because the individual coating layers are joined, applied stress may be transferred from coating layer to coating layer within the composite. Therefore, if a multi-layered coating system is subject to sufficient external force, such as that imposed by changes in temperature or humidity, the resulting stress will be dissipated by disruption of the composite at its weakest point.

Failure can occur adhesively across a coating-to-coating interface, or cohesively within one of the coating layers. Cohesive failure may be lateral, appearing as delaminations and splitting of the affected layer; alternately, the failure may be vertical, appearing as checks or cracks in the multi-layered system.

Coating layers based on different binder types have different cohesive and adhesive characteristics. Differences caused by coating layer aging (even though initially they may have been generically the same) can also lead to different cohesive and adhesive characteristics. Therefore, the various coating layers are not equal in their resistance to external stress, nor are they equal in contraction and expansion characteristics. Additionally, external and internal stresses in the coating system may be derived from shrinkage, expansion, or both.

When evaluating an existing coating condition, the physical test results on the present coating system are paramount. The ability of a coating to resist removal from a substrate is an important coating property. Intact coatings must be tightly adhered, not too thick, and not too brittle. Systems failing to meet these criteria are not good candidates for new or additional overcoating.

R.1.4 Galvanic Corrosion

When designing for exterior metal exposure in the Hawaiian marine environment, it becomes necessary to pay attention to dissimilar metal corrosion. The Hawaiian marine climate is very aggressive; salt is present at relatively high levels in the humid air. Consequently, the salt is readily deposited on exterior, exposed surfaces and forms corrosive electrolyte concentrates to promote galvanic corrosion.

At Aloha Stadium, several dissimilar metals were used and are in contact with one another, thus leading to the potential for galvanic corrosion. Many of these dissimilar metals were introduced into the stadium as part of the corrosion abatement program of the 1980s and early 1990s. Dissimilar metal isolation mechanisms were used in some cases, but with apparent limited success. Significant corrosion attributed to dissimilar metals was observed. In one instance, the fasteners that secure the metal roof deck to the structure have fractured due to apparent galvanic corrosion, bringing about concerns regarding the structural integrity of the roof.

All metals have an electro-motive potential and, given the proper conditions, one metal will tend to corrode in the presence of another metal. Under such conditions, one metal will become the anode (corrosion occurs) and the other will become the cathode (more resistant to corrosion or at least partially protected by the anode). Oftentimes when a design requires dissimilar metal contact, the galvanic compatibility is managed by finishes, such as painting or galvanizing, or through isolation means, such as barrier coatings or inert (plastic, neoprene) washers or spacers. The finishing or isolation material selected prevents the dissimilar materials from being in contact and protects the base materials from corrosion.

Table R2 - Anodic Index

Metals / Metallurgy	Index (V)
Gold, solid and plated, Gold-platinum alloy	0.00
Rhodium plated on silver-plated copper	0.05
Silver, solid or plated; monel metal. High nickel-copper alloys	0.15
Nickel, solid or plated, titanium an s alloys, Monel	0.30
Copper, solid or plated; low brasses or bronzes; silver solder; German silvery high copper-nickel alloys; nickel-chromium alloys	***0.35***
Brass and bronzes	0.40
High brasses and bronzes	0.45
18% chromium type corrosion-resistant steels	0.50
Chromium plated; tin plated; 12% chromium type corrosion-resistant steels	0.60
Tin-plate; tin-lead solder	0.65
Lead, solid or plated; high lead alloys	0.70
Aluminum, wrought alloys of the 2000 Series	***0.75***
Plain carbon and low alloy steels	***0.85***
Aluminum, wrought alloys other than 2000 Series aluminum, cast alloys of the silicon type	***0.90***
Aluminum, cast alloys other than silicon type, cadmium, plated and chromate	0.95
Hot-dip-zinc plate; galvanized steel	***1.20***
Zinc, wrought; zinc-base die-casting alloys; zinc plated	***1.25***
Magnesium & magnesium-base alloys, cast or wrought	1.75
Beryllium	1.85
Source: http://www.corrosionsource.com/technicallibrary	

One measure available to aid in the control of galvanic corrosion is to consider the "Anodic Index" of the metals in contact, presented in Table R2. For design, the following guidelines have been suggested in the literature to control galvanic action:

- *Harsh environments*, the Hawaiian marine environment present at Aloha Stadium would fit into this category; that is outdoors, high humidity, and high chloride (salt) environment. Typically there should be not more than 0.15 V difference in the "Anodic Index". (For example; a gold - silver combination would have a difference of 0.15V, thus being acceptable).

- *Normal environments*, consistent with storage in warehouses or non-temperature and humidity controlled environments, should typically not have more than 0.25 V difference in the "Anodic Index".
- *Controlled environments*, such that are temperature and humidity controlled, a 0.50 V difference in the “Anodic Index” can be tolerated.

The highlighted metals (italicized bold) in Table R2 apply to the conditions at Aloha Stadium. As a relevant example, galvanized steel was employed in various locations throughout the stadium. This table indicates that the hot-dip galvanized steel will likely corrode in the presence (and electrical contact) of normal carbon steel if the galvanized steel is exposed to the environment (e.g. 1.20 - 0.85 = 0.35V, which is greater than 0.15V, the recommended difference to control galvanic corrosion in harsh environments). The zinc becomes the sacrificial anode in this couple and will corrode or be consumed, forming a white corrosion by-product.

R.2. Field Survey Observations

R.2.1 General

In recognition of the past problems at the stadium with respect to corrosion damage of the weathering steel and the subsequent painting of the steel, WJE’s field investigative efforts for the structure and structural integrity focused on the condition of coatings applied to main structural members, the presence of corrosion (if any) on these members, and commensurate section loss (if any) on these members. The nature and location of each type of deterioration was documented on appropriate field sheets and supplemented with photographs. Given the conditions we observed, WJE established a visual rating system for the present coating system to quantify its condition and the type of rehabilitation work we felt was necessary; this rating system also facilitated the preliminary cost estimates (see Part IV) of repair needed for budgeting purposes. The rating system is summarized in Table R3 and discussed in greater detail in Section S.

Other conditions relating to deterioration or structural performance were also noted and documented. In particular, these items consisted of adding weep holes and the observed condition of the epoxy fillers used previously as a means to shed water in pocketed areas.

In addition to the global review of the paint condition throughout the stadium bowl, WJE performed limited in-depth studies of distressed coating areas. These studies were used to gain a better assessment of the particular observed condition and the possible cause of the deterioration or distress in the coating system at the particular location. In some coating failure areas of the

Table R3 - WJE Field Rating System

Coating system	Estimated Level of Rehabilitation
P0	Power wash
P1	Power wash and top coat
P1+	Power wash, local repairs, and topcoat only
P2	Power wash, local repairs, three coat system
P3	Power wash, sandblasting, and three coat system
P4	Power wash, sandblast, three coat with structural repairs, or complete replacement (if more economical)

structure, certain types of recurring defects or deficiencies were detected, and generally consisted of the following:

- Incorrect coating sequence
- Low tape adhesion test results
- Coatings are relatively brittle
- Pinholes are present
- Chalked coating layers
- Coating layer(s) has excessive thickness
- Coating layer(s) has low thickness
- Edge corrosion on structural steel members
- Coating loss on structural steel members
- Rust nodules (formerly pinhole)
- Deteriorated coating with a weak boundary layer

A summary of the conditions observed during the field investigation is described in the following sections.

R.2.2 Observed Coating Sequence

The conventional coating sequencing addressed in Paragraph R.1.2 appeared to be followed in a broad sense for most of the detailed survey areas. However, we did find some locations where the coating sequence was incorrect, thereby adversely impacting the long-term performance of the coating. Table R4 shows two examples of coating mis-sequencing and the actual layer constituents. In the case of Example 1, the zinc-rich primer was not in contact with the steel substrate, and hence not providing the beneficial galvanic action that it is intended to provide.

Table R4 - Coating Sequence Observations

Specified Sequence	Example Sequence 1	Example Sequence 2
Zinc-rich primer	Epoxy intermediate coat	Zinc-rich primer
Epoxy intermediate coat	*Zinc-rich primer	Epoxy intermediate coat
Urethane topcoat	Urethane topcoat	*Zinc-rich primer
		Urethane topcoat

* ***Note:*** *Zinc-rich primer does not function when it is not in contact with the steel substrate.*

In the surveyed areas, the intermediate coat was either colored orange or white, apparently representing coatings from two different manufacturers applied in different phasing sequences. In addition, a Soya alkyd-based coating was observed being used for touch-up and repairs. This coating does not have the characteristics or durability to match the original three-coat system applied to the steel.

Below the stands, we also noticed a difference in the coatings. Below the East Moveable Stands, it appeared the full three-coat system was applied to the steel, as the top coat was brown colored. In the West Moveable Stands, the weathering steel framing beneath the stands apparently had only the primer coat and white colored epoxy intermediate coat applied. Evidently, the lack of UV exposure in this area below the stands led to a reduced coating on the steel, possibly as an economic savings at the time the steel was painted.

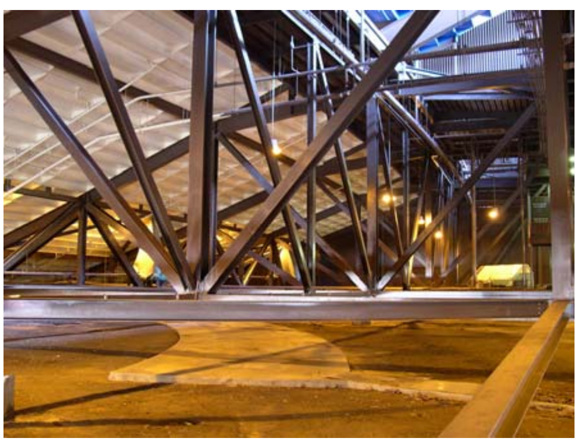


Figure R-3. Three-coat system observed beneath the East Moveable Stands.

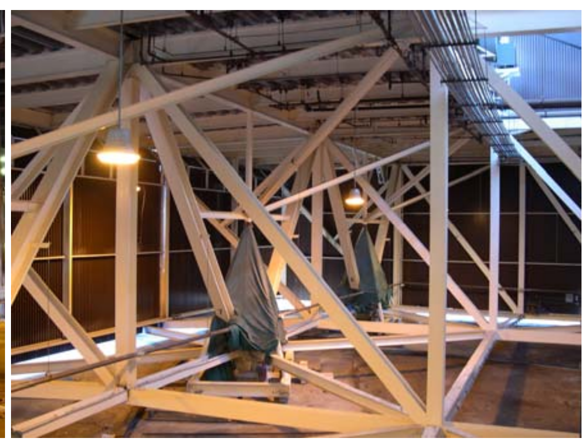


Figure R-4. Two-coat system observed beneath the West Moveable Stands.

When various areas of the steel in the structure are being readied for maintenance coating, the existing coating system should be thoroughly reviewed for coating types and for instances of improper coating sequences. Incorrect existing coating components and incorrect coating layer sequence will influence how the maintenance coating system will be applied.

R.2.3 Observations Regarding Adhesion

To review the coating adhesion, WJE performed coating adhesion tests in accordance with one accepted industry standard, Method A of ASTM D3359, *Standard Test Methods for Measuring Adhesion by Tape Test*. In this test, a prescribed set of patterned cuts is made in the coating system down to the substrate with a sharp razor blade. A standard adhesive tape is firmly applied to the patterned cuts and then pulled from the cut paint-surface. The relative degree of adhesion is assessed based on the amount of coating removed after tape removal. The rating system used in this standardized test is summarized in Table R5.

Table R5 - Coating Adhesion Test Ratings

Rating	Description
5A	No peeling or removal
4A	Trace peeling or removal along incisions or at their intersection
3A	Jagged removal along incisions up to 1/16 in. on either side
2A	Jagged removal along incisions up to 1/8 in. on either side
1A	Removal of most of the area of the X under the tape
0A	Removal beyond the area of the X

Areas of apparent distress typically demonstrated low adhesion results of Rating 3A or less. Some of the worse adhesion results were demonstrated on some of the coated structural steel in the East Stands area (see Paragraph R.2.6).

The coating system below the movable East Stands appears to be in good condition. However, the coating system was applied very thick and, when tested, demonstrated marginal adhesion (Rating 3A) in two of the three areas tested. Additionally, the coating tends to be pliable in this area, perhaps the consequence of the excessive thickness.

Adhesion tests conducted in areas where the coating was generally intact and demonstrated lesser deterioration gave results of Rating 4A and above.

R.2.4 Pinholes

Pinholes were observed in the coated surfaces of several areas. Pinholes provide an immediate path for intrusion of chloride and moisture. The consequence is corrosion of the steel beneath the coatings. Figure R-5 illustrates rust nodules on the top flange of a beam under the East Stands, which are the consequence of chloride penetration into pinholes. Figure R-6 shows a more advanced consequence of the corrosion that developed.

Figure R-5. Close-up view of pinholes in the coating

Figure R-6. Close-up view of pinholes in the coating where rust has developed.

The conditions illustrated in Figures R-7 and R-8 show more advanced underfilm corrosion, and the paint blisters and pitting that result from these coating breaches. In Figure R-7, the zinc-rich primer is being consumed, causing the white colored corrosion around the corrosion pits.

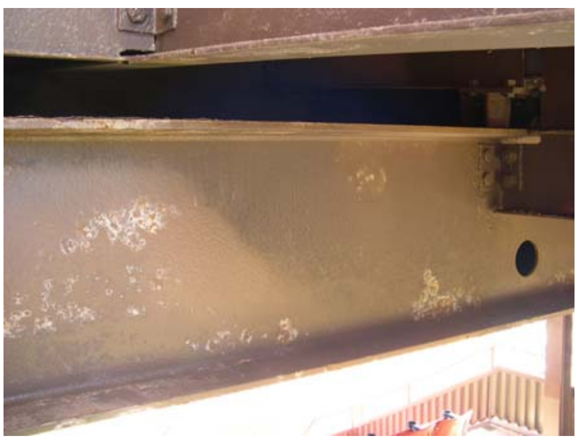
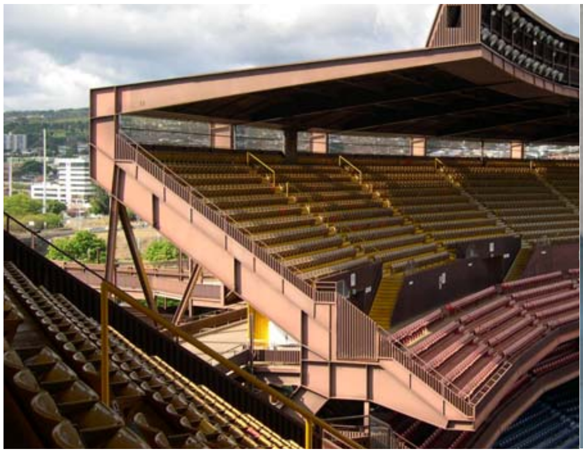


Figure R-7. Coating blisters, steel pitting, and white corrosion from the zinc-rich primer.

Figure R-8. Paint blistering observed on a diagonal flange interior.

R.2.5 Surface Chalking

The topcoat was chalked and discolored in various areas. Infrared analysis of the topcoat indicates that its binder contains an aromatic component. Coatings with an aromatic component are not generally UV resistant and therefore prone to chalking. Figures R-9 and R-10 show examples of a chalked coating, which has a dull hue.



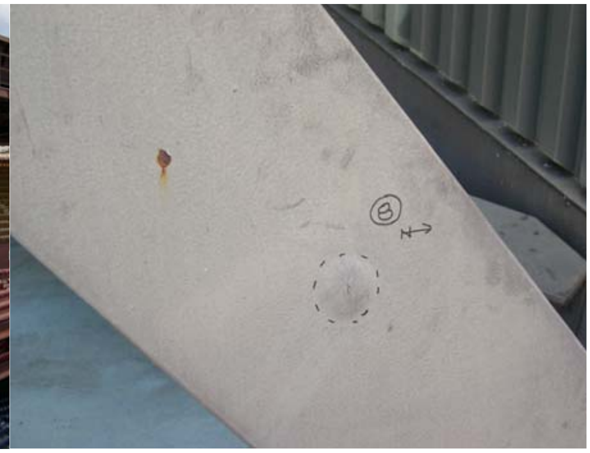


Figure R-9. Chalked coating on a raker bent of the upper level

Figure R-10. Close-up view of the chalked coating on a diagonal member

R.2.6 Top Coat Durability

In several areas of the East Stands, the effect of sunlight on the topcoat has led to the formation of a thin, poorly-bonded (Rating 0A, the lowest rating), deteriorated layer of topcoat. Structural steel edges exhibit the exposed intermediate coat due to erosion of the topcoat layer, as shown in Figures R-11 and R-12. In both photographs, the white epoxy intermediate coat is showing through.

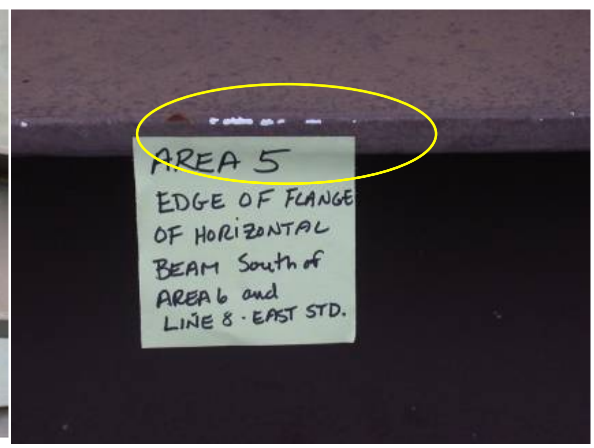


Figure R-11. Thin top coat observed on the flange tip.

Figure R-12. Close-up view of the thin top coat at the tip of a flange.

R.2.7 Coating Thicknesses

In some areas, coating thickness was measured to be high or excessive. An example of an area containing average high coating thickness is given in Table R6 for an area below the East Stands. High coating thickness regions were identified in localized areas. As discussed later, excessive or high coating thickness can shorten the life span of a coating due to built-up stresses.

In contrast to high or excessive coating thicknesses, in some areas the coating thickness was fairly low. An example of average low thickness is given in Table R6 for the corrugated metal wall panels on the stadium interior. Thin coatings can have numerous thin spots and pinholes leading to chloride penetration and corrosion of the metal beneath the coating.

Table R6 - Coating Thickness Observations

Coat or Layer	**Thickness** (per coat, in mils)		
	Typical "normal"	**Example "thick coat"** (below East Stands)	**Example "thin coat"** (corrugated panels)
Zinc-rich primer	1.8	4.1	0.10
Epoxy intermediate coat	4.0	5.9	0.22
Aliphatic urethane topcoat	2.5	4.1	0.49
Total system thickness	9.3	14.1	0.81

R.2.8 Miscellaneous Observations

Edge corrosion - Edge corrosion on the flange tips of the structural steel was frequently observed, shown in Figures R-13 and R-14. The coating at edges is often thin due to increased surface tension effects around the 90° corners as the coating system cures. Thin coatings are more susceptible to penetration by chloride and moisture, which can later result in corrosion.

Figure R-13. Advanced flange tip corrosion observed on a roof beam in the upper balcony.

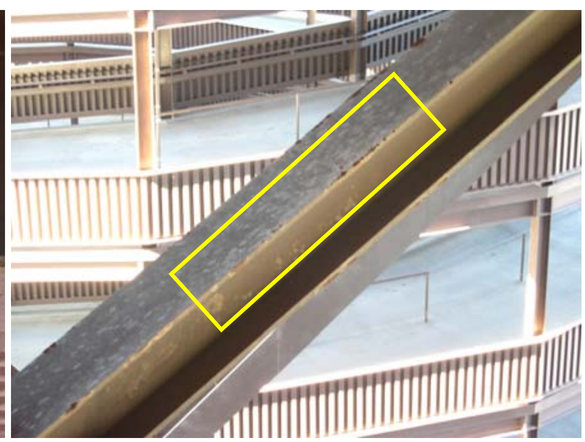


Figure R-14. Flange tip corrosion observed on a diagonal bracing member.

Corrosion patches - A variety of random occurrences were observed on the structure with notable areas of corrosion and coating loss. Figure R-15 illustrates an example of such an area; the corrosion shown occurs at the end of a diagonal element where water and contaminants wash down and inundate the coating. In this particular area, the coating system was up to 70 mils thick, chalked, and brittle. Figure R-16 shows corrosion on a beam web laid flat, which tends to collect water.

Figure R-15. Brittle failure of a thick coating layer, exposing the underlying steel.

Figure R-16. Cracked coating on a beam web that led to underfilm corrosion.

Maintenance painting - Repair of localized failures has been attempted with limited success. Coincidently, a number of maintenance painting areas were observed to be only within "arms reach" of the nearby access. Regions requiring maintenance painting in difficult access locations tended to be avoided or missed entirely. Figure R-17 shows a typical maintenance painting repair where corrosion is apparent at the periphery of the repair. Coating compatibility was another issue observed in the field. Figure R-18 shows apparent repainting of a corrugated wall section with a reddish-brown paint has resulted in a peeling failure.

Figure R-17. Corrosion observed at the periphery of a repair area.

Figure R-18. Incompatibility of the maintenance paint over a corrugated panel.

R.2.9 Galvanized Steel Performance

Galvanized steel elements were installed as part of structural repairs in the 1980s and 1990s. The zinc protective coating is typically being consumed in this aggressive environment, which is the expected performance for this coating. Figures R-19 through R-22 show examples of white corrosion product bleeding through the painted elements. On Figure R-20, the trough for the roof gutter is lined with copper. Therefore, the corrosion shown in Figure R-20 could be at least in part due to galvanic corrosion of dissimilar metals.

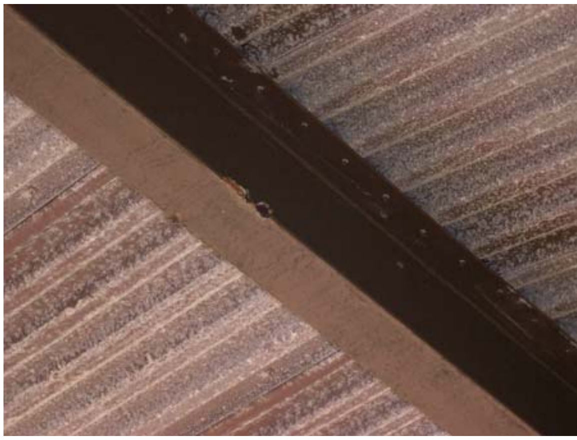


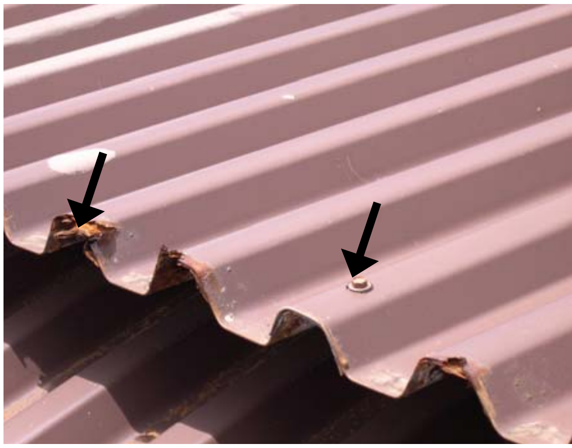
Figure R-19. Typical metal roof deck corrosion

Figure R-20. Metal roof deck corrosion beneath the gutter trough on the roof.

Figure R-21. Overall view of the underside of a roof deck showing the extent of roof deck corrosion.

Figure R-22. White corrosion bleed through on a painted pipe brace member.

Figures R-23 and R-24 show conditions observed at the top surface of the metal roof panels. Here, stainless steel screws are used to fasten the metal roof deck to the underlying weathering steel structure. The metal roof panels are typically galvanized steel, although aluminum panels were used at some locations. Figure R-24 shows apparent galvanic corrosion of stainless steel screw fasteners used with aluminum roof panels. At other locations, the fasters have fractured due to corrosion.



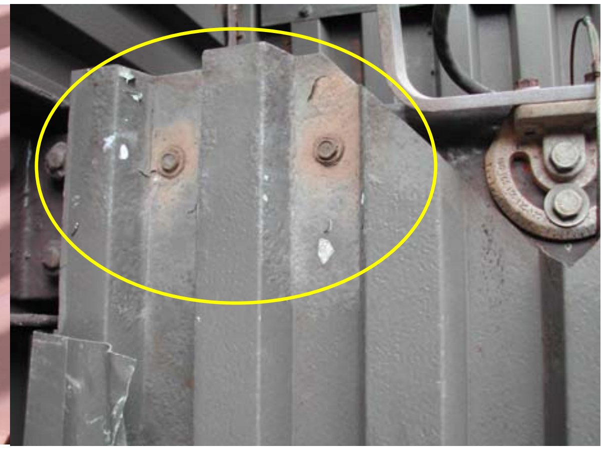


Figure R-23. Metal roof deck corrosion along the panel edge. Note the corroding galvanized fastener even with a neoprene washer.

Figure R-24. Corrosion of the galvanized fasteners and aluminum deck panel in the light enclosures.

R.2.10 Polymeric Filler Materials

Polymeric “filler” materials were used in pockets and at depressed areas in the steel. The fillers are intended to relieve ponding and to provide corrosion protection. These were primarily located at hubs on the external space frame and at connection nodes on the interior space truss.

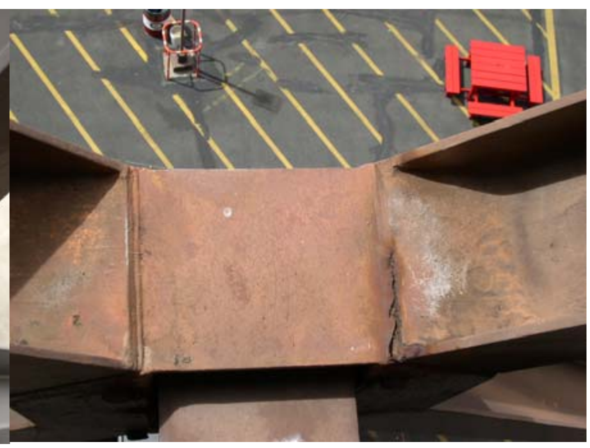


Figure R-25. Cracked coating over a hub pocket filler.

Figure R-26. Cracked coating and corrosion observed at a hub pocket filler.

The fillers at a number of the hubs and connection nodes have localized failures. At the lower hubs, the “polymeric” filler seemed to have more evidence of distress. Figures R-25 and R-26 show breaches of the coating system applied over the “polymeric” filler and general failure of the coating on the horizontal steel surface. Figures R-27 and R-28 show other conditions where the paint and underlying “polymeric” filler have cracked or are exhibiting crazing type cracking. Cracks in this barrier typically were accompanied by rust stain bleed-through, thus indicating corrosion has developed beneath the filler materials at some of these locations. The exact filler materials previously used remain to be identified.

Figure R-27. Crazing type cracks in the coating at a hub pocket.

Figure R-28. Close-up view of the cracked coating and corrosion at a hub pocket filler

R.3. Recommendations

R.3.1 Current coating system

Much of the current coating system on the Aloha Stadium appears to be adequately protecting the weathering steel at this time. However, it may continue to do so for only a limited period of time, depending on the coating condition and its exposure location. Throughout the stadium, localized failures have occurred in the coating system. Presently, the east side has more coating system problems than the other areas. It is important to recognize that exposure varies within the stadium, bringing about microclimate effects throughout the structure.

The manifestation of failed or distressed coatings will become more prevalent, and areas currently corroding will continue to do so, with the severity and extent of corrosion increasing. The service life of the present coating is essentially exhausted, and deterioration of this coating has initiated. Clearly, the first maintenance painting of the stadium is overdue. Further delay of maintenance painting could result in greater difficulty, time, and expense to remediate the coating system as it continues to deteriorate further. For example, areas suitable for overcoating at this time may become candidates for full replacement if deterioration continues unabated. Additionally, corrosion-related deterioration progresses at an accelerating rate, not at constant rate.

Based on the visual and physical evidence gathered in the field, overcoating of the steel structure is recommended at most locations. However, there are risks associated with overcoating and it is important that these risks be minimized with further in-depth, investigative work prior to painting.

A possible risk associated with an overcoating strategy is the potential for premature failure of the coating system, which could result from a variety of problems. Common problems include incompatibility between existing and new paints, such as disruption of coating system integrity due to stress imposed by new coatings; osmotic blistering from soluble salts trapped at coating interfaces; marginal surface preparation; or excessive undercutting by over coated rust. Unfortunately, overcoating performance issues usually do not occur immediately after application. Rather, the issues often occur months or even years after application, due mainly to external stresses from temperature or humidity changes typically encountered during the early service life.

In employing an overcoat strategy for the steel, another issue that must be considered is the coating thickness. A thick coating exacerbates the built-up internal stress of a coating system. A higher degree of risk is usually associated with overcoating existing conventional coating systems that approach 20 mils in thickness. As described earlier, shrinkage stresses in a coating can increase until they exceed the force of adhesion of the coating system to the substrate, or cohesive force between or within coating layers. This is of more concern where the coated surface experiences a substantial temperature variation.

These issues will have to be addressed in the future by performing additional testing in specific areas to be coated. Condition assessments of the existing coatings presently on the structure in the specific areas are important and imperative in further studies to determine whether they can support the application of new coatings. This primarily involves an assessment of the existing coatings to determine if they are still tightly adhered, not too brittle, and not too thick. Assessment of the extent and degree of coating deterioration and visible corrosion are also valuable. It is generally considered to be more cost effective to clean the entire structure when it demonstrates more than 20 percent corrosion, as opposed to spot cleaning.

Recall, the multiple contract phasing of prior work in previous years has led to the apparent use of different coating brands on the steel, as well as other variables. Different brands of products were used with differing performances observed in the microclimates to which they were exposed. It will be important to determine what was done, where, when, what product, and application quality of prior work.

R.3.2 New coatings

The coating system selected for new steel, or existing steel where the existing coatings have been removed, must obviously be capable of resisting the local environment to protect the steel. The stadium essentially experiences a marine or industrial exposure, and any new steel or fully sandblasted steel should use a zinc-rich system similar to the original protective coating system applied to the stadium in the 1980s and 1990s.

There are commonly two types of zinc-rich coating systems - inorganic and organic. On normal steel surfaces, organic, zinc rich systems are thought to be not as effective as a well-applied, high-quality inorganic zinc-rich system. However, the track record of the organic system on this structure and other weathering steel projects reported in the literature indicates good performance. Organic zinc-rich systems are more forgiving of the substrate conditions inherent with weathering steel and operator error, thus holding down installation coats. Weathering steel knowingly has local areas of corrosion pitting and other surface imperfections. Surface preparation should include removal, by power washing, of all contaminants including chlorides (from environmental exposure in Hawaii) and sulfates from the surface, and sandblast surface preparation in accordance with SSPC SP-10. Specification provisions dealing with the cleanliness of the substrate prior to painting must address chloride remediation as best as possible.

Providing additional protection to edges and crevices is also crucial. As was exhibited on some wide-flange sections in the stadium, these areas are typically the first to corrode, as they are difficult to paint with an appropriate film thickness or build. Most coatings shrink upon cure and areas most affected by this phenomenon are edges, illustrated in Figure R-29. The shrinkage stresses of coating cure draw the coating away from edges leaving the area minimally covered. Crevices require special attention as the coating needs to be worked to completely flow into and seal these surfaces. Adding body or film thickness edges can be accomplished by stripe coating. A stripe coat is an additional paint coat applied specifically to edges, crevices, welds, nuts and bolts. Applying a stripe coat in these areas provides additional protection and thus additional assurance that a continuous barrier is achieved. The coverage in crevices can be accomplished by working the coating in by brush or back rolling.

Special specification provisions governing the work on this specific project should address project specific details, such as the preparation and painting of inaccessible areas. It should also address other details like the preparation and painting of edges, corners, and discontinuous areas located around bolt heads, protrusions, and threads. The specification should also limit coating open time and attempt to control salt re-deposition in this Hawaiian environment.

As we have discussed at some length, the Aloha Stadium is in an aggressive marine environment with various micro-climates throughout the stadium proper. In evaluating and specifying any future coating systems, it would be highly beneficial and cost-effective to prepare mock-ups in different stadium exposure locations within the next year. The mock-ups would be used to evaluate various recoating procedures and products, as well as choosing the best surface preparation and best brands of coating products. In this manner, it is possible that specific product brands could be pre-qualified for later specifications.

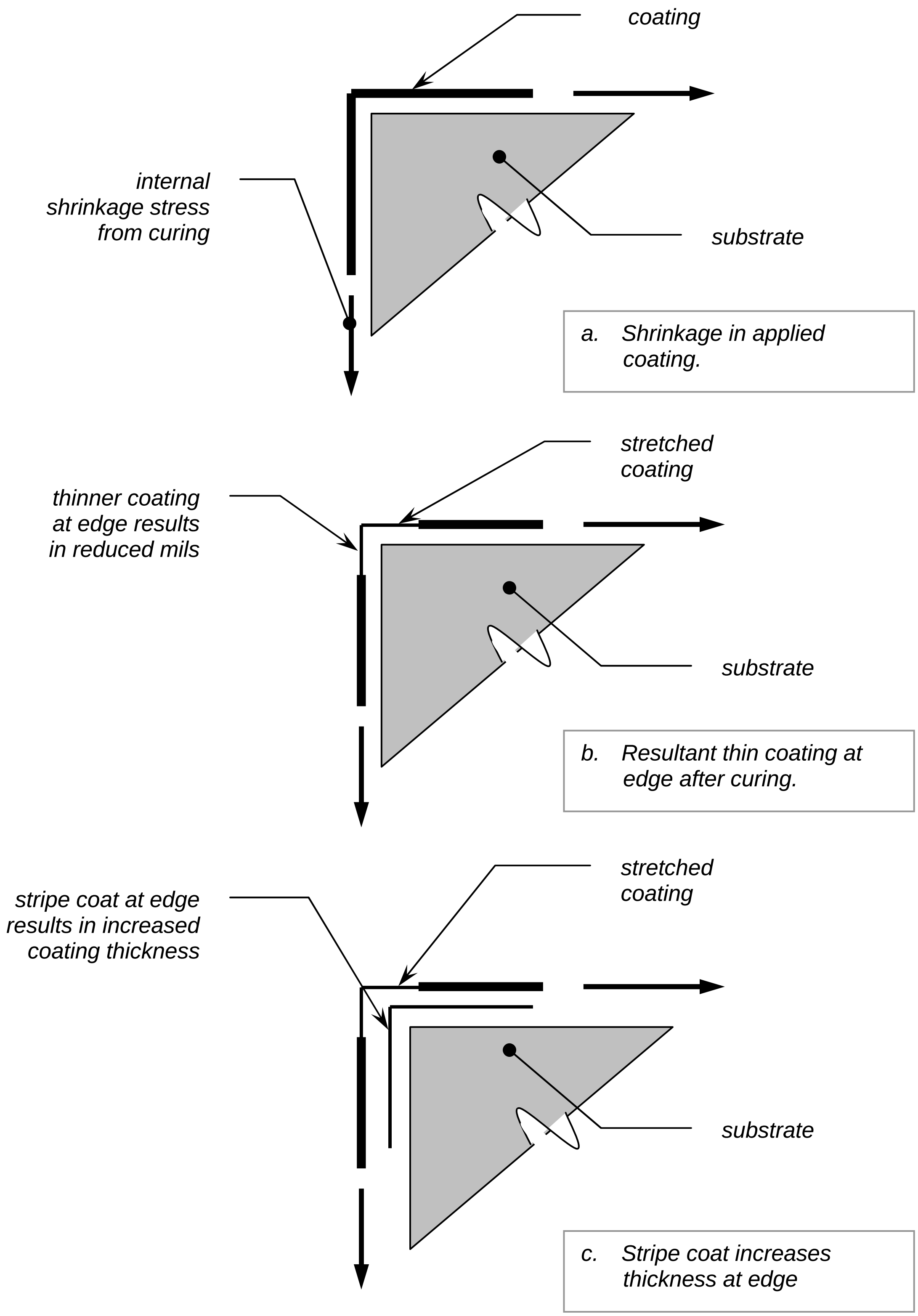


Figure R-29. Thin coating phenomenon at edges and typical method to address the condition.

R.3.3 Galvanized Elements

Where the present coating system on the galvanized steel has been compromised, the zinc protective coating is typically corroding and producing the associated white corrosion deposits. This is the expected performance for this coating, as the zinc is being consumed in this aggressive environment. The re-application of a suitable coating with a proper thickness, coupled with an elimination of pinholes in the coating, would retard the corrosion of the galvanizing and maintain a suitable aesthetic appearance. Therefore, repair by completely removing the existing coatings and applying new coatings should be considered. In some instances, such as metal deck, it may be more cost effective to replace the deck in-kind with a shop-applied coating system on the new deck panels.

R.3.4 Filler Materials

The present polymeric filler materials should be removed and replaced at the exterior hub regions. Prior to replacement of any filler, the weathering steel should be washed to remove salts, sandblasted to remove corrosion, and then coated. Alternate replacement materials should be investigated, such as concrete, polymer-modified mortar, or different polymeric-type filler, possibly extended with sand or inert aggregate.

An alternate coating system for horizontal surfaces should be investigated. A three-coat coating system with a urethane top-coat is not well suited for a horizontal application where water can pond. A urethane waterproof membrane (40 to 50 mil thickness), a hot-applied roofing membrane, or sheet metal flashing are suggested alternates to provide a covering that is more durable than the present system. Based on the aggressive environment present at the stadium, it is recommended that a trial repair be installed and its performance monitored before implementing this type of system throughout the stadium.

Part II – Condition Survey

Section S - Structural Elements Condition Survey

S.1. Background

S.1.1 Field Survey Methods

A team of seven WJE engineers visited Aloha Stadium during the weeks of 22 August 2005 and 29 August 2005 to conduct a field survey of various structural elements throughout the Stadium. The purpose of the site visit was to observe and document the conditions related to the weathering steel framing supporting the different seating sections in the Stadium. Other weathering steel framing elements, such as the curved bridges and spiral ramps, and the concrete framing members in the lower portions of the fixed stands were also included in this survey.

In general, the survey was conducted to document any ongoing deterioration of the structural members that has occurred after the weathering steel members were painted in the 1980s and early 1990s. This deterioration includes, but is not limited to, coating system (paint) failures, moisture intrusion, continuing steel corrosion, and steel section loss. The nature and location of each type of deterioration was documented on appropriate field sheets and supplemented with photographs. Other conditions relating to deterioration or structural performance were also noted and documented.

Due to the light floor system on the perimeter concourse, which is a lightweight concrete on metal deck structure, a manlift or scissors lift was not permitted inside the Stadium. Therefore, the field survey consisted primarily of visual observations of the weathering steel and concrete framing elements. Binoculars were often used to obtain an additional viewing perspective for framing elements that were not easily accessible. In addition, a manlift was placed at grade level to access some framing elements at the perimeter of the moveable portions of the Stadium. The close-up observations made from the manlift were used to verify the initial visual observations of these perimeter framing members.

To augment information obtained in the visual surveys, detailed survey methods were also employed in various areas. These methods included steel thickness measurements using a digital Krautkramer thickness gauge and hammer tapping on concrete surfaces to verify soundness. In addition, detailed testing of the paint coating system was also performed. The paint coating testing is discussed in further detail in Section R.

S.1.2 Paint Repair Designations

For purpose of documenting the condition of various weathering steel framing elements, a rating system was implemented during the field survey. Visual observations were used to rate the visible condition of the steel member. The rating system correlates to the extent of repair or rehabilitation work that appears to be necessary in order to reduce the observed ongoing deterioration. The rating system ranges from power washing steel members that do not exhibit ongoing deterioration, to replacement of steel members that exhibit severe corrosion and section loss. This rating system is described in the table below.

Painting Designation	Description
P0	This designation applies to an existing coating system that appears to be in good condition. No breaches in the existing coating system are readily observed. Surfaces may have significant accumulation of dirt and debris. Surface powerwash recommended to remove dirt/debris and to unclog weep holes.
P1	This designation includes the description of **P0**, but the paint surface may also be exhibiting signs of fading or wear, for example, as a result of UV exposure. Therefore, an additional top coat application is recommended following the powerwash.
P1+	This designation includes the description of **P1**, but the paint surface may exhibit chalking. Therefore, additional surface preparation may be required to ensure proper bond of the new paint top coat. This may include hand preparation of the surface such as light abrasion of the surface with a scrubbing pad.
P2	This designation includes localized repairs to the existing paint coating, typically at localized corrosion. The areas of corrosion are small enough that surface preparation using hand tools, such as needle-guns, would be most efficient. Typically, these repair areas occur along flange tips of the framing members, where the needle-gun can accurately remove the paint in the affected area at the flange tip (whereas sandblasting would remove a larger than needed area of paint on the flange and web). If the repair area is on a web or flange surface, each repair area is typically less than 2 or 3 square feet. Once the surface is prepared, a three-coat paint system is applied that is compatible with the existing paint system. The new three-coat system must also be compatible with the new top coat (**P1**) that may be applied in areas adjacent to the localized repair.
P3	This covers large areas of failed paint and/or corrosion that require a sandblasting surface preparation to achieve bare steel (about SP-10) of the framing members. These areas are similar to **P2** repairs, but are more widespread, so needle-gun preparation would be quite tedious and laborious. In general, if a member has closely spaced areas of corrosion requiring **P2** repairs, the member is instead rated **P3**. Once the surface is prepared, a three-coat paint system is applied that is compatible with the existing paint system. The new three-coat system must also be compatible with the new top coat (**P1**) that may be applied in areas adjacent to the localized repair.
P4	This pertains to steel framing members that exhibit widespread **P3** repairs in addition to ongoing corrosion and section loss. Therefore, structural repairs may be required in addition to any **P3** coating repair. Alternatively, complete replacement of the steel framing member may be an option. Member replacement may be selected due to the observed section loss, or because it would likely be less expensive to replace the member than to perform a **P3** repair.

It should be noted that the rating system and recommendations presented in this section are based solely on observation of visible condtions, such as peeling paint or weathering steel corrosion, performed during the 2005 field survey. The intent of the rating system was to visually assess the coating condition on a global basis and help develop preliminary estimates of the extent of necessary coating work. Limited detailed coating studies were performed at various locations, as discussed in Section R, and it was determined that some areas exhibited deficiencies such as incorrect coating layer sequence, poor adhesion to steel, and/or brittle coating properties. As a result, ratings and recommendations presented in this chapter may need to be revised in the future based on the results of recommended further testing of the coating systems.

As an example, field observations may indicate that a structural member requires a new paint top coat (P1) but subsequent coating studies may reveal that the existing coating is not adequately adhered to the steel. A new top coat would not be effective if the existing coating system is not properly adhered. Therefore, sandblasting and reapplication of the three-coat system (P3 repair) may be more appropriate in this case. This is one example of several issues that will require study prior to implementation of coating repairs.

S.1.3 Grouping of Structural Elements

To aid the field survey and documentation of the visual observations, the Stadium was divided into a total of eight “quadrants”. The fixed and moveable portions of Stadium seating were each divided into four “quadrants”: northeast, southeast, southwest, and northwest, as shown in Figure S-1.

Within any “quadrant” the structural elements were grouped according to seating section. The five sections were Lower Field Seating (orange), Upper Field Seating (blue), Loge Seating (brown), Lower Tier Seating (red), and Upper Tier Seating (yellow). The structural framing is essentially the same for each “quadrant”, except for the Lower Field Seating, which is supported by structural steel framing in the moveable sections and by concrete framing elements in the fixed seating sections. Structural element groupings were also created for concourse framing members, bracing members, curved bridges, spiral walkway ramps, sign truss framing, and the stairwell framing. The structural element groups for the fixed and moveable stands are shown in Figures S-2 and S-3, respectively. Figure S-4 shows the typical groupings of structural elements. A summary of the conditions observed during the field investigation for each of the various groups of structural elements is described in the sections that follow.

S.1.4 Microclimate

It was apparent from the field survey that the deterioration observed in the weathering steel members correlated to the exposure conditions, or the microclimate exposure of the various elements. The prevailing wind is from the east or mauka side of the Stadium. Therefore, wind-driven moisture and airborne chlorides typically create an aggressive environment for the windward side of the weathering steel framing elements. For example, typical structural elements, such as the raker girders or spiral ramps, exhibit more extensive corrosion and coating failures in the eastern quadrants of the Stadium than in the western quadrants. The seat plate in the western quadrants provides a limited “shielding” effect against the aggressive wind-driven environment, thereby offering some protection to the underside framing elements. In general, when deterioration is discussed in the sections that follow, very often the described deterioration is more prevalent in the eastern quadrants than the western quadrants.

S.1.5 Structural Elements Not Included in the Field Survey

In some cases, access to various structural element groupings was found to be limited or impossible. Visual observations of these elements were not included in our field survey. Most notably, these elements include the steel framing surrounding the elevator (within the cylindrical elevator tower) at the south end of the Stadium and the roof framing members at the satellite concession stands at the north and south ends of the Stadium. Furthermore, several areas of the raker framing elements are enclosed by metal deck wall panels. These areas include concession areas, restrooms, and those within pipe chases. A portion of these areas have maintenance access doors, which permitted some access to these otherwise parts of enclosed raker elements. However, in many cases, only one side of the raker is accessible. Significant areas of many raker elements and numerous other framing elements have no ready, direct access. Areas without ready access may require temporary removal of the wall panels to perform visual observations and to complete any necessary coating system or corrosion repairs.

S.1.6 Figures

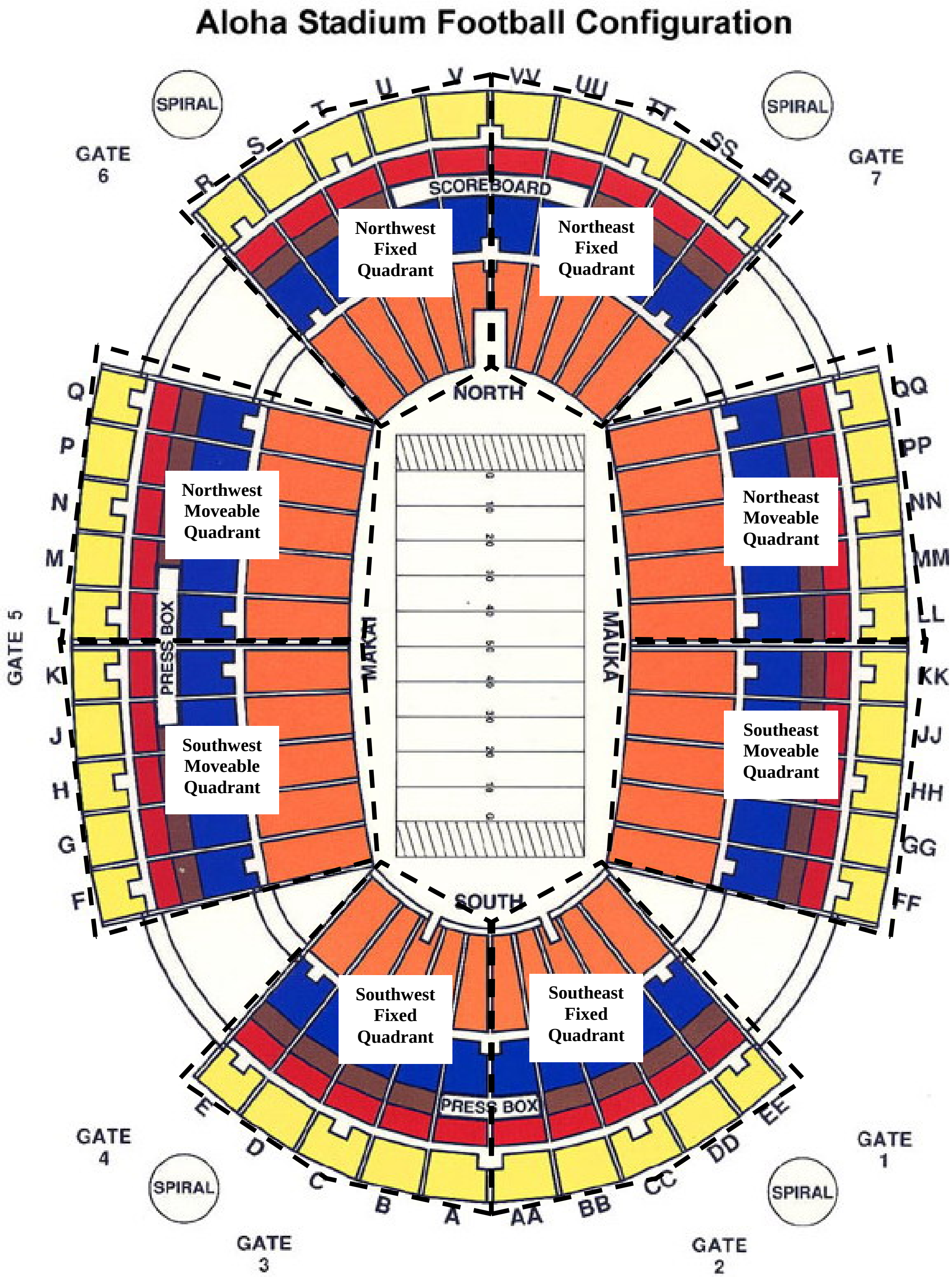


Figure S-1. Layout of the eight "quadrants" used for the field survey

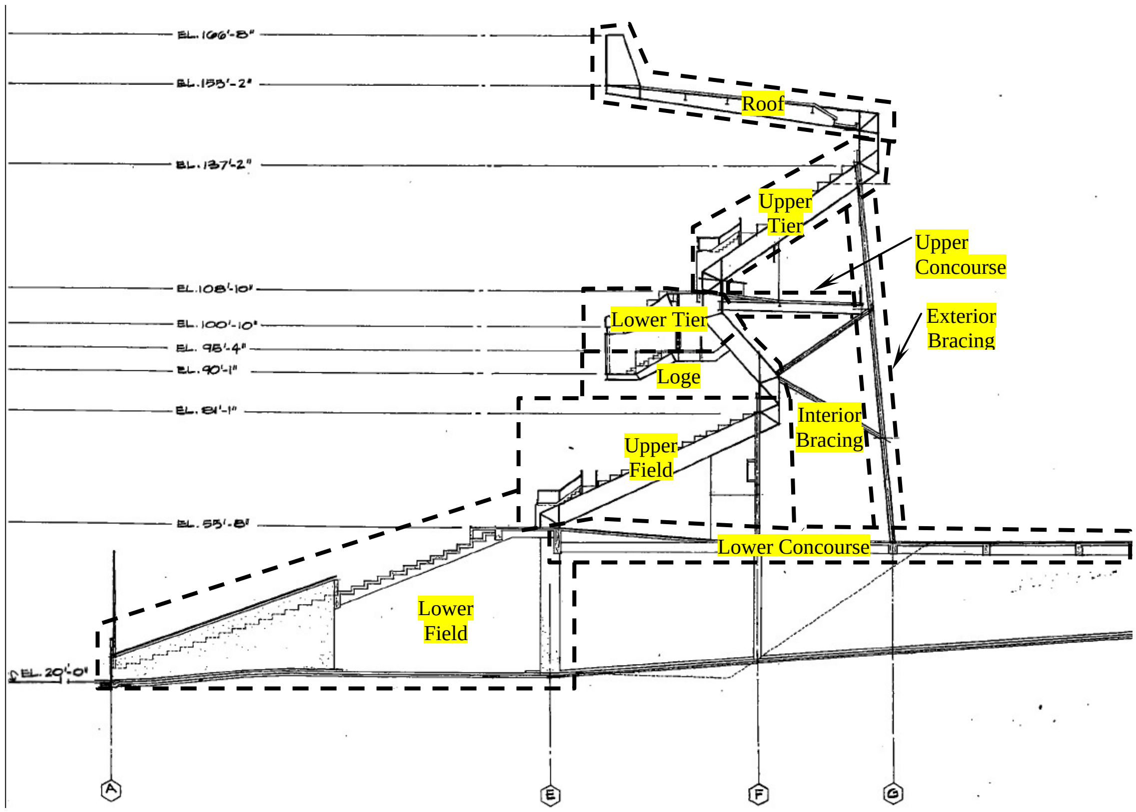


Figure S-2. Grouping of structural elements for the fixed stands

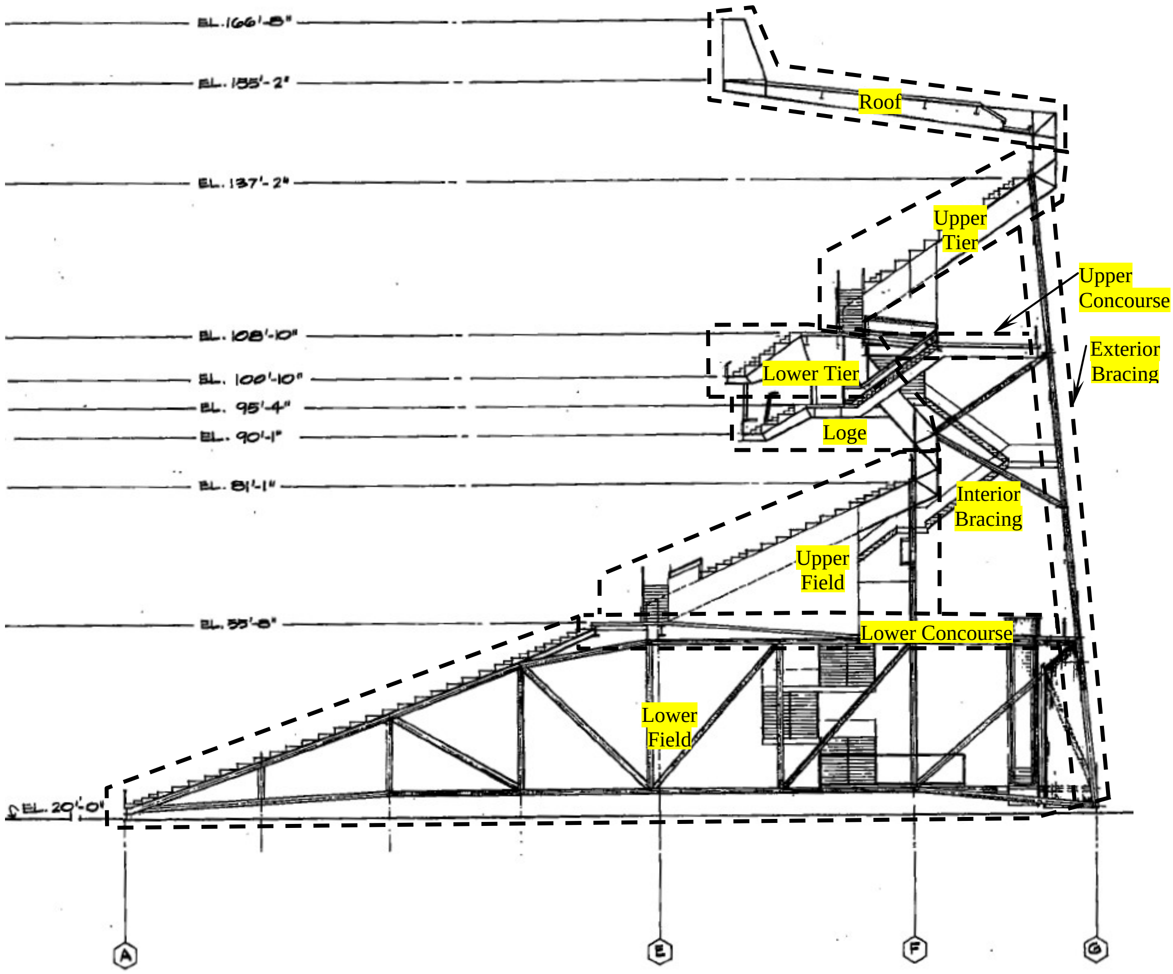


Figure S-3. Grouping of structural elements for the moveable stands

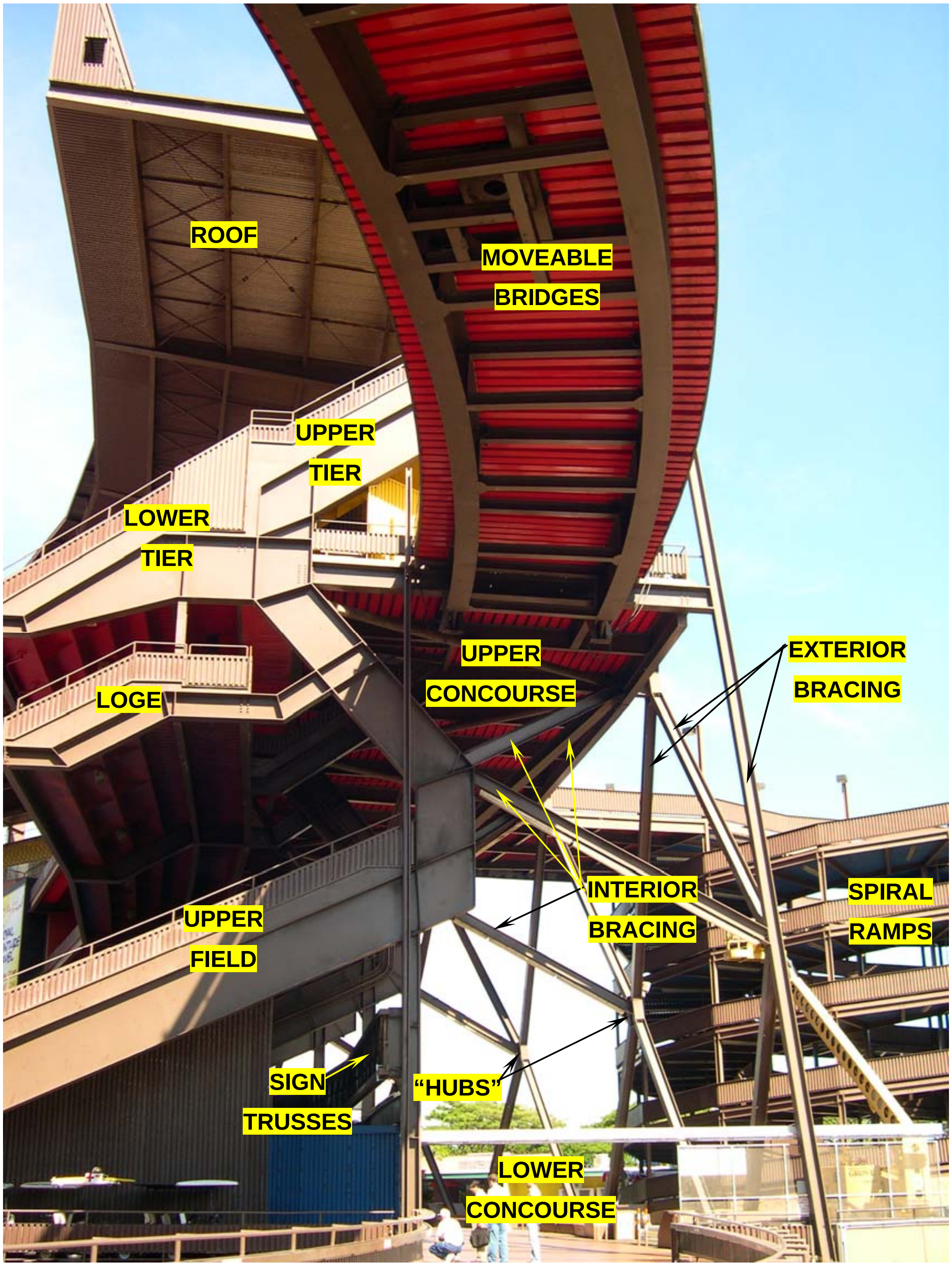


Figure S-4. Typical groupings of structural framing elements

S.2. Lower Field Seating (Orange Section) Structural Elements (Fixed Stands)

S.2.1 Background

Structural framing for the lower field seating (orange section) in the north and south fixed stands is made up of precast tread and riser members supported on concrete raker girders and columns. Typical topside and underside views of these concrete elements are shown in Figures S-5 and S-6, respectively. The areas beneath the fixed stands are used for Stadium offices, locker rooms, maintenance, and equipment storage. Many of theses areas were finished spaces which severely limited visual access to these concrete elements. During the field survey, visual observations were only made in the areas with exposed structural concrete elements.

S.2.2 Observed conditions

The underside survey revealed that several areas of the framing concrete elements exhibited signs of leakage, such as moisture staining and efflorescence (visible white deposits on the surface of the concrete). In most cases the leaks did not appear to be active. Epoxy-injection or filler repairs made in the past appeared to be effective in mitigating moisture intrusion.

The underside survey also revealed a noticeable shear crack in the concrete transfer girder located over the vehicle tunnel entrance at the north end of the Stadium. Evidence of leakage was also observed at these cracks. In the northwest quadrant, spalling was observed at the end of a precast tread and riser member, as shown in Figure S-7.

Several localized areas of concrete delamination and spalling were discovered during the visual survey of the top surface of the precast tread and riser members, similar to the deterioration shown in Figure S-8. These areas of deterioration included previous repair patches that have since failed. Failure of sealant that was previously installed in various cracks in the concrete was also observed, as shown in Figure S-9. In addition, several unrepaired cracks were observed in the aisle at the rear of this seating section as well as in the roof of the baseball dugouts at the south end of the Stadium.

S.2.3 Recommendations

Based on our visual observations, we recommend the following repairs be performed to the concrete framing elements in the lower field seating sections of the fixed stands:

- Repair localized areas of concrete spalling and delamination on the top surface of the precast tread and riser members.

- Replace failed sealant repairs in cracks that were previously routed-and-sealed. In addition, rout-and-seal repairs should be performed to the unrepaired concrete cracking observed in the dugout roof and the rear aisle.

- It should be noted that, after the existing membrane has been removed, additional concrete repairs and/or crack rout-and-seal repairs may be discovered during replacement of the membrane system. Discussions relating to the condition of the existing membrane and replacement recommendations are presented in Section D.

- Repair the spalled ends of the precast tread and riser member in the northwest fixed quadrant.

- It is recommended that the shear crack observed in the beam above the tunnel entrance in the north fixed stadium be investigated. The cause of the shear cracking, an evaluation of the beam capacity, and the source of the moisture intrusion should be included in this investigation.

S.2.4 Figures

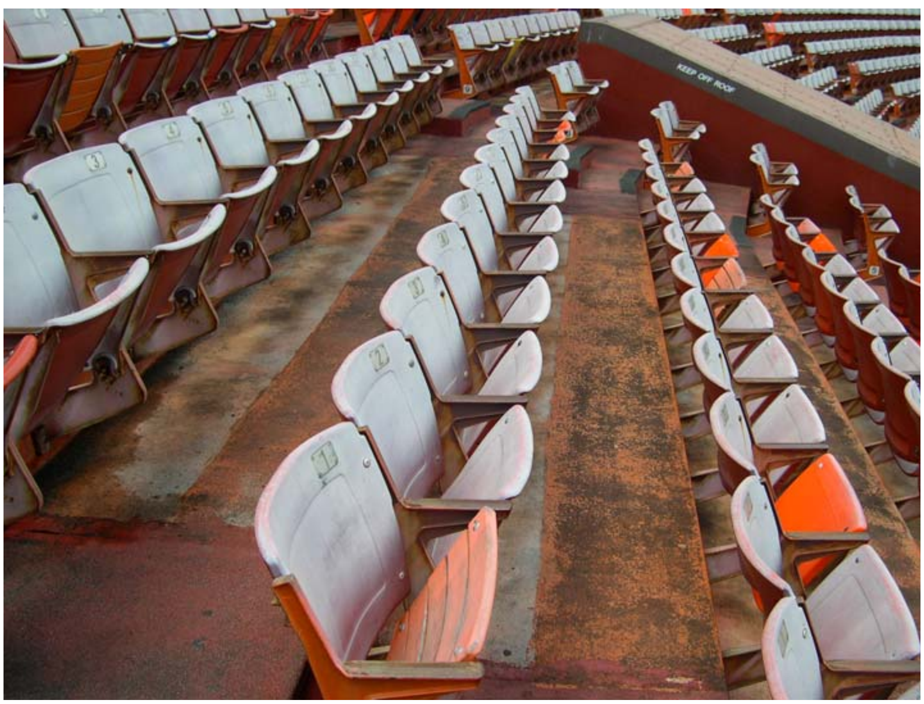


Figure S-5. Top surface of the precast tread and riser members in the lower field seating areas (fixed stands)

Figure S-6. Typical underside framing of the lower field seating areas (fixed stands)

Figure S-7. Concrete spalling observed at the end of a precast tread and riser member

Figure S-8. Typical area of concrete deterioration observed on the precast tread and riser members

Figure S-9. Weathered sealant in a previous crack rout-and-seal repair observed on the topside of the lower field seating area (fixed stands)

S.3. Lower Concourse Structural Elements (Fixed Stands)

S.3.1 Background

The structural system for the lower concourse in the fixed stands is a concrete slab supported by concrete beams and columns. This concrete slab structure, shown in Figure S-10, extends beyond the perimeter of the Stadium into a concession plaza area between the spiral walkway ramps. The concrete slab is coated in the concourse area within the Stadium. An asphalt overlay is currently over the concrete slab in the areas beyond the Stadium's perimeter. Because the topside of the concrete slab is covered with a waterproofing membrane and an asphalt overlay, visual observations performed during the field survey were primarily concentrated on the underside of the concrete slab.

S.3.2 Observed conditions

Areas of active and prior leakage were observed throughout the underside of the lower concourse slab. This leakage was evidenced by moisture staining and efflorescence leaching through cracks on the underside of the concrete slab. An example of slab cracking exhibiting efflorescence is shown in Figure S-11.

Cracking and other similar deterioration was also observed in the asphalt overlay, as shown in Figure S-12. As a result, an inspection opening was made in the asphalt overlay at the north and south lower concourses of the Stadium to determine the type and condition of the waterproofing system, if any, between the concrete slab and the asphalt overlay. A built-up asphalt waterproofing membrane does exist beneath the asphalt topping above the main entrance and office area at the south region of the lower concourse; however, a waterproofing membrane was not observed beneath the asphalt topping at the north region of the lower concourse.

During our inspection, cracks were being patched with pourable asphalt by building maintenance personnel. The workmen informed us that the patching does reduce the water leakage issue that persists into the office area below. Therefore, it is likely some breaches exist in the waterproofing membrane. However, other sources of possible water leakage were observed. For instance, it is likely water is leaking at flashing locations at the perimeters. Also, an unsealed conduit penetration was observed adjacent to the concrete base of the steel framing for the Stadium.

S.3.3 Recommendations

We recommend the following for the lower concourse structural elements in the fixed stands:

- The cracking and deterioration in the asphalt overlay allows water to penetrate through the asphalt to the concrete slab below. Currently, water appears to be migrating through breaches in the waterproofing system, resulting in moisture staining on the underside of the concrete slab. Therefore, replacement of the asphalt topping and the waterproofing system over the concrete slab is recommended at the south lower concourse area that is located over the main entrance and offices for the Stadium.

- Removal of the existing coating and installation of a waterproofing membrane in the lower concourse walkway within the Stadium is also recommended. These recommendations are discussed further in Section F.

- Concrete repairs are likely required to the top surface concrete slab; however, the extent of the repairs will not be known until after the waterproofing membrane and asphalt overlay are removed and the condition of the concrete slab is evaluated.

- Currently, the need for overhead repairs to the underside of the concrete slab is limited, but may increase if water continues to penetrate through the existing cracks.

S.3.4 Figures

Figure S-10. Typical concrete framing in the lower concourse (fixed stands)

Figure S-11. Leakage observed and moisture staining on the underside of the lower concourse concrete slab

Figure S-12. Typical deterioration observed in the asphalt overlay above the concrete slab

S.4. Lower Field Seating (Orange Section) Structural Elements (Moveable Stands)

S.4.1 Background

The structure for the lower field seating areas in the moveable stands consists of a large space frame of weathering steel members. The primary component of this space frame is a steel truss located beneath each raker girder line, as shown schematically in the previous Figure S-3. Bracing trusses, oriented perpendicular to the steel trusses shown in Figure S-3, are located at Column Line C.7, Column Line D.9 (near Column Line E), and Column Line F. The bracing trusses are used to transfer vertical and lateral loadings to the moveable bearing supports located beneath the bracing trusses at column lines C.7 and F. Overall views of these structural steel framing elements are shown in Figures S-13 and S-14.

Horizontal steel bracing members are located in the same plane as the bottom chord of the primary and bracing trusses. The bracing members in this plane are designed to help distribute lateral loads imposed on the moveable stands. Due to the weak-axis orientation of the members in this lower plane of steel members (including primary truss bottom chord, bracing truss bottom chord, and bottom chord in-plane bracing members) several members were acting as “troughs” and subsequently collecting water. As part of the corrosion abatement program in the 1980s and early 1990s, weep holes were drilled in these lower members to allow water to drain from the “trough”. In addition, a polymeric epoxy filler was used at the nodes or structural connections between these members to keep water from collecting in low spots within the connection nodes and to direct water toward the newly installed weep holes.

The carbon steel seating plate used to form the treads and risers in this seating section is also included in this structural element grouping. This seat plate has a waterproofing membrane on the top surface and the underside is painted. It is our understanding that the original seat plate exhibited a “back slope,” which resulted in several areas of ponding water on the top surface of the treads. A prior retrofit was performed by cutting a small section of the vertical riser out of the seat plate and effectively raising the intersection of the tread and riser plate in an effort to eliminate the back slope.

S.4.2 Observed conditions

Past corrosion damage in this area, and damage in the observed coating applications, indicated that moisture presence in this covered area has been relatively high in the past. Therefore, some initial observations were made during the field survey related to the humidity levels in the areas beneath the lower field seating. A survey of the relative humidity levels in this area indicated that the humidity was typically a few percentage points higher than the exterior of the Stadium. This is likely related to the lack of air circulation in the space beneath the lower field seating.

Furthermore, standing water was observed on the concrete bearing transport slabs, as well as on the exposed soil between these slabs. Inadequate drainage of this soil suggests that the soil likely remains moist, thus contributing to the higher humidity levels in this area.

In general, the condition of the paint coating system below the lower field seating appeared to be in better condition than in other areas of the Stadium. This is likely due to the limited exposure to UV and direct weather. A build up of dirt and debris was commonly observed on the steel framing members, as illustrated in Figure S-15. This dirt and debris commonly clogged the weep holes in the lower truss members.

Paint failures and localized corrosion of lower plane bracing members were frequently observed. The paint failures were almost exclusively located at the flange tips of these framing members, as shown in Figure S-16. In the west quadrants, it was estimated that approximately 15 percent of the length of these members exhibited corrosion of the flange tips. In the east quadrants, the flange tip corrosion was more common along the top flange of these members, estimate at up to 50 percent of the member length in some areas. Paint failures were occasionally observed in truss members above the lower plane, such as diagonal members. At several lower connection nodes of the truss members, the coating was observed to be built-up and excessively thick, as shown in Figure S-17.

The epoxy filler located at the connection nodes of the lower members of the primary and bracing trusses was typically found to be cracked, as shown in Figure S-18. Instead of directing water away from these nodes as intended, the cracked filler may actually draw water into the node through the crack itself.

Water also appeared to be collecting at the intersection of the top and bottom chords of the primary truss (near seating Row 1). Evidence of prior corrosion and web pitting was observed in this area, but it appears that a weep hole was never provided at this location. Currently, paint failures and light surface corrosion are observed in this area.

The top surface of the seat plate exhibited signs of severe wear to the waterproofing membrane, and as a result, surface corrosion of the seat plate was observed at many locations. In some instances, the surface corrosion was accompanied by pitting and section loss, shown in Figure S-19. On the backside of the seat plate, it appeared that wind-driven rain is entering the retrofitted, horizontal seat joint at the tread and riser heel shown in Figure S-20. As a result, corrosion and pack rust was observed on the underside or back of the seat plate, as shown in Figure S-21. Pack rust in the seat plate joint was typically concentrated in the lower rows of the lower field seating sections. By original designed, water flows from the upper seating rows, down the seat plate, and towards the field. This drainage pattern may contribute to the observed pattern of distress.

S.4.3 Recommendations

Based on our observations made during the field survey, we recommend the following for the lower field framing in the moveable stands:

- An effort should be made to reduce humidity levels in the areas beneath the lower field seating. This can be accomplished by installation of louvers to improve air circulation. Also, the installation of a concrete slab over the exposed soil, with proper drainage, would help reduce the standing water and moist conditions created by the exposed soil. This recommendation is also discussed in Section T as it also relates to the transport system for the moveable seating stands.

- Weep holes should be installed at the base of the bottom chord of the primary truss (near Row 1), as water is currently trapped by the web stiffener in this area.

- The present epoxy filler materials should be removed and replaced at the lower nodes of the truss. Prior to replacement, the weathering steel should be sandblasted and painted in the area adjacent to the epoxy filler. Alternate replacement materials may include a polymer-modified mortar or a different epoxy-type filler, possibly extended with sand or inert aggregate. It is also recommended that a trial repair be installed to determine the performance of the selected repair material.

- All structural steel framing should be powerwashed (P0 repair) to remove the chlorides from the surface of the coating. Powerwashing would also help to remove any build up of dirt and debris on the surface of the members, as well as serve to unclog the weep holes.

- The underside of the seat plate should be powerwashed (P0 repair) to remove chlorides, dirt, and debris from the surface.

- Localized paint repairs (P2) are required at all areas exhibiting paint coating failures and ongoing corrosion. These areas are concentrated in the lower plane of framing members. Furthermore, the corrosion is typically observed at the flange tips of these members. In members with concentrated areas of corrosion (P2 repairs), sandblasting and painting repairs (P3) are recommended.

- Localized paint repairs (P2) are also required on the backside of the seat plate joints exhibiting corrosion and pack rust.

- To prevent wind-driven rain from entering the joint in the steel seat plate, it is recommended that a cove bead of sealant be placed in this horizontal joint on the exterior prior to replacement of the waterproofing membrane. The interior side of this same joint may also need sealant treatment. Replacement of the waterproofing membrane on the top surface of the seat plate is recommended and is discussed further in Section D.

- Sandblasting the corroded areas on the top, exposed side of the seat plate (tread) will be required before a new waterproofing membrane is applied. A seat plate stiffener retrofit is recommended in the seat plate areas exhibiting moderate corrosion and section loss. A stiffener welded to the underside of the corroded area will help reduce perceived deflection of the seat plate by spectators and provide additional support to the steel tread plate. In areas of severe corrosion and section loss, the seat plate will require removal of the deteriorated area and a replacement plate to be welded in its place.

S.4.4 Figures

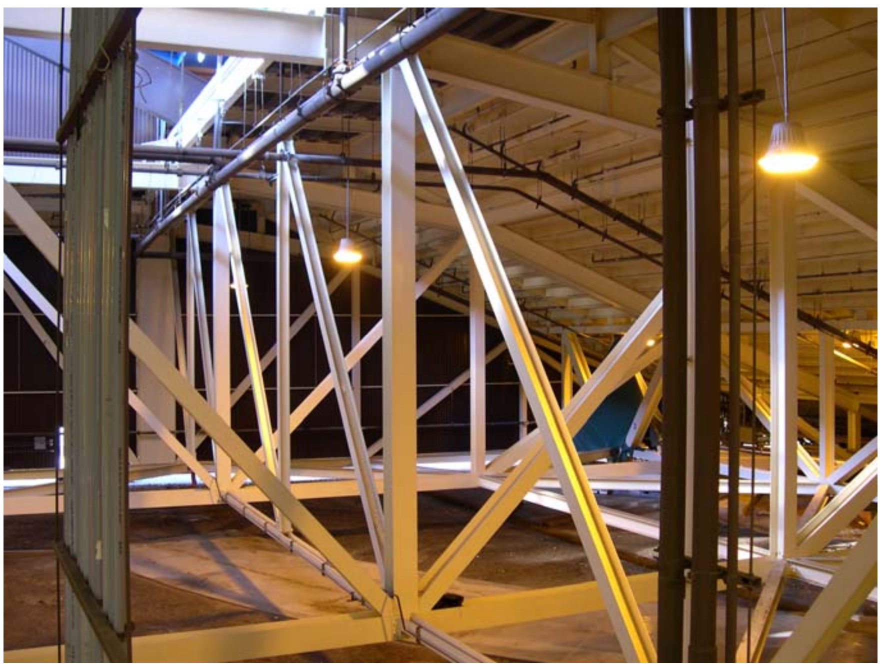


Figure S-13. Typical structural steel framing members for the lower field seating areas (moveable stands)

Figure S-14. Typical structural steel framing members for the lower field seating areas (moveable stands)

Figure S-15. Clogged weep hole and debris trapped at a lower truss connection node

Figure S-16. Coating failure and corrosion typically observed at flange tips

Figure S-17. Excessively thick coating observed at a lower truss node

Figure S-18. Typical epoxy filler retrofit at connection node that has cracked

Figure S-19. Areas of surface corrosion observed on the top surface of the tread and riser plate

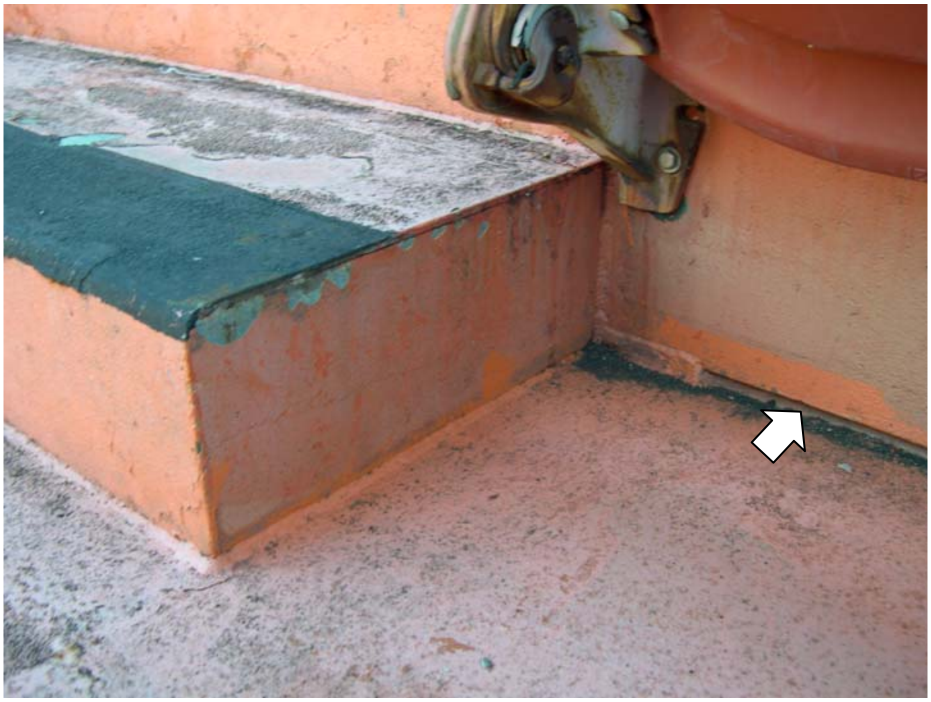


Figure S-20. Joint (at arrow) between tread and riser plates (point of entry for wind driven rain)

Figure S-21. Corrosion and pack rust observed on the back side of the seat plate at the horizontal joint between tread and riser plates

S.5. Lower Concourse Structural Elements (Moveable Stands)

S.5.1 Background

The structural elements for the lower concourse in the moveable stands include the metal deck and concrete topping, as well as the steel framing members that support the metal decking. The floor system consists of two layers of metal deck, as shown in Figure S-22 reproduced from the original drawings. Deep metal “flutes,” equally spaced, span between the primary weathering steel framing members. A corrugated metal form deck is placed over the “flutes” and is used as the formwork for the thin concrete topping. Small diameter, one inch long studs are specified in the detail, apparently intended to create composite behavior between the metal deck and concrete slab. Lightweight concrete is specified for the floor system, apparently to reduce the weight of the structure supported by the air-supported transport bearings.

Due to past corrosion in the metal deck system, the removal and replacement of the metal deck and concrete topping in the moveable stands lower concourse was performed in phases between 1980 and 1982. The replacement system outwardly appears to be similar to the original system. Field observations indicate that the repairs did not extend in “difficult to reach locations,” such as below the electrical (transformer) rooms, and area with numerous plumbing penetrations.

S.5.2 Observed conditions

In general, the weathering steel framing members of the lower concourse appeared to be in good condition. However, the framing members adjacent to large openings in the lower concourse, shown in Figure S-23, exhibited widespread areas of paint failures and surface corrosion. The opening in the concourse exposed these coated weathering steel members to the elements, such as wind-driven rain.

Corrosion of the metal deck flutes was observed in several areas, such as adjacent to expansion joints, as visible in Figure S-24. Some flute ends have been retrofitted to address prior corrosion, as shown in Figure S-25, but in many cases it appears the retrofit is beginning to deteriorate. In addition, the retrofit apparently installed locally at flute ends and it is unclear how it is developed into the original flute. Corrosion of the metal deck flutes was also observed beneath electrical (transformer) room, as shown in Figure S-26, which appears to be the original deck system. The deck in this region consists of very closely spaced flutes, likely overtopped with the thin form deck observed elsewhere.

Sporadic corrosion of the upper metal deck was observed beneath areas with moisture sources, such as restrooms or possibly beneath areas with breaches in the membrane. In these areas, it appears that corrosion to the lower flutes is limited, but this observation may change when the flutes are viewed up-close from the top side (after the upper deck is removed). Corrosion of the upper corrugated metal deck was also observed beneath the vomitory walls, shown in Figure S-27. Wind-driven rain is permitted to run down the surface of the vomitory wall panels; it appears that this water collects and becomes trapped beneath the vomitory wall panel. Similarly a narrow strip of upper deck corrosion was observed along the row of drain line penetrations adjacent to the restroom, as shown in Figure S-28. The metal deck at the drain lines appears to be from original construction.

S.5.3 Recommendations

Based on the observations made during the field survey, the following items are recommended for the structural elements of the lower concourse:

- All weathering steel framing members should be powerwashed (P0 repair) to remove the chlorides from the surface of the coating. Powerwashing would also help to remove any build up of dirt and debris on the surface of the members.

- Sandblasting and application of the three-coat paint system (P3 repair) is required at the weathering steel framing members in and adjacent to the large openings in the concourse.

- Due to the observations of ongoing corrosion in the metal deck, replacement of the metal deck and/or metal flutes is recommended in areas of moderate to severe corrosion. This includes the previously repaired metal deck adjacent to the expansion joints, as well as regions of limited access, such as beneath electrical (transformer) rooms and vomitory walls.

- Repair of the narrow strip of metal deck along the bathroom drain lines is recommended; however, due to the numerous penetrations in the upper deck due to these drains, it is unclear how effective the upper metal deck actually is. This area will require further investigation.

- Breaches in the waterproofing membrane have allowed water to penetrate into the thin concrete topping and metal deck. The thin concrete topping likely requires repair; however, the extent of repair will not be known until after the waterproofing membrane is removed and the condition of the concrete is fully evaluated. Replacement of the waterproofing membrane over the lower concourse is discussed further in Section F.

S.5.4 Figures

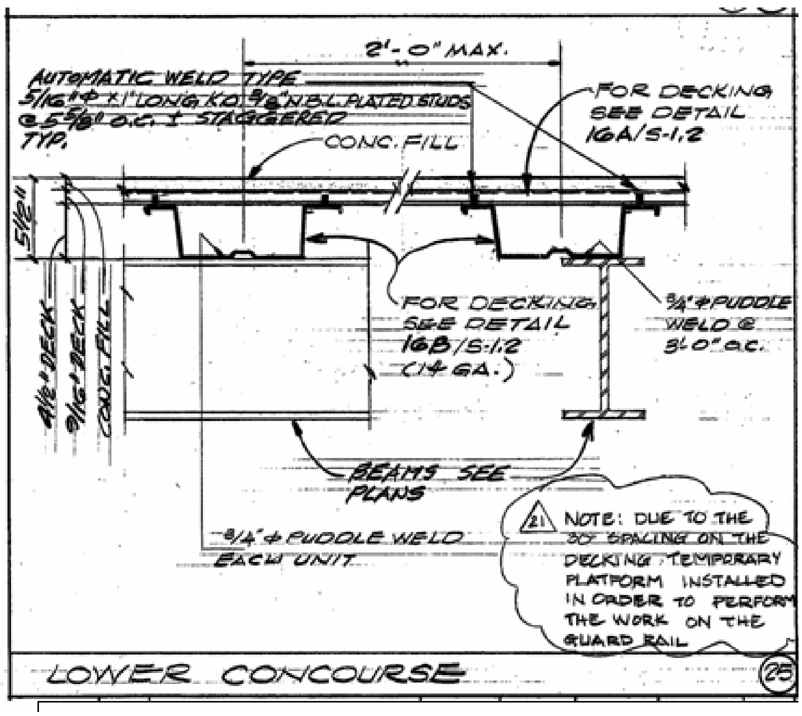


Figure S-22. Metal deck detail at lower concourse (from the original drawings)

Figure S-23. Typical corrosion and paint failures observed in the framing members at typical large opening in the lower concourse

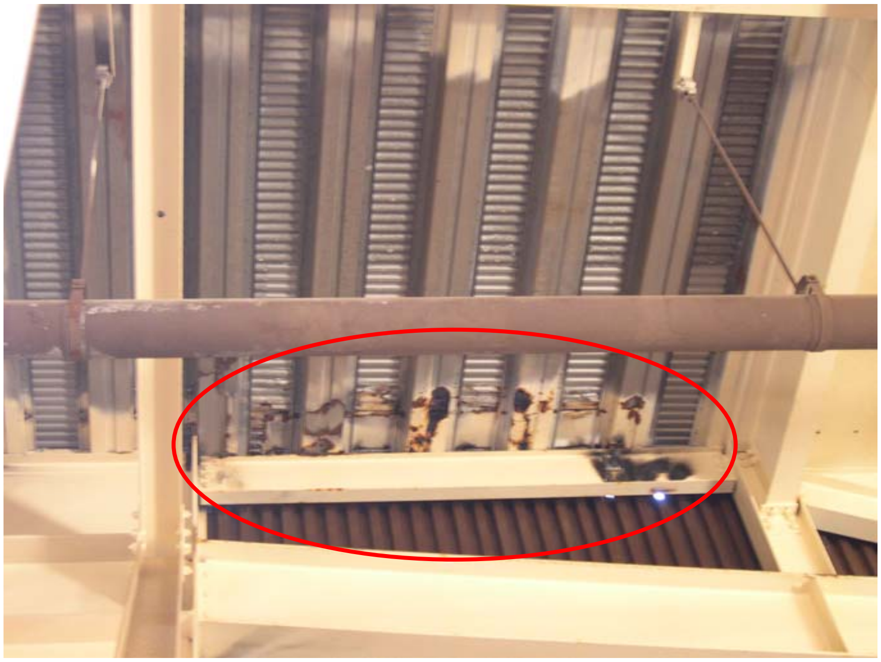


Figure S-24. Area of metal deck corrosion at the lower concourse adjacent to an expansion joint

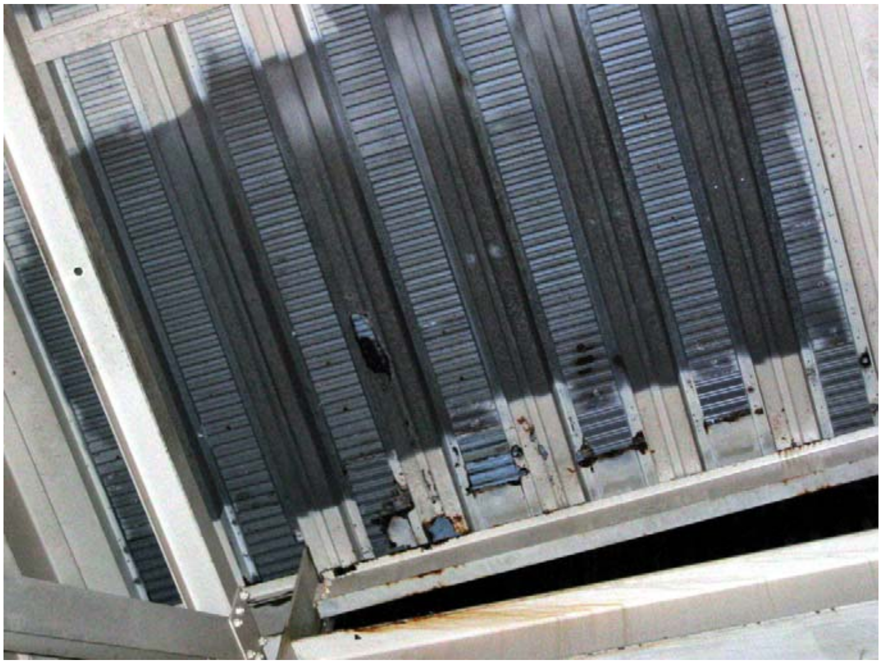


Figure S-25. Area of metal deck corrosion at the lower concourse adjacent to an expansion joint

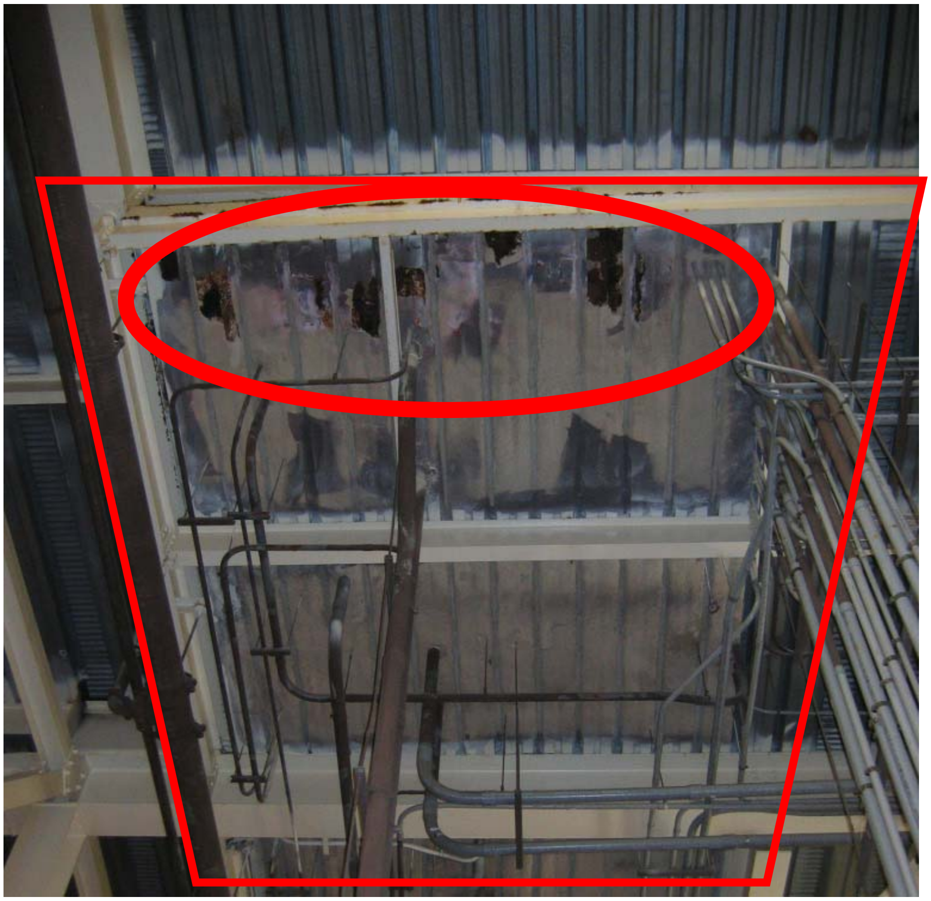


Figure S-26. Metal deck deterioration beneath the electrical (transformer) room, appears to be original metal deck

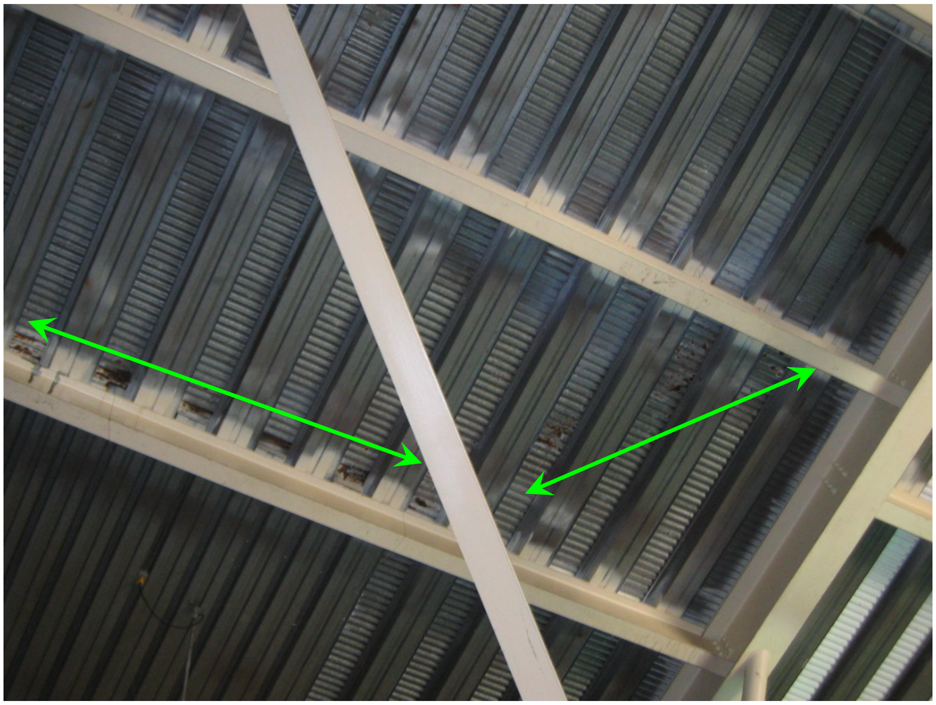


Figure S-27. Corrosion observed beneath the vomitory wall

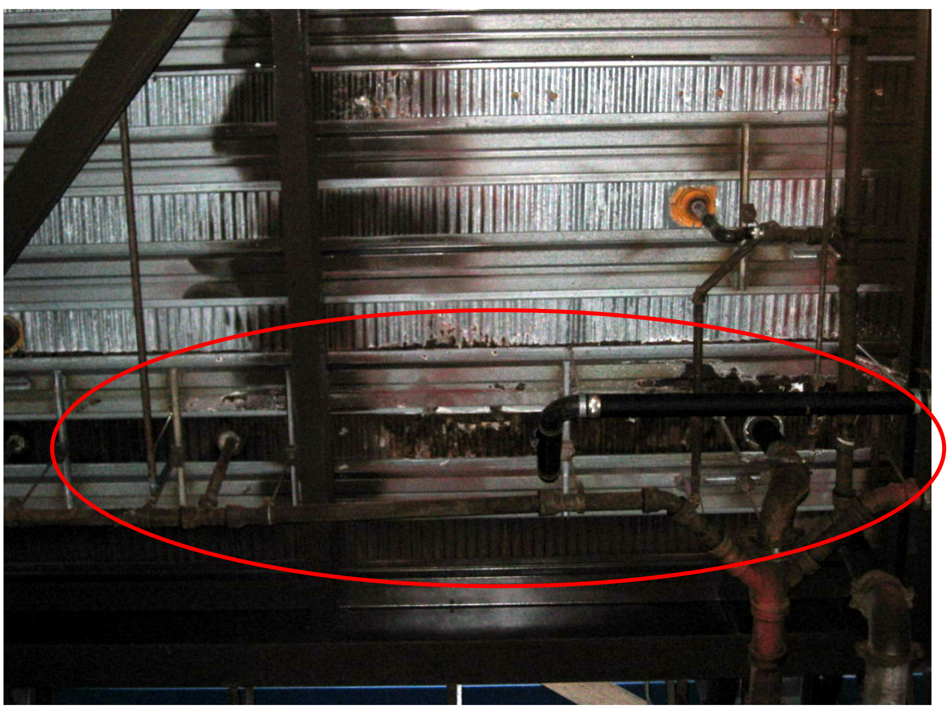


Figure S-28. Area of metal deck corrosion along drain line penetrations

S.6. Upper Field Seating (Blue Section) Structural Elements

S.6.1 Background

Referring to Figures S-2 and S-3, the structural framing for the upper field seating sections includes the raker girders from the lower concourse to the lower elbow at the rear of this section. A plate girder spans transversely between the lower raker elbows and forms the rear wall of this seating area. In addition, a column extends from this elbow to the lower concourse level and another beam spans transversely between columns at approximately mid-height. Beam members are also used to frame the stairwells, adjacent to the vomitories, at the front of this section. Moreover, the seat plate used for the tread and riser system is included as part of this structural element grouping. Figure S-29, shows the layout of the typical structural members in the upper field seating section.

S.6.2 Observed conditions

The coating system on the structural members in the eastern quadrants typically exhibited failures, resulting in surface corrosion of the underlying weathering steel in these areas. The areas of surface corrosion were commonly noted on the primary raker girders, most notably the lower elbow, the supporting column, the transverse beam at midheight of the column, and the plate girder at the rear of the seating section. These elements are directly exposed to the wind from the east, which creates a more aggressive environment. Typical corrosion of the plate girder and seat plate in an eastern quadrant is shown in Figure S-30. Similarly, corrosion of a raker girder lower elbow in an eastern quadrant is shown in Figure S-31.

The paint coating failures and surface corrosion observed in the western quadrants were much less extensive than the deterioration observed in the eastern quadrants. Observed distress was typically limited to the flange tips of the primary raker girder, lower elbow, column and the plate girder.

In general, the top side of the seat plate is protected by the Loge Level seating structure; however, the front rows of this section are not covered by upper seating levels or the roof structure. Localized areas of surface corrosion on the seat plate top side were observed in regions where the waterproofing membrane had peeled or failed. These areas were concentrated in the front rows of the section exposed to weather. The back surface of the seat plate appeared to be in good condition with some accumulation of dirt/debris on the coating system. Localized areas of corrosion, as shown in Figure S-30, were observed. These areas of corrosion were typically located on the underside of the seat plate in the eastern quadrants, which is the windward side of the seat plate.

A plate girder spanning between the lower raker elbows, just above the last seating row, forms the rear wall of the seating section. At several locations, this girder appeared to have a pronounced lateral sweep, as depicted in Figure S-32. This condition seems to have been present prior to the 1980s and 1990s repairs to the Stadium, as evidenced by the varying position of the replacement railing attachment along the length of the girder.

S.6.3 Recommendations

Based on our observations, we recommend the following repairs be performed to the upper field framing members:

- Large-scale sandblasting and painting (P3) repairs are recommended at the structural members in the eastern quadrants. These members include the primary raker girder in the vicinity of the lower elbow, the supporting column, the transverse beam at midheight of the column, and the plate girder at the rear of the seating section.

- Localized paint repairs (P2) are required at all other areas exhibiting paint coating failures and ongoing corrosion. These areas are concentrated on the flange tips of the framing members, including the primary raker girder, lower elbow, and at the plate girder at the rear of the section.

- The top coat of the coating system should be re-applied (P1 repair) to the weathering steel members in the remaining areas.

- The underside of the seat plate should be powerwashed (P0 repair) to remove chlorides, dirt, and debris from the surface.

- Localized paint repairs (P2) are also required on the backside of the seat plate exhibiting corrosion. These repairs are typically located in the eastern quadrants, where the back side of the seat plate is exposed to prevailing winds.

- Sandblasting the corroded areas on the top side of the seat plate will be required before a new waterproofing membrane is applied. Replacement of the waterproofing membrane on the top surface of the seat plate is recommended and is discussed further in Section D.

- Further investigation regarding the lateral sweep of the girder at the rear of the section is also recommended. The investigation should include an analysis to determine the ability of the girder to transfer lateral loads in its current condition, and to verify whether the girder is required for the transfer of lateral loads. If an overall wind load analysis is performed for the entire stadium structure, this plate girder analysis could be included.

S.6.4 Figures

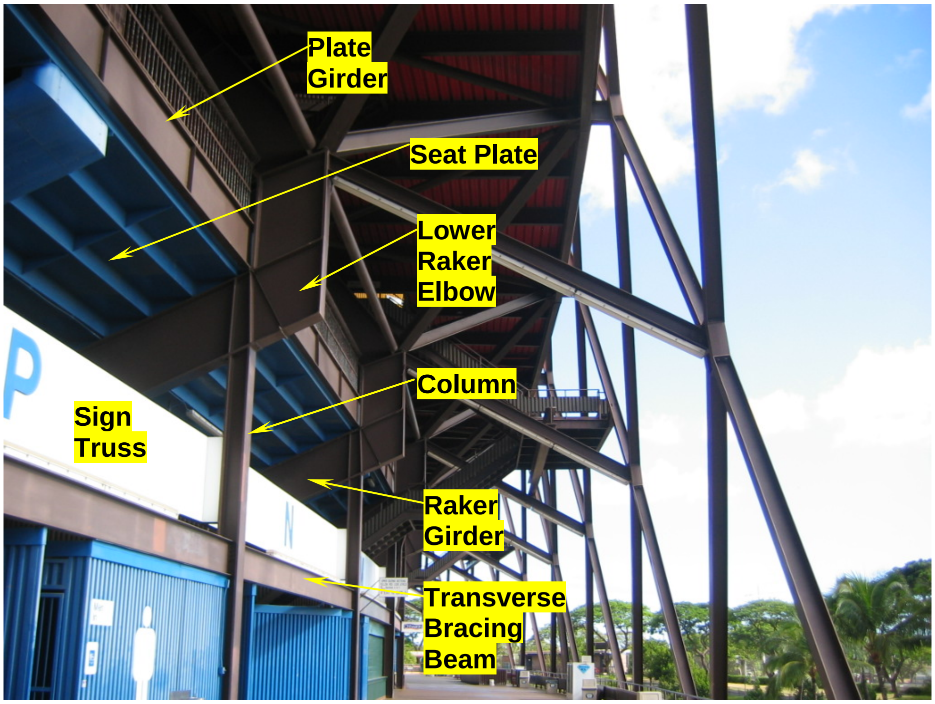


Figure S-29. Typical structural framing for the upper field seating section

Figure S-30. Corrosion observed on the plate girder and seat plate at the rear of the lower field seating section

Figure S-31. Typical surface corrosion observed at the lower elbow in the eastern quadrants of the Stadium

Figure S-32. Lateral sweep of the plate girder between raker lines

S.7. Loge Seating (Brown Section) Structural Elements

S.7.1 Background

The structural framing for the Loge Level includes the cantilevered portion of raker girder extending from the primary raker girder. A small section of the primary raker girder, from the lower elbow to the cantilevered raker, is also included. The seat plate used to form the tread and riser system in this seating area and the metal deck and concrete topping used at the walkway, at the rear of the section, are also incorporated in this structural element grouping. The metal deck and concrete topping in the rear aisle of the Loge Level were replaced in 1989. Wide-flange framing members span transversely between the cantilevered raker to support the seat plate and metal deck above. Additionally, the framing members used for the narrow stairwell, leading from the Loge Level to the upper concourse, are also part of this grouping. Figure S-33, shows the layout of the typical structural members in the Loge Level seating section.

S.7.2 Observed conditions

The coating system on the structural members in the eastern quadrants typically exhibited failures, resulting in surface corrosion of the underlying weathering steel in these areas. These areas of surface corrosion were commonly noted on the primary raker girders, the exterior transverse beam, and the framing for the Loge stairwell. These elements are directly exposed to the wind from the east, thus creating a more aggressive environment from wind-driven moisture and airborne chlorides. Typical corrosion of the raker girder at the Loge Level in the eastern quadrant is shown in Figure S-34 and corrosion of the exterior transverse beam is shown in Figure S-35. Similarly, typical corrosion of the stairwell framing in the eastern quadrants is shown in Figure S-36. Other deterioration in the eastern quadrants included flange tip corrosion of the secondary transverse beams, as well as at the cantilevered raker supporting the Loge Level. In some cases, the observed flange tip corrosion was noted along the whole length of these members or extended into the web.

The paint coating failures and surface corrosion observed in the western quadrants was much less extensive than the deterioration observed in the eastern quadrants. The areas of corrosion and coating failures were typically limited to the flange tips of the primary raker girder, raker cantilever, transverse beams, and the structural framing members of the stairwell.

Overall, the metal deck in this section is in fair condition, but localized areas of white deposits, indicating sacrificial corrosion of the zinc, were observed at various locations in the Loge Level. The metal deck behind the football press box was found to have more extensive corrosion and white deposits than the typical areas in the Loge Level. In addition, the metal deck in this area seemed to be of different construction vintages. The deterioration observed in this area of metal deck is shown in Figure S-37.

In general, the seat plate top side is protected by the lower tier seating level; however, localized areas of surface corrosion on the top side of the seat plate were observed in regions where the waterproofing membrane had peeled or failed. The back surface of the seat plate appeared to be in good condition with some accumulation of dirt/debris on the coating system. Fading of the coating on the underside of the seat plate was observed in some sections. Fading of the paint coating, as a result of UV exposure, is very common for paints with red and brown tints. Localized areas of corrosion on the back surface of the seat plate were also observed.

S.7.3 Recommendations

Based on our observations, we recommend the following repairs be performed to the Loge Level framing members:

- Large-scale sandblasting and painting (P3) repairs are recommended at the structural members in the eastern quadrants. These members include the primary raker girders, the exterior transverse beam, and the framing for the loge stairwell.

- Localized paint repairs (P2) are required at all other areas exhibiting paint coating failures and ongoing corrosion. These areas are concentrated on the flange tips of the framing members, including the primary raker girder, the raker cantilever, transverse beams, and the stairwell framing.

- The top coat of the coating system should be re-applied (P1 repair) to the weathering steel members in the remaining areas.

- The underside of the seat plate should be powerwashed (P0 repair) to remove chlorides, dirt, and debris from the surface. The underside of the seat plate will require the re-application of a new paint top coat in some areas, primarily due to UV fading of the existing coating. This can be performed on an as-needed basis or as part of a future program to recoat the underside of the seat plate in all sections. Localized paint repairs (P2) are also required on the backside of seat plate areas exhibiting corrosion.

- Localized paint repairs (P1 and or P2) are recommended at the areas of metal deck exhibiting corrosion and white deposits. The areas of corroded metal deck behind the football press box should be replaced.

- Sandblasting the corroded areas on the top side of the seat plate will be required before a new waterproofing membrane is applied. Replacement of the waterproofing membrane on the top surface of the seat plate is recommended and is discussed further in Section D.

S.7.4 Figures

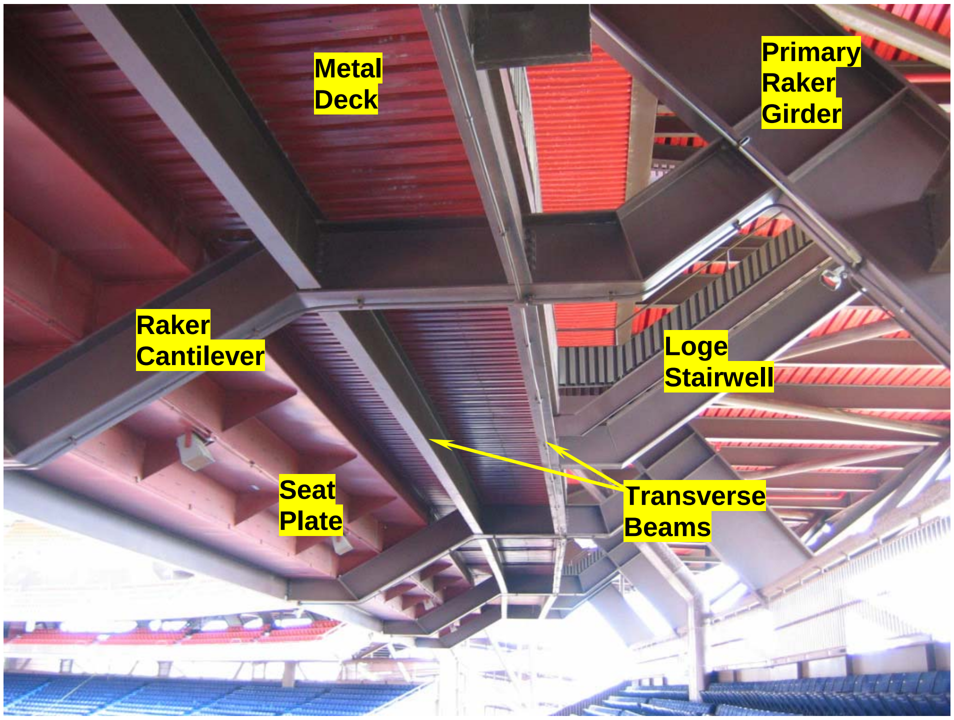


Figure S-33. Typical structural framing for the Loge Level

Figure S-34. Corrosion of the primary raker girder and cantilevered portion of the raker in the Loge Level

Figure S-35. Flange tip corrosion observed in Loge Level framing members

Figure S-36. Observed corrosion at the Loge Level stairwell

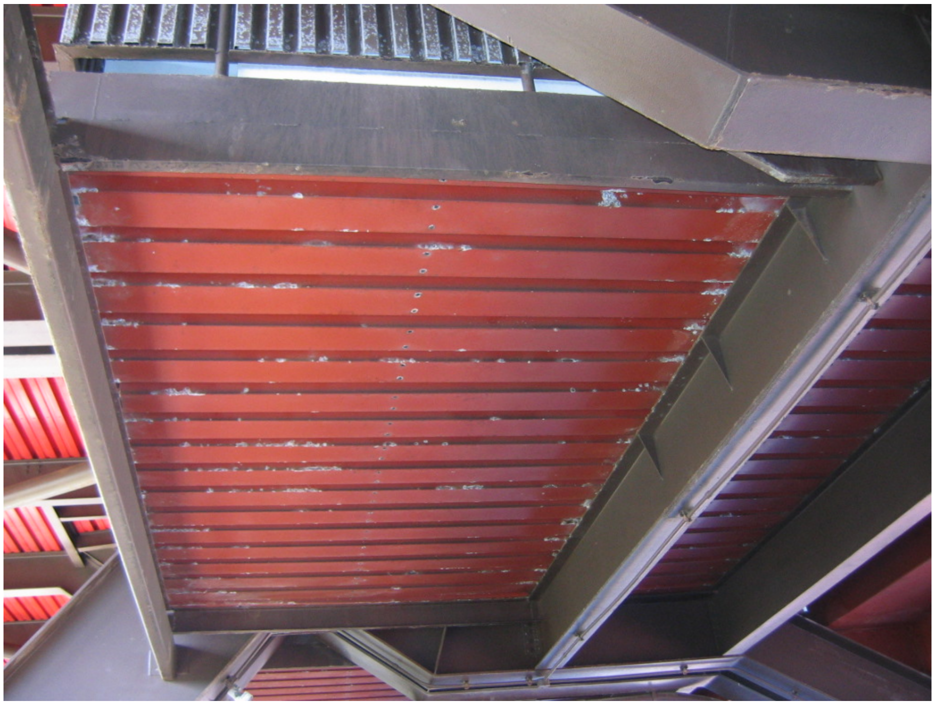


Figure S-37. Observed corrosion of metal deck behind the football pressbox

S.8. Upper Concourse Structural Elements

S.8.1 Background

The structural elements for the upper concourse consist of the metal deck and concrete topping as well as the steel framing members that support the metal decking. An overall view of this floor system is shown in Figure S-38. A deep metal roof-type deck spans between the primary weathering steel framing members. A corrugated metal form deck is placed over these deep “flutes” and is used as the formwork for the thin concrete topping, as shown in Figure S-39. This deck is similar to that of the lower concourse on the moveable seating stands.

Prior corrosion to the metal deck system resulted in a phased removal and replacement of the metal deck and concrete topping in the upper concourse of the moveable stands between 1980 and 1983. The replacement of the metal deck and concrete topping at the upper concourse of the fixed stands was performed in 1987. The metal deck in the upper concourse areas was subsequently painted in 1988. In addition, prior analyses indicated concerns with the outside slab edge beams at the upper concourse level, and these edge beams were repaired throughout the Stadium in 1992.

S.8.2 Observed conditions

In general, the weathering steel framing members of the upper concourse exhibited paint failures and localized corrosion. Typically the paint blistering and corrosion was observed on the flange tips of the weathering steel members; however, in some cases the deterioration was widespread throughout the framing member. Members exhibiting extensive paint coating failures and surface corrosion were typically located along the exterior edge of the upper concourse.

The metal deck flutes appear to be performing satisfactorily. In most areas the metal deck is in good condition. Areas of significant metal deck corrosion or widespread failures of the deck coating system were not observed at this time.

S.8.3 Recommendations

Based on the observations made during the field survey, the following items are recommended for the structural elements of the upper concourse:

- The paint top coat should be re-applied (P1 repair) to all weathering steel framing members, in addition to localized repairs to areas exhibiting paint coating failures or corrosion (P2 repair).

- Sandblasting and application of the three-coat paint system (P3 repair) is required at various members throughout the upper concourse. These members are typically edge beams located along the exterior perimeter of the upper concourse.

- Concrete repairs may be required to the thin concrete topping; however, the extent of the repairs will not be known until after the waterproofing membrane is removed and the condition of the concrete topping is evaluated. Replacement of the waterproofing membrane over the upper concourse is discussed further in Section F.

S.8.4 Figures

Figure S-38. Typical upper concourse weathering steel framing and metal deck

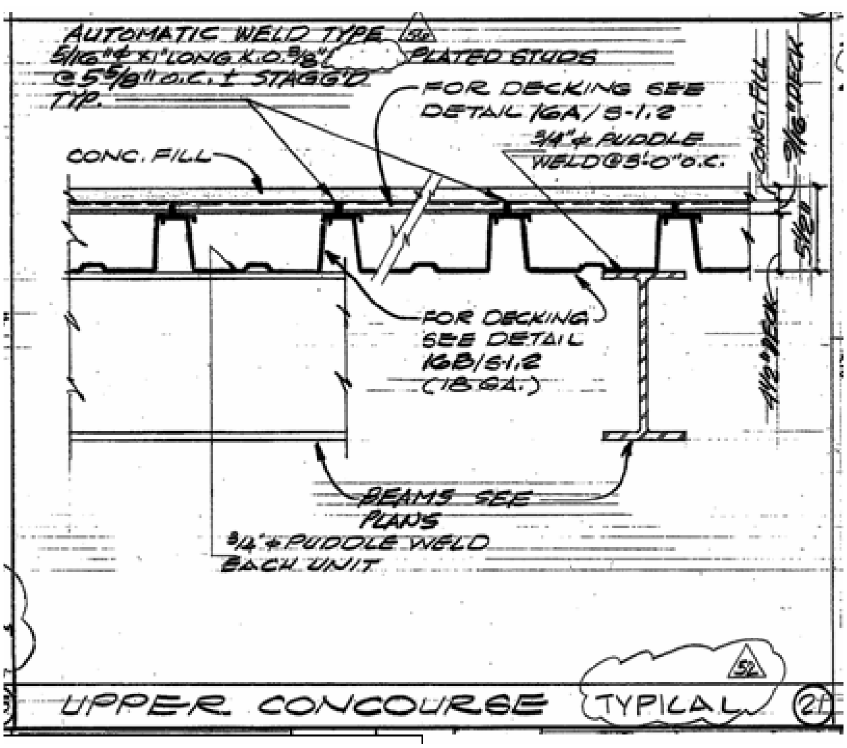


Figure S-39. Typical detail for upper concourse metal deck

S.9. Lower Tier Seating (Red Section) Structural Elements

S.9.1 Background

The deep section of cantilevered raker supporting the lower tier seating is the primary framing element in this section. The column "hanger" on the underside of the lower tier level, which supports the Loge Level, is also included in this structural element grouping. A small section of the primary raker girder, from the cantilevered raker at the Loge Level to the middle elbow at the upper concourse, is also included. The seat plate used to form the tread and riser system in this seating section is also part of this structural element grouping. Intermediate wide-flange framing members span transversely between the cantilevered raker to support the seat plate as well as a mechanical "pipe chase" enclosure that spans transversely between the middle raker elbows. Figure S-40 shows the layout of the typical structural members in the lower tier seating section.

S.9.2 Observed conditions

Various framing members in the eastern quadrants typically exhibit coating failures, resulting in surface corrosion of the underlying weathering steel in these areas. These elements include the primary raker girders and the transverse beams framing the pipe chase. Flange tip corrosion was often observed in the raker cantilever, as shown in Figure S-41. Other deterioration included flange tip corrosion of the intermediate transverse beams, as well as moderate coating failures and surface corrosion on various hanger columns. All these elements are directly exposed to the wind from the east, thus creating a more aggressive environment from wind-driven moisture and airborne chlorides. Typical corrosion of the raker girder and of the framing elements for the pipe chase is shown in Figure S-42.

The paint coating failures and surface corrosion observed in the western quadrants was much less extensive than the deterioration observed in the eastern quadrants. Observed distress in the western quadrants was typically limited to the flange tips of the primary raker girder, the raker cantilever, the transverse beams, and the hanger columns. The flange tip deterioration is similar to the corrosion shown in Figure S-41

The condition of the middle elbow of the raker girders, located within the pipe chase, was observed at several locations. Access to these members was provided by a hatch in the wall panels adjacent to the rear aisle on the topside of this seating section. Typically only one side of each raker girder was visible from each hatch. To observe the other side of the raker girder, an opening in the metal deck wall panels would have to be made. It appeared that moisture was infiltrating to these elbow locations because slight surface corrosion of the raker girder flanges was observed in some areas. Furthermore, prior pitting of the web was observed at a few locations, as shown in Figure S-43. At these locations, there did not appear to be any new or ongoing corrosion. Finally, the web cutout used for installation of the electrical/mechanical conduit was observed and is shown in Figure S-43. This web cutout is detailed on the original construction drawings.

In addition to the observations made at the raker elbow, the lower tier framing members within the south scoreboard were observed. The members appeared to be in good condition, as the scoreboard panels provide shelter from the elements.

The top side of the seat plate is protected by the roof structure; however, localized areas of surface corrosion on the top side of the seat plate was observed in regions where the waterproofing membrane had peeled or failed, as shown in Figure S-44. The underside or back of the seat plate appeared to be in good condition with some accumulation of dirt/debris on the coating system. Localized areas of corrosion on the underside of the seat plate were observed.

S.9.3 Recommendations

Based on our observations, we recommend the following repairs be performed to the lower tier framing members:

- Large-scale sandblasting and painting (P3) repairs are recommended at the structural members in the eastern quadrants. These members include the primary raker girder at the rear of the seating section and the structural framing beams of the pipe chase.

- Localized paint repairs (P2) are required at all other areas exhibiting paint coating failures and ongoing corrosion. These areas are concentrated on the flange tips of the framing members, including the primary raker girder, the raker cantilever, transverse beams, and The top coat of the coating system should be re-applied (P1 repair) to the weathering steel members in the remaining areas.

- the hanger columns.

- The underside of the seat plate should be powerwashed (P0 repair) to remove chlorides, dirt, and debris from the surface.

- Localized paint repairs (P2) are also required in areas on the underside of the seat plate exhibiting corrosion.

- Sandblasting the corroded areas on the top side of the seat plate will be required before a new waterproofing membrane is applied. Replacement of the waterproofing membrane on the top surface of the seat plate is recommended and is discussed further in Section D.

S.9.4 Figures

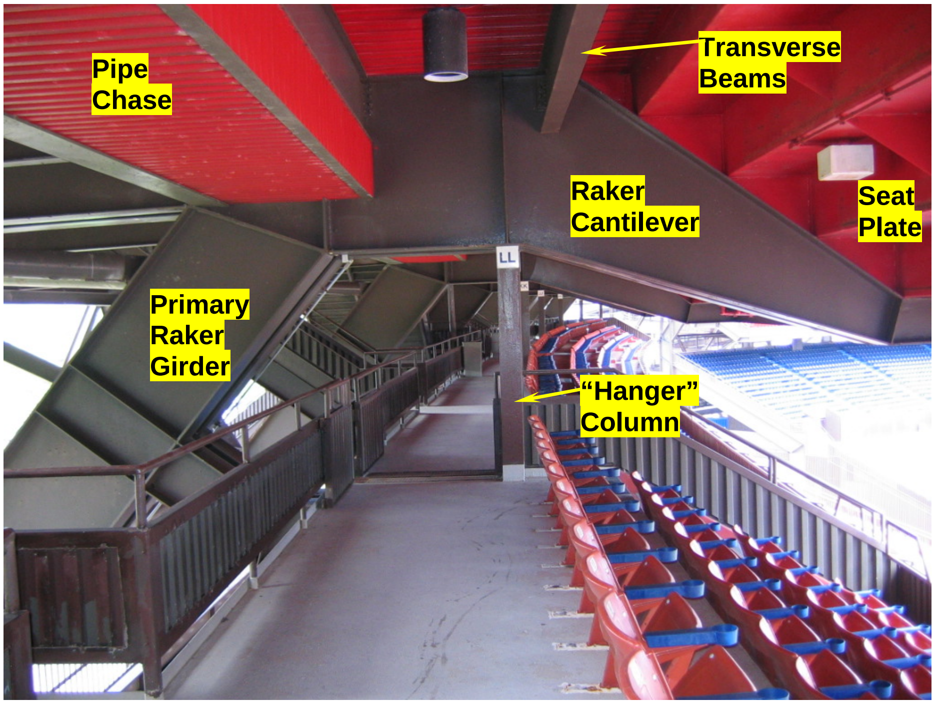


Figure S-40. Typical structural framing for the lower tier seating section

Figure S-41. Typical flange tip corrosion observed at the cantilevered portion of raker supporting the lower tier seating level

Figure S-42. Observed corrosion at intersection of pipe chase framing member and primary raker girder

Figure S-43. View of primary raker girder within pipe chase, note pitting caused by prior web corrosion (upper arrow) and web cut-out (lower arrow)

Figure S-44. Areas of surface corrosion observed on the top surface of the tread plate in the lower tier seating section

S.10. Upper Tier Seating (Yellow Section) Structural Elements

S.10.1 Background

The structural framing for the upper tier seating sections includes the raker girders from the upper concourse to the upper elbow at the rear of this section. A plate girder spans transversely between the upper raker elbows and forms the rear wall of this seating area. Wide-flange beam members are used to frame the stairwells, adjacent to the vomitories, at the front of this section. In addition, the seat plate used for the tread and riser system is included as part of the structural system. Figure S-45 shows the layout of the typical structural members in the upper field seating section.

S.10.2 Observed conditions

In general, the paint coating on the weathering steel members was in good condition. Localized areas of surface corrosion were noted on the primary raker girders, but these areas were typically limited to the bottom flange tips of the primary raker girder and the upper elbow. These corroded areas were slightly more extensive at the eastern quadrants of the Stadium. Retrofits to divert water away from the bottom flange of the raker girder, as shown in Figure S-46, were observed. In most cases, the retrofit appeared to be working; however, at some locations corrosion and pack rust was observed in the vicinity of the retrofit. Finally, the lower portions of various raker girders were enclosed by metal deck panels forming the walls of the concession areas and restrooms. These areas were consequently not available for observation.

The top side of the seat plate is protected by the roof structure and, as a result, did not exhibit the extensive areas of surface corrosion that were observed in the lower seating bowl. Localized areas of surface corrosion on the top side of the seat plate were observed in regions where the waterproofing membrane had peeled or failed. The back surface of the seat plate appeared to be in good condition with some accumulation of dirt/debris on the coating system. Localized areas of corrosion and pack rust were observed at the joint between the tread and riser plate as shown in Figure S-47. This condition appears to be caused by wind driven rain entering the seat plate joint, similar to the point of entry shown in Figure S-20.

A plate girder spanning between the upper raker elbows, just above the last row, forms the rear wall of the seating section. At several locations this girder appears to have a lateral sweep, as shown in Figure S-48. This condition seems to have been present during the 1980's and 1990's repairs to the Stadium, as evidenced by the varying position of the railing attachment along the length of the girder. In some cases the entire diameter of the railing could not be welded to the top flange of the plate girder exhibiting this lateral sweep.

S.10.3 Recommendations

Based on our observations, we recommend the following repairs be performed to the upper tier framing members:

- The top coat of the coating system should be re-applied (P1 repair) to the weathering steel members.

- Localized paint repairs (P2) are required at all areas exhibiting paint coating failures and ongoing corrosion. These areas are concentrated on the flange tips of the primary raker girder and at the plate girder at the rear of the section.

- The underside of the seat plate should be powerwashed (P0 repair) to remove chlorides, dirt, and debris from the surface.

- Localized paint repairs (P2) are also required on the backside of the seat plate joints exhibiting corrosion and pack rust.

- To prevent wind-driven rain from entering the joint in the seat plate, it is recommended that a bead of sealant be placed in this joint prior to replacement of the waterproofing membrane. The interior side of this same joint may also need sealant treatment.

Replacement of the waterproofing membrane on the top surface of the seat plate is recommended and is discussed further in Section D.

- Sandblasting the corroded areas on the top side of the seat plate will be required before a new waterproofing membrane is applied.
- Further investigation regarding the lateral sweep of the girder at the rear of the section is also recommended. The investigation should include an analysis to determine the ability of the girder to transfer lateral loads in its current condition, and to verify whether the girder is required for the transfer of lateral loads. If an overall wind load analysis is performed for the entire stadium structure, the analysis of this plate girder could be included as part of the larger analysis.

S.10.4 Figures

Figure S-45. Typical structural framing for the upper tier seating section

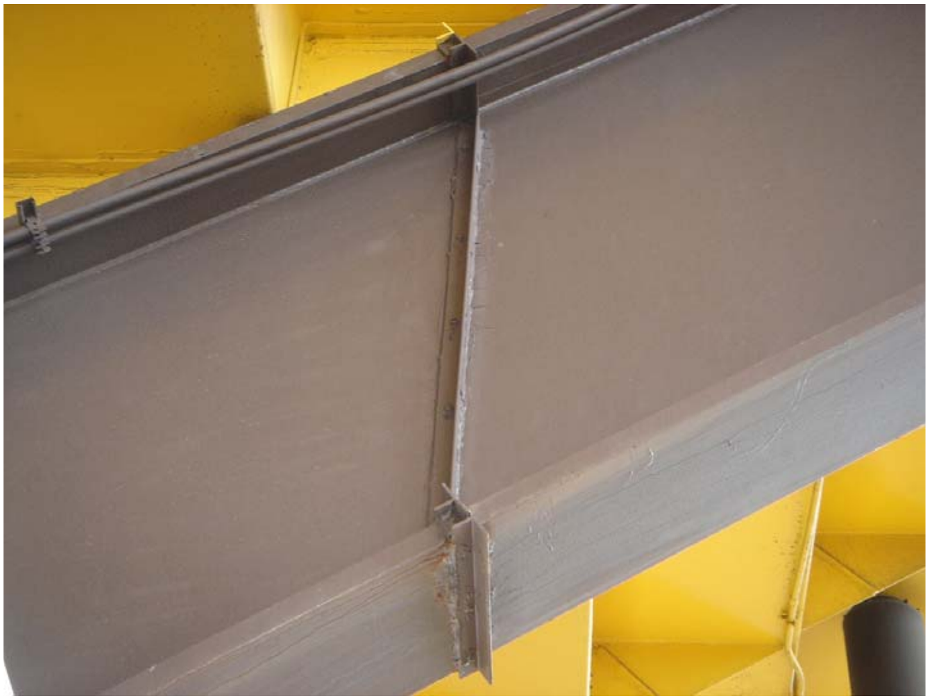


Figure S-46. Typical water runoff retrofit to prevent water from collecting on the bottom flange at the raker elbow

Figure S-47. Corrosion and pack rust at tread/riser plate joint

Figure S-48. Lateral sweep of the girder at rear of upper tier seating

S.11. Roof Canopy Structural Elements

S.11.1 Background

The structural framing for the roof includes the cantilever beam extension from the primary raker members, which is approximately 60 feet long. Wide-flange purlins span transversely between the cantilevered segments of the raker to provide intermediate supports for the metal roof deck above the weathering steel framing. Single angle bracing members are welded near the bottom flange of the purlins, typically at three intermediate points along the span. Figure S-49 shows the typical layout of the steel framing members.

Currently, a metal roof deck system is mechanically fastened to the top of the weathering steel framing members. Due to extensive corrosion, the original weathering steel metal deck at the roof level was removed in 1987 and 1988. The roof framing remained in place without any metal deck for several years. A new metal roof deck was installed throughout the Stadium in about 1990.

At the exterior perimeter of the current metal deck, a trough or gutter is created to capture and direct rain water to the roof drains. The roof access hatches are located adjacent to the gutter trough. An enclosure for the stadium field lighting is located along the interior edge of the roof, at the tip of the roof cantilevered. The underside of the roof canopy is shown in Figure S-49 and the top of the canopy is shown in Figure S-50.

S.11.2 Observed conditions

Different types of metal roof deck were observed throughout the Stadium; for example, both galvanized metal deck and aluminum metal deck were observed at different areas. In almost allquadrants, significant corrosion has developed and has corroded the deck away at limited, localized areas. Corrosion of the galvanized metal deck was evidenced by formation of white corrosion deposits on the deck surface, as shown in Figure S-51.

Severe corrosion and section loss was commonly observed in the metal deck in the vicinity of the rain gutter at the exterior perimeter of the roof framing. This severe corrosion typically progressed into the weathering steel members supporting the gutter. Examples of this corrosion and deterioration are shown in Figures S-52 and S-53. The corrosion at the gutter is likely due to the gutter serving as an ample and constant source of moisture in this area. In addition, the interior of the gutter was observed to be lined with copper. As a result, galvanic corrosion due to dissimilar metals may also be taking place (see Section R for further discussion).

It is our understanding that the replacement metal roof deck was intended to act as a structural diaphragm for the roof structure. As a result, horizontal X-bracing in the roof plane appears to have been removed, as shown in Figure S-54. (This X-bracing is not shown on original structural drawings, but is believed to have been installed to serve as a diaphragm bracing when the original roof deck was removed and the roof framing left without a deck for a number of years.) In order for the metal roof deck to act as a structural diaphragm for lateral loads, the deck must be properly secured to the steel framing members. Currently, metal TEK-type screws were used to attach the deck to the framing members. However, corrosion of these fasteners and the metal deck adjacent to the fastener was commonly observed, as shown in Figure S-55. In some cases, the fastener fractured due to this corrosion, as shown in Figure S-56. In addition, corrosion blossoms, shown in Figure S-57, were observed in the flange of the structural steel framing adjacent to some fasteners.

Generally, the observed deck corrosion was more extensive in the eastern quadrants of the Stadium than in the western quadrants. However, all four quadrants of moveable stands exhibited widespread corrosion throughout the metal decking. In the fixed quadrants, the metal deck at the north end is exhibiting deterioration similar to the moveable stands, especially at the gutter troughs. At the southern quadrants of the fixed stands, white corrosion deposits are beginning to form on the surface of the metal deck, indicating the initial stages of zinc corrosion. However, the areas of severe corrosion and section loss were not observed in these southern quadrants.

Paint failures and surface corrosion were typically observed on the weathering steel members and galvanized steel members (raker cantilever, purlins, and angle braces) of the roof structure throughout the Stadium. In general, this deterioration was observed on the flange tips of the framing members. As discussed previously, corrosion blossoms were also common in the top flange adjacent to the metal deck fasteners. This deterioration was worse on the eastern quadrants than the western quadrants. In the eastern quadrants, the surface corrosion often extended past the flange tips and into the webs of the weathering steel members. In other cases, the corrosion was at the flanges along the whole length of the member, not just in localized areas. Typical paint failures and surface corrosion are shown in Figures S-57 and S-58.

Areas of paint failures, corrosion, and section loss were also observed in the weathering steel members and metal deck panels in the field lighting enclosure at the field edge of the roof structure. This distress was pronounced in some instances.

S.11.3 Recommendations

As discussed in Section R, several dissimilar metals are used and are in contact, thus leading to the likely presence of galvanic corrosion in these structural members. The roof canopy structure consists of weathering steel framing members, galvanized steel or aluminum metal roof deck, galvanized or stainless steel deck fastener screws, and a gutter trough lined with copper. All of these dissimilar metals in contact are a ready source for galvanic corrosion of these structural elements. The rain gutters have a constant moisture source, contributing to the observed severe corrosion and section loss on the metal deck in this area.

Based on observations made during the field survey, the following recommendations are made for the roof canopy structure:

- White surface deposits, corrosion and section loss on structural members, and corrosion and fracture of mechanical fasteners were all commonly observed in several areas of the metal roof canopy throughout the stadium. This deterioration compromises the ability of the existing metal roof deck to act as a diaphragm, potentially creating a structural problem. Therefore, it is recommended that the metal deck be replaced throughout the Stadium. If a material such as aluminum or galvanized steel is selected for the replacement deck, it should be properly protected against corrosion and galvanically isolated from the existing steel structure.

- A membrane, or fabric, roof is an alternative to replacement of the metal roof deck. However, a membrane roof cannot serve as a structural diaphragm. Therefore, cross bracing members will require reinstallation between the roof canopy framing. This recommendation is discussed further in Section D.

- Due to the coating failures and surface corrosion observed in the eastern quadrants of the moveable stands, we recommend large-scale sandblasting and painting (P3) repairs for all weathering steel framing elements in these quadrants.

- At the quadrants in the fixed stands and the western quadrants in the moveable stands, the observed coating failures and surface corrosion on the weathering steel members do not seem extensive enough to warrant the performance of sandblasting and painting (P3 repairs) everywhere. Therefore, it is recommended that the top coat be re-applied (P1 repair) and that localized corrosion repairs (P2) be performed when required. Some members that exhibit more widespread corrosion may require a sandblasting and painting (P3) type repair. It should be noted that after the removal of the metal deck in these sections, additional corrosion will likely be observed on the top flange of the weathering steel framing members. If this corrosion is extensive, it may be more efficient to perform sandblasting and painting (P3) repairs to various groups of members.

- As a result of the severe corrosion and section loss to the weathering steel gutter framing members, it is recommended that these members be replaced (P4 repair) in the eastern quadrants of the moveable stands and the northeast quadrant of the fixed stands. At the gutter framing in the remaining quadrants, a sandblasting and painting (P3) type repair is typically required.

- For angle bracing members exhibiting wide-spread corrosion and section loss, it may be more cost effective to replace the angle (P4 repair) than to perform sandblasting and painting (P3) repairs.

- Repairs to the weathering steel framing members of the electrical (lighting) chase are recommended during the replacement of the metal roof deck. The metal deck surrounding the chase should also be replaced at that time.

S.11.4 Figures

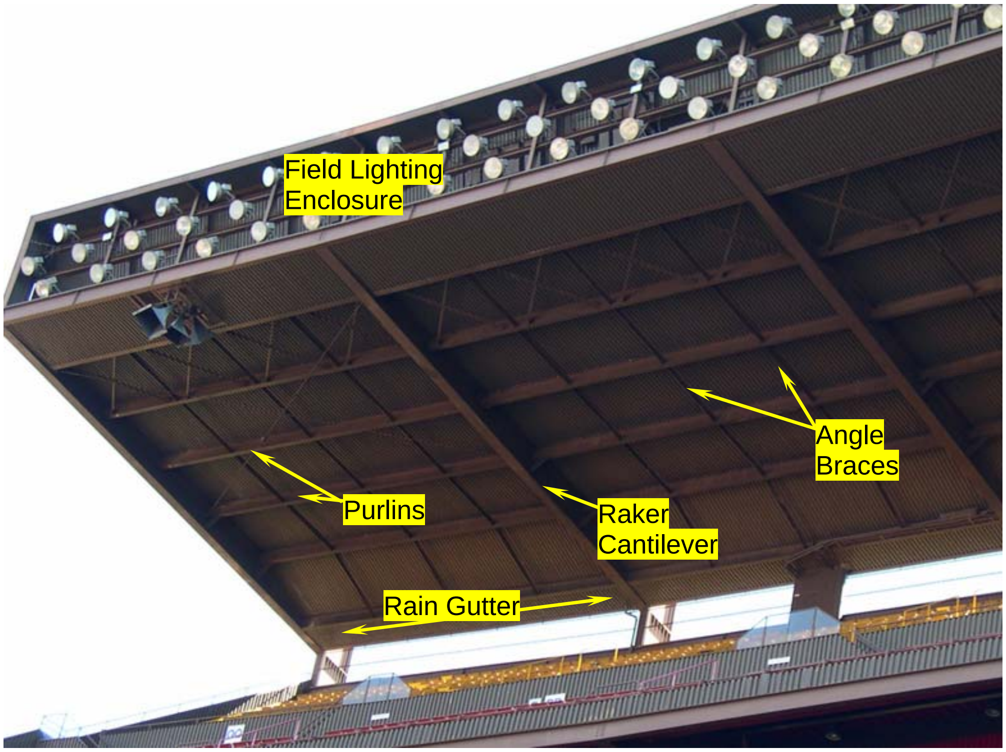


Figure S-49. Typical structural framing for the roof canopy, viewed from below

Figure S-50. The roof canopy, viewed while on top of the roof

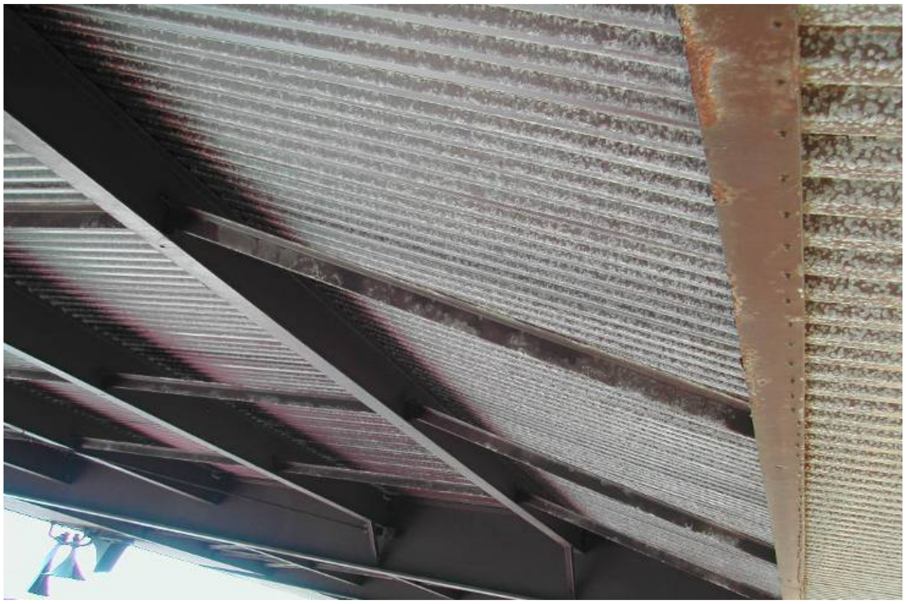


Figure S-51. Galvanic corrosion (white deposits) on the metal deck

Figure S-52. Severe corrosion and section loss of the metal deck and framing members beneath the rain gutter

Figure S-53. Severe corrosion and section loss of the metal deck and framing members beneath the rain gutter

Figure S-54. Missing cross braces in the roof system framing

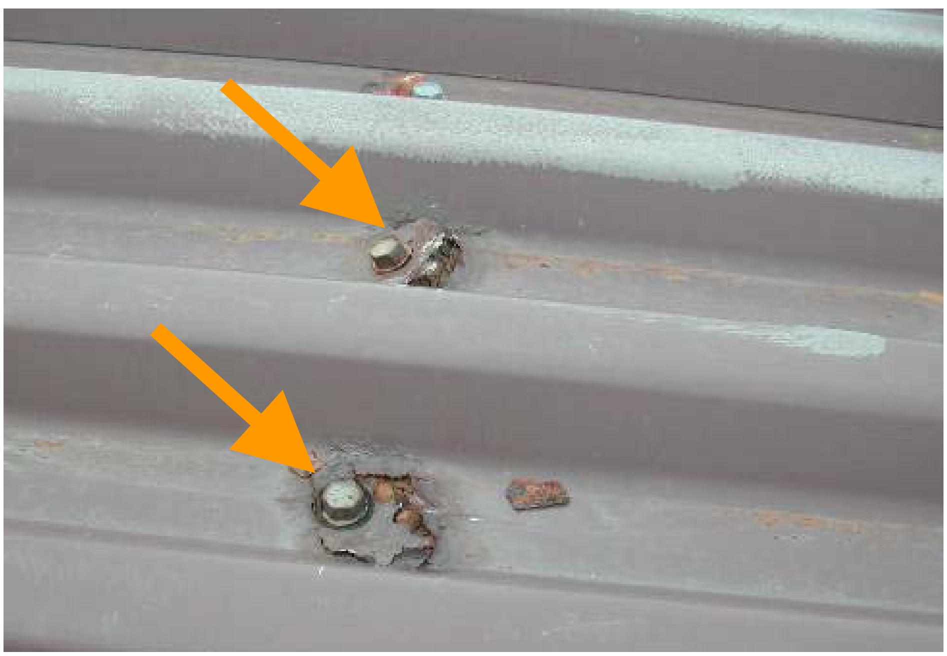


Figure S-55. Corrosion of the metal deck in the vicinity of the fastener

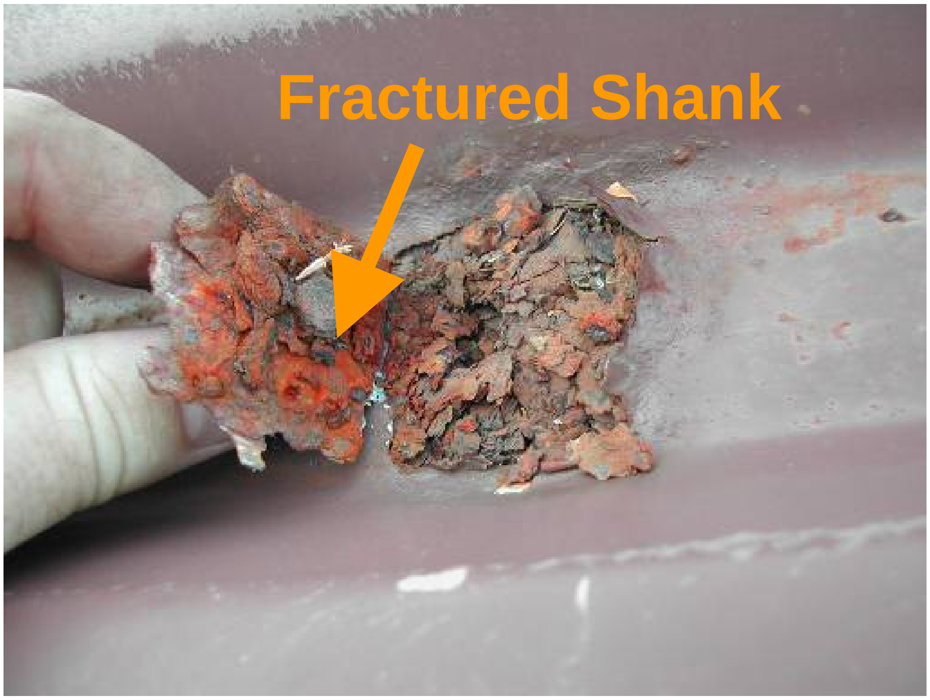


Figure S-56. Failure of the metal deck fastener due to corrosion

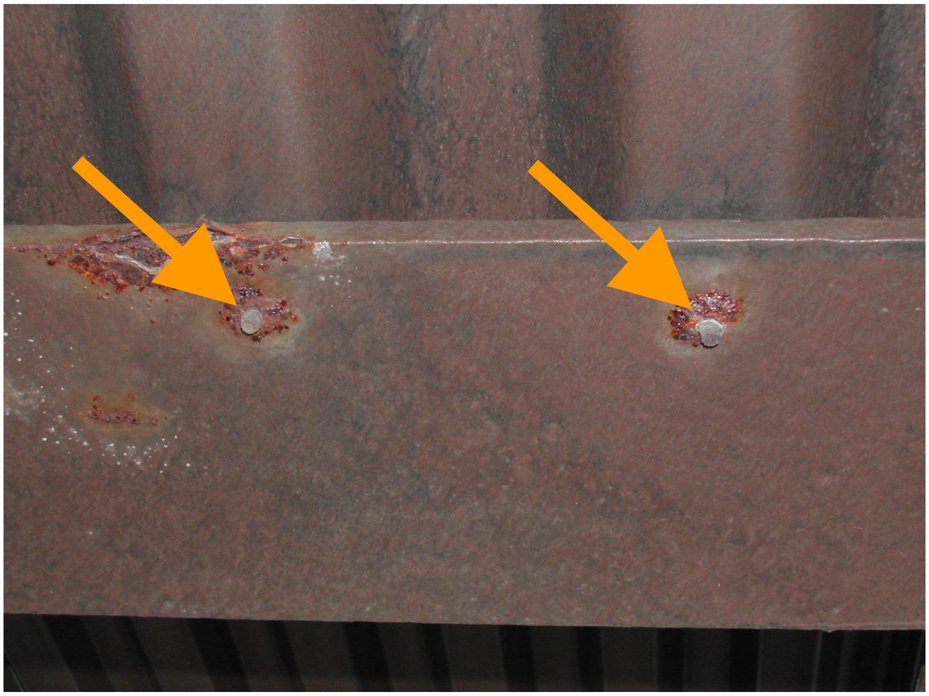


Figure S-57. Corrosion blossoms in the weathering steel member around the metal deck fastener

Figure S-58. Flange corrosion observed at the raker cantilever

S.12. Exterior Bracing Structural Elements

S.12.1 Background

The exterior bracing consists of the diagonal X-bracing members along the perimeter of the Stadium, at the outside edge of the pedestrian concourses. At the moveable stands, the exterior bracing spans vertically from the top of the upper tier framing to the level of the transport bearings, which is approximately at field level. At the fixed stands, the exterior bracing stops at the lower concourse level. Figure S-59 shows an overall view of the exterior bracing elements at the moveable stands; the layout of exterior bracing elements in the fixed stands is similar.

The intersection of the diagonal X-bracing members is referred to as a "hub". The intersecting wide-flange shapes connect at a steel box, fabricated from steel plates welded together. A typical hub and hub box is shown in Figure S-60. From review of the previous reports and repair documents, it is evident that these hub regions were susceptible to corrosion damage shortly after the original construction. The original hub configuration had two pockets on the top which collected water and typically did not dry out. It appears that this trapped water found its way into the interior of the hub boxes, and consequently sustained moisture exposure resulted in continued and advanced corrosion to these regions.

As part of the 1980s and 1990s corrosion mitigation program, the pockets on the top of the hub were filled with polymeric epoxy filler, finished with a slightly sloping top surface to divert water. The sealed hub boxes were drilled out, cleaned, flooded with paint, and closed off. The holes are presently sealed with “dummy” structural bolts, held in place by epoxy. The whole region was then painted with a coating system similar to that used for the rest of the structural steel.

S.12.2 Observed conditions

As a result of the constant UV exposure, the coatings on these weathering steel bracing members typically exhibited a chalked surface, as shown in Figure S-61. Localized areas of corrosion were also observed, but these areas did not appear to be as common as on other framing members in the Stadium. However, larger areas of coating failures, as shown in Figures S-61 and S-62, did appear to be more common in the exterior bracing members. This type of coating failure is related to underfilm corrosion and is precipitated by coating breaches or coating breakdowns, such as that caused by excessive coating thickness. Section R provides more detail as to the types of coating failures observed.

The upper and lower hubs exhibited similar conditions throughout the stadium. In general, the top surface of the hub showed cracking of the paint system at the edges of the endplate, as shown in Figure S-63. These breaches in the coating allowed moisture to directly reach the steel, promoting corrosion of the underlying weathering steel. In addition, the coating was observed to be wearing thin and spot corrosion of the steel was also observed. Due to the horizontal surface and moisture accumulation, the coating on the top of the hub was typically chalked. Figures S-64 and S-65 show other types of corrosion distress and coating failures observed at the upper hubs. Some of this corrosion is concentrated at the weldments of the hub box.

At the lower hubs, the polymeric epoxy filler seemed to exhibit more evidence of distress. This distress included breaches of the coating atop the epoxy filler, general failure of the coating on the horizontal steel surface, and cracks, crazing, or both in the paint and underlying epoxy filler. Cracks in this barrier typically were accompanied by rust stain bleed through, thus indicating corrosion of the underlying steel. Again, the horizontal top surface and its tendency to accumulate moisture resulted in chalking of the paint system on top of the hubs.

In order to ascertain whether corrosion was continuing inside the hub boxes, thickness of the hub box steel plates was surveyed with non-destructive testing techniques. This survey was conducted on the lower hubs of the east movable stands. On the front face, readings were taken at the top, middle, and bottom of the north and south plates. On the side face, readings were obtained at the top and bottom. The recorded steel thickness measurements typically exceeded the thicknesses specified by the original structural design drawings, suggesting that only minor incidences of section loss occurred within the hub box.

At the lower hub between Column Lines 13 and 14, the condition of the epoxy filler and breaches in the coating on top of the hubs were examined close-up by making an exploratory opening into the epoxy filler. The conditions observed at this opening are shown in Figures S-66 and S-67. At this opening, moisture penetrated into the epoxy through a crack in the coating. The top lift of the epoxy was somewhat saturated with water and the steel end plate was corroding at this entire lift thickness. Corrosion byproduct (rust) from the steel had leached into the lift line, and had caused delamination or interlayer debonding between lifts of the epoxy. Based on these observations, it is suspected that these filler regions are acting as reservoirs for water where the coating is breached.

S.12.3 Recommendations

Based on our field observations of the exterior bracing members and the hubs, the following recommendations are presented to address existing conditions and to help prevent future deterioration:

- It is recommended that the top coat be re-applied to the surface of these bracing members. Due to the chalked coatings on these members, additional preparation of the coating surface (P1+ repair) may be required. Areas of localized corrosion and paint failures should be addressed (P2 repairs) as required. Some members exhibiting more widespread corrosion may require a sandblasting and painting (P3) type repair.
- The coating system and other components of protection at the hubs have reached their useful service life. Initial signs of coating breaches have resulted in continued corrosion of the weathering steel beneath the coating and polymeric epoxy filler. The corrosion damage observed was minor but if not addressed in a timely fashion, the corrosion will cause continued distress to the protection system. In the worst case, the corrosion can result in potential structural integrity concerns at the hubs. Therefore, a sandblasting and painting (P3) repair is recommended at each hub throughout the Stadium.
- The present polymeric epoxy filler at each hub should be removed and replaced. Prior to replacement, the weathering steel should be sandblasted and painted. Alternate replacement materials should be investigated, such as concrete, polymer-modified mortar, or a different epoxy-type filler, possibly extended with sand or inert aggregate.
- An alternate coating system on the horizontal surface of the hub should be investigated. A three-coat paint system with a urethane top-coat is not well suited for a horizontal application where water can stand. A urethane waterproofing membrane (40 to 50 mil thickness), a hot-applied roofing membrane, or sheet metal flashing are possible alternates that could provide a covering that is more durable than the present system. Because of the aggressive environment present at the Stadium, it is recommended that a trial repair be installed and its performance monitored.

S.12.4 Figures

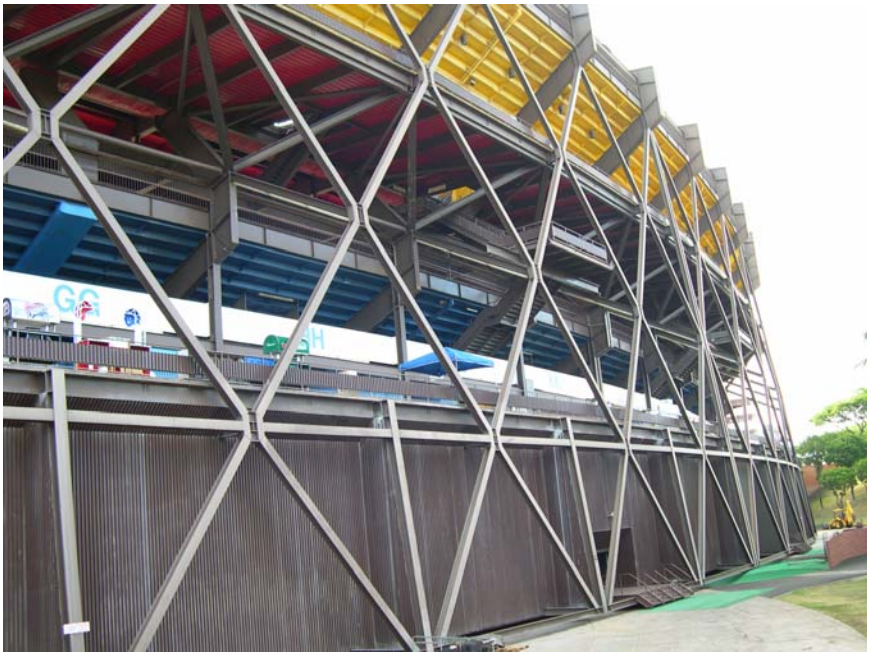


Figure S-59. Typical layout of exterior bracing in the moveable stands

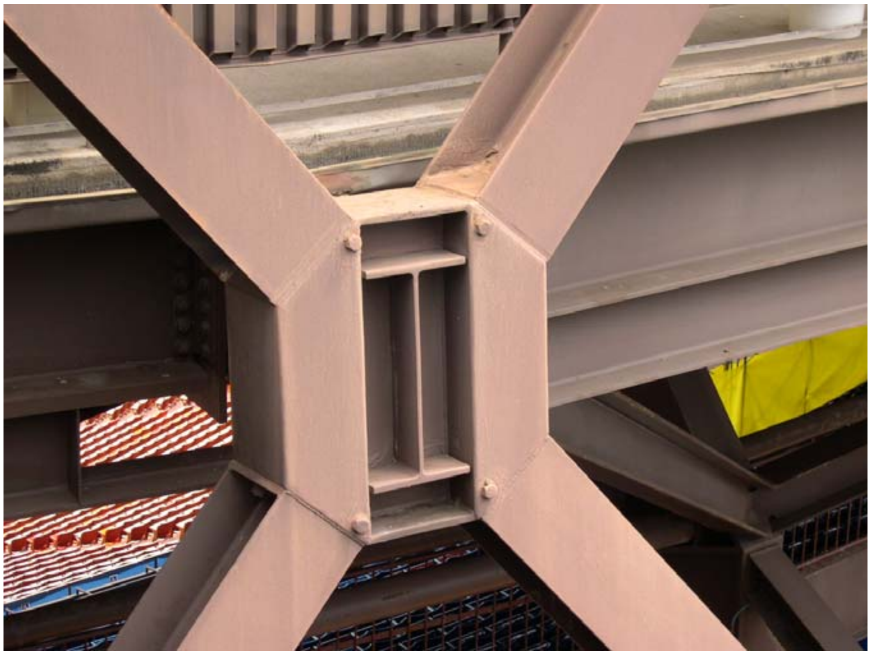


Figure S-60. Typical hub box

Figure S-61. Exterior bracing members exhibiting a chalked coating surface and peeling of the coating system

Figure S-62. Area of coating failure on an exterior bracing member

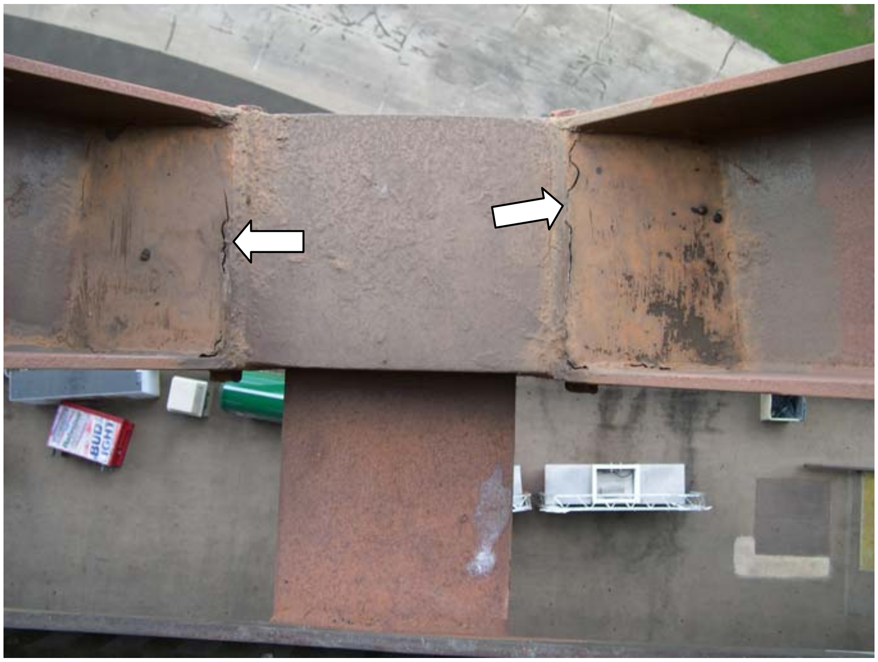


Figure S-63. Breaches (cracks at arrows) in the top coating over the epoxy filler at the hub box

Figure S-64. Coating failure at the hub box

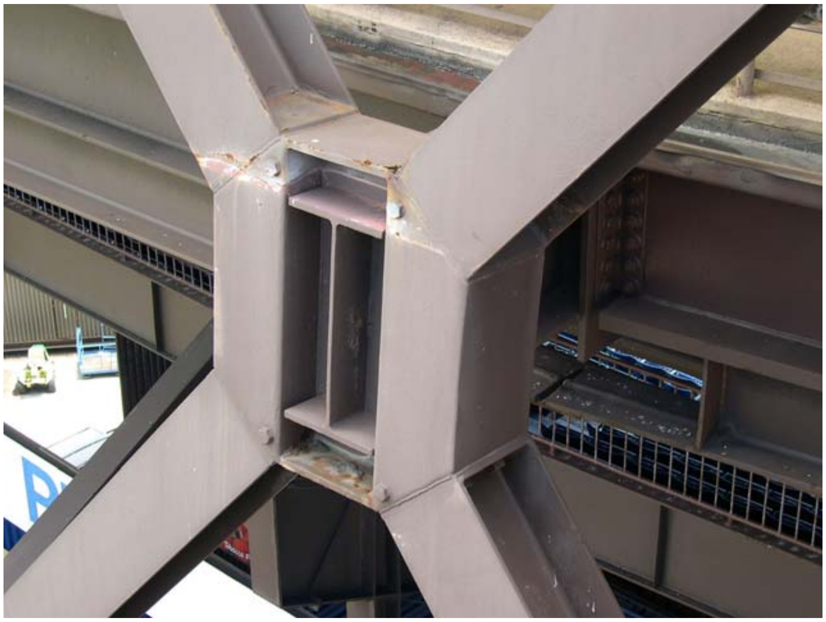


Figure S-65. Steel corrosion observed at the hub box

Figure S-66. Exploratory opening in the filler material atop the hub box

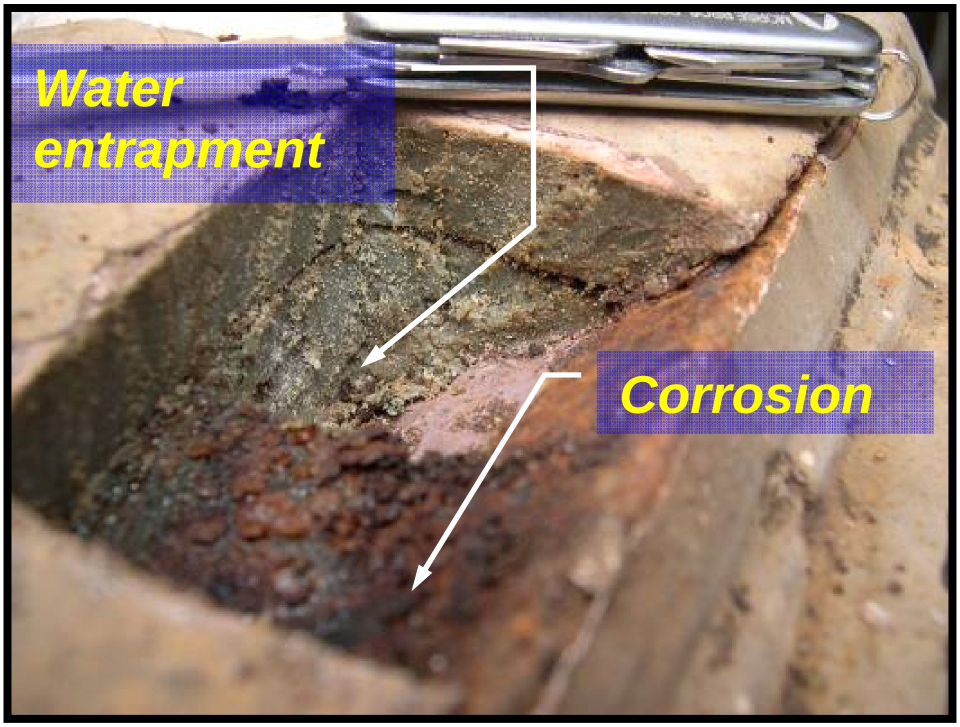


Figure S-67. Trapped water and corrosion observed beneath the filler material

S.13. Interior Bracing Structural Elements

S.13.1 Background

This group of structural elements includes the two wide-flange bracing members extending from the lower raker elbow to upper hub locations on the exterior bracing near the upper concourse. A wide-flange bracing member also extends downward from the same lower raker elbow to a lower hub on the exterior bracing. These members are part of the original stadium structure and are shown in Figure S-68.

Analyses performed during the 1980s and 1990s indicated that the upper concourse metal deck was not adequate to act as a structural diaphragm under lateral loadings. As a result, diagonal pipe bracing members were added beneath the upper concourse throughout the Stadium in 1988. These diagonal pipe bracing members are noted in Figure S-68. In addition, to strengthen the out-of-plane bending capacity of the raker girder at the elbow between the upper field section and the Loge Level, horizontal pipe bracing was added between the elbows at Line “F” in 1988, also labeled in Figure S-68. This horizontal pipe brace retrofit was performed throughout the Stadium. The pipe bracing members beneath the upper concourse and between the raker elbows are included in this structural grouping.

S.13.2 Observed conditions

Corrosion of the original bracing members at the raker elbows was commonly occurring at the flange tips along the entire length of the member. This type of corrosion is shown in Figure S-69. The corners of the flange edges on these members appear “sharper” than those of flange edges on other wide-flange beams throughout the Stadium. The sharp corners likely have resulted in shrinkage of the coating system at the flange edge as the coating was initially applied. The likely thinner protective coating at the flange edge corners may have caused the widespread paint failures, resulting in the corrosion observed at the edge corners of these members. In some cases, the surface corrosion extended onto the width of the flange and into the web of the member.

The lower nodes of these members, at the attachment to the raker elbow, often displayed extensive coating failures and surface corrosion. These nodes also contained filler material, which should be further examined up-close to evaluate its performance.

The coatings on the diagonal pipe braces beneath the upper concourse were not performing well. Coating blisters and spotty areas of corrosion were typically observed along the length of these bracing members, as shown in Figure S-70. Also, the connection plates at each end of the member are exhibiting localized corrosion. It is possible that there is trapped moisture within these sealed pipe bracing members. Airborne moisture and humidity may have migrated into the pipe through weld breaches.

White deposits were typically observed throughout the horizontal pipe braces located at the raker elbows. The white deposits on these members, as shown in Figure S-71, indicate that the zinc protective coating on the galvanized pipe braces is being consumed in this aggressive environment. Corrosion of zinc protective coatings is discussed further in Section R.

S.13.3 Recommendations

Based on our observations, we recommend the following repairs be performed to the interior bracing members:

- In general, sandblasting and painting (P3) repairs are required on all interior bracing members. This includes the original wide-flange bracing members, the diagonal pipe braces beneath the upper concourse, and the horizontal pipe braces at the raker elbow.

- Further investigation should be performed to verify that there is no entrapped moisture within the diagonal pipe braces at the upper concourse.

- The polymeric filler material used at the lower diagonal brace node should be investigated in more detail. Similar to the hub fillers, this material may need replacement throughout the Stadium.

S.13.4 Figures

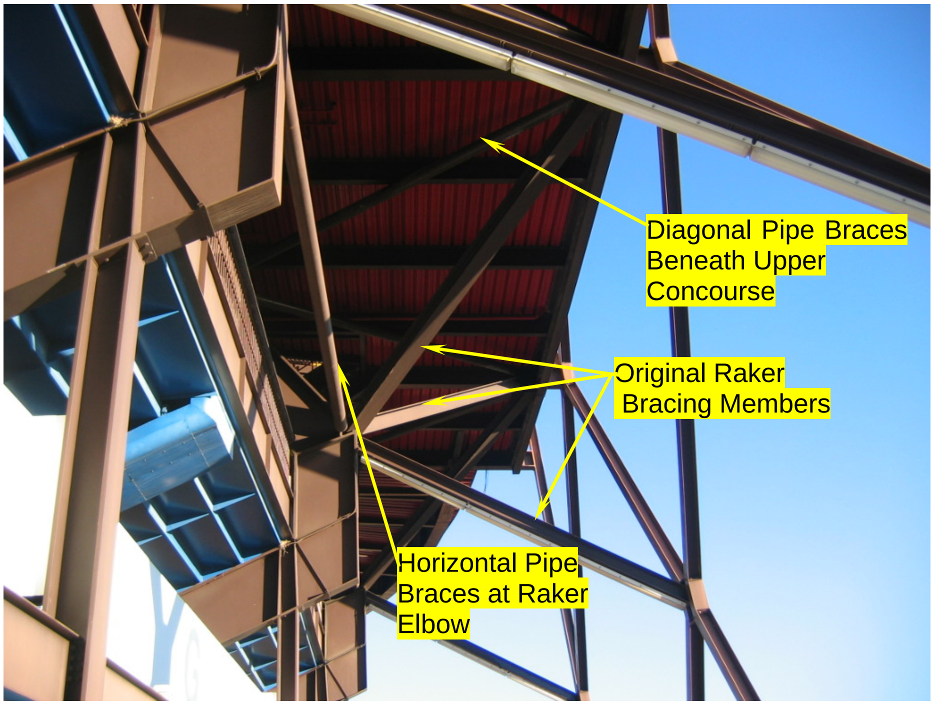


Figure S-68. Layout of interior bracing members

Figure S-69. Widespread corrosion and paint failure of the original bracing members

Figure S-70. Corrosion of diagonal pipe brace beneath upper concourse

Figure S-71. Corrosion of horizontal pipe bracing members that connect raker elbows

S.14. Main Stairwell Structural Elements

S.14.1 Background

The stairwell structure includes weathering steel framing members as well as the diamond steel plate used for the treads and risers. One stairwell is located in each of the four quadrants of the moveable stands. Each stairwell leads from the upper concourse down to an exit at the field level at the back of the stadium. Intermediate landings provide access to the Loge Level and lower concourse. Typical stairwell framing above the lower concourse is shown in Figure S-72.

S.14.2 Observed conditions

It appears that the stairwell framing members above the lower concourse are not shielded by other surrounding elements. Consequently, exposure to the aggressive wind environment (such as wind-driven moisture and airborne chlorides) seems to have resulted in widespread corrosion of the weathering steel framing members and the tread and riser plates. This corrosion is illustrated in Figure S-73. Below the lower concourse, the stairwell framing members are sheltered by the wall panels surrounding the lower field seating structure. Because of this sheltering, the stairwell framing below the lower concourse is performing better than the stairwell framing above the lower concourse. However, several areas of corrosion and pack rust were observed in the joint between the tread and riser plates, as shown in Figure S-74, often resulting in corrosion-related deformation of the riser plate.

S.14.3 Recommendations

Based on our observations, we recommend the following repairs be performed at all four stairwells in the moveable stands:

- Perform global sandblasting and painting (P3) repairs to all structural elements of the stairwells above the lower concourse.

- The stairwell framing below the lower concourse should be powerwashed (P0 repair) to remove the chlorides from the surface of the coating. Powerwashing would also help to remove any build up of dirt and debris on the surface of the members.

- Localized paint repairs (P2) are required at the framing members below the lower concourse exhibiting paint coating failures and ongoing corrosion. In members with larger areas of corrosion, sandblasting and painting repairs (P3) are recommended.

- Tread/riser replacement repairs are recommended in areas where corrosion and pack rust has resulted in deformation of the tread/riser plate.

S.14.4 Figures

Figure S-72. Typical stairwell framing above the lower concourse

Figure S-73. Corrosion and coating failures observed on the stairwell framing

Figure S-74. Corrosion and pack rust has resulted in deformation of the riser plate

S.15. Moveable Bridges

S.15.1 Background

The moveable bridges are used to connect the fixed and moveable portions of the stands when the Stadium is in the football configuration, as shown in Figure S-75. A demountable bridge is located at both the upper and lower concourses at each corner of the Stadium, for a total of eight bridges. Each bridge consists of two curved girders connected with cross framing members that support the metal deck and lightweight concrete walkway, as shown in Figure S-76. At both ends of the bridge, each curved girder is connected to the stadium structure using a hanger mechanism, as shown in Figure S-77. Prior to moving the Stadium sections to the baseball configuration, the hanger mechanism is retracted and a hydraulic lifting system (described in Section T) is used to lower the bridges to the ground. The upper bridge structure nests onto the lower bridge and both bridges are transported, using air-supported bearings, to a storage area beneath the fixed stands.

During our field survey, it was noted that the bridges appeared to be sensitive to pedestrian induced vibrations and deflections. The deflection seemed to be exaggerated by the nature of two curved girders of unequal length. Reportedly, stiffening measures to control deflection were installed to the bridges in 1993, but were subsequently removed after the hydraulic lifting system could not support the additional weight of the stiffening elements. Further discussions of prior and current analyses of the curved bridges are presented in Section III.

S.15.2 Observed conditions

Localized paint failures and corrosion was observed at the steel framing members of the moveable bridges. These areas of deterioration were concentrated at the bottom flange tips of the framing members.

It was observed that the moveable bridges do not have an explicit method to drain surface water. Currently, water follows the existing slope of the bridge surface, draining off of the bridge deck along discontinuities in the toe rail or into the expansion joint at either end of the bridge.

S.15.3 Recommendations

Based on our observations, we recommend the following be performed at all eight moveable bridges:

- Nondestructive testing of the hanger mechanism, particularly the prawl plate and pin components, is recommended to verify their structural integrity.

- The paint top coat should be re-applied (P1 repair) to all weathering steel framing members, in addition to localized repairs to areas exhibiting paint coating failures or corrosion (P2 repair).

- The installation of a drainage system within the decks of the moveable bridges should be considered.

Additional recommendations, pertaining to the structural and deflection performance of the moveable bridges, are given in Part III.

S.15.4 Figures

Figure S-75. Moveable bridges at the upper and lower concourses

Figure S-76. Close-up view of the bridge structural framing

Figure S-77. General view of the hanger mechanism on one end of a demountable bridge

S.16. Sign Truss Framing

S.16.1 Background

Sign trusses, as shown in Figures S-29 and S-45, are located around the inside edge of each concourse walkway, at both the upper and lower concourses. The trusses are used to support the signage detailing the section designation. A wide flange beam is used at the top and bottom chords of the truss and the chords are connected with single angle web (diagonal and vertical) members. Each end of the truss is supported from a raker girder.

S.16.2 Observed conditions

The weathering steel truss members exhibited extensive coating failures and surface corrosion of the sign truss framing members, as shown in Figure S-78. This condition is especially true for the sign trusses in the eastern quadrants, or Mauka, side of the Stadium that is constantly exposed to the aggressive environmental elements, including wind, wind-driven moisture, and airborne chlorides. The sign trusses in the western quadrants typically exhibited less deterioration; however, sign truss framing adjacent to the vomitory openings on the west side also exhibited significant corrosion and coating failures. It appears that the wind-driven environmental elements, mentioned above, are forced through the vomitory openings, resulting in deterioration of the sign truss framing adjacent the vomitory.

S.16.3 Recommendations

Because localized needle gun (P2) corrosion repairs or overall sandblasting and painting (P3) repairs would be quite tedious and costly for these relatively small truss members, we recommend that a program be implemented for replacement of these sign trusses:

- Replacement of the sign trussed should be phased based on the level of deterioration present in each sign truss. Painted carbon steel framing, aluminum, or galvanized steel materials are possible options for replacement truss framing, provided the selected material is properly protected, galvanically isolated, or both.

- The sign trusses in the eastern quadrants would have the highest priority for replacement. The sign trusses in the western quadrants would have a lower priority for replacement.

- As an alternate to replacment, sign trusses with little or no deterioration may be repaired by performing localized corrosion (P2) repairs and re-applying the top coat (P1 repair) to all existing weathering steel framing members.

S.16.4 Figures

Figure S-78. Widespread corrosion of sign truss framing members

S.17. Spiral Walkway Ramps

S.17.1 Background

One spiral ramp is located in each of the four quadrants in the fixed stands. Each ramp structure consists of two helical ramps that are intertwined to form the ramp structure. Each spiral ramp leads from the upper concourse to the lower concourse. A typical ramp is shown in Figure S-79. The spiral ramps are located on the periphery of the Stadium, and are therefore readily exposed to wind-driven rain and airborne chlorides.

As a result of extensive corrosion of their weathering steel elements, all four original ramps were temporarily repaired in 1993. Subsequently, in 1995, all four original ramps were demolished and replacement ramps were constructed. The replacement ramps are of a similar appearance and design as the original ramps, except that the replacement ramps are framed in galvanized steel that has been painted.

S.17.2 Observed conditions

As with other features of the stadium, the eastern ramps are exposed to a more aggressive environment than the western ramps. As a result, the eastern ramps are currently exhibiting more extensive surface corrosion and coating failures. White corrosion deposits from the galvanizing are most commonly observed on the columns of the spiral ramps, as shown in Figure S-80. The beam framing members are partially sheltered by the metal deck above and, therefore, exhibited less corrosion than the column members. Nevertheless, coating failures were observed on various beam elements, as shown in Figure S-81. Corrosion of the galvanized metal deck, located above the beam framing members, was also noted as shown in Figures S-80 and S-82.

S.17.3 Recommendations

The spiral ramp structures were reconstructed using galvanized and coated steel elements. Because of pinholes in the original paint coating, the zinc protective coating of these members is being consumed in this aggressive environment, as expected for the zinc coating component. As a result, white corrosion products bleed through and are observed on many of these painted elements. The re-application of a suitable coating with a proper thickness would retard the corrosion of the galvanizing zinc and maintain a suitable aesthetic appearance.

WJE previously investigated the coating performance on the spiral ramps. Detailed repair recommendations were presented to the State of Hawaii in a previous report dated 30 June 1999. This letter should be consulted for further details.

S.17.4 Figures

Figure S-79. Typical spiral ramp


Figure S-80. Corrosion of the galvanized steel framing members


Figure S-81. Adhesion failure of the coating system on the beam element

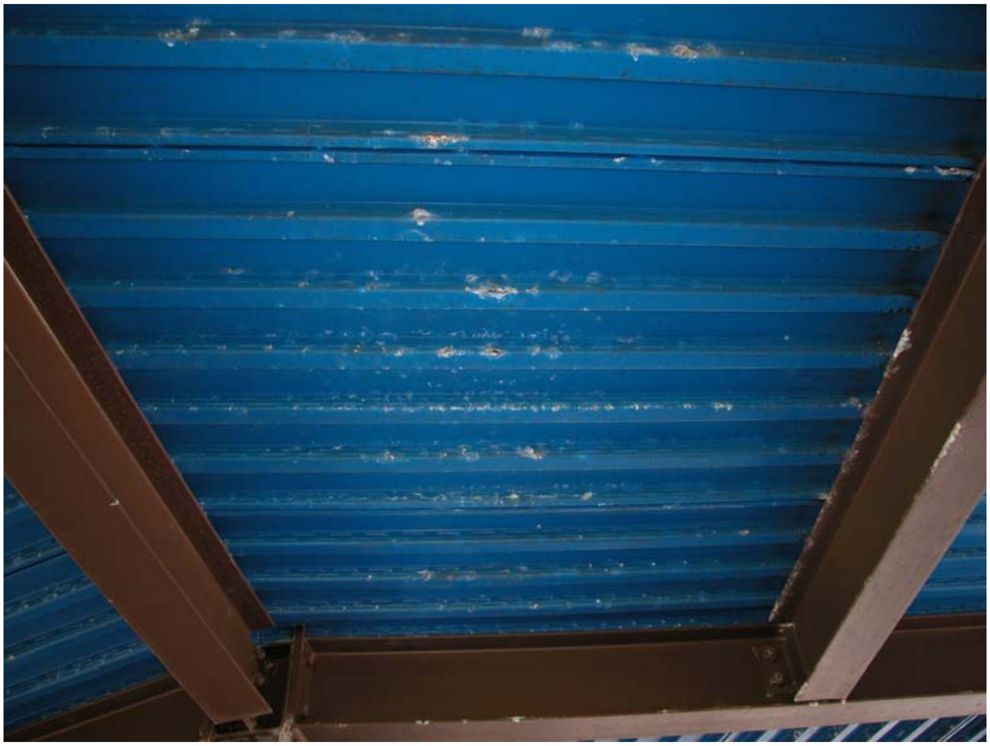


Figure S-82. Corrosion of the galvanized steel deck in the spiral ramp

S.18. Pivot Points on Moveable Seating Stands

S.18.1 Background

During repositioning of the four movable seating stand sections between football and baseball configuration, each seating stand section rotates around a fixed pivot point connected to the adjacent fixed concrete seating stand section. The pivot points are located at the four corners of the football field, as shown in Figure S-83. Each pivot consists of a steel bearing hinge assembly on a round concrete base connected to a rectangular concrete pedestal footing, as shown in Figure S-84. The pedestal is then connected to the adjacent concrete foundation walls for the fixed stand section. Connection of the pedestals to the adjacent walls differs between the north and south pivots due to the presence of the baseball dugouts near the south pivots.

A review of the pivots was performed by Robert Englekirk Consulting Structural Engineers, Inc. (REI) in 1994 to determine the cause of cracking observed in the concrete bases, pedestals, and surrounding walls, and to recommend repairs. REI stated in their report dated 12 July 1994 that cracking observed in the round concrete bases was due to lateral displacement of the steel pivot assembly that occurs during repositioning of the stands. Cracking observed in the southeast and southwest concrete pedestals and walls was attributed by REI to a deficiency in structural capacity for transfer of the imposed loads to the foundation. Cracking observed at the pedestals and walls for the north pivots was less extensive than the south pivots due to differences in foundation configuration between the north and south pivots. Repair recommendations, which included demolishing the concrete bases, pedestals and portions of the adjoining foundation walls, and rebuilding of the elements with additional steel reinforcement at all four pivots, were provided in repair documents that were entitled “Aloha Stadium - Strengthen Pivot Points” by REI dated February 1995. Reportedly, these repairs were performed in 1995; however, we have been unable to confirm this.

S.18.2 Observed Conditions

WJE performed a visual review of the pivot assemblies on 20 October 2005 to observe the implemented repairs recommended by REI and to document the existing condition of the steel and concrete elements. The addition of reinforcing steel was not verified but the minimal cracking observed in the concrete foundation walls and pedestals, and the thickened wall observed along the playing field within the dugouts (Figure S-85) suggest some repairs were performed. Typical cracking and delaminations were observed on the round concrete bases below each of the steel pivot assemblies, as shown in Figures S-86 and S-87. Some cracking was also observed on the concrete pedestals and walls, though no delaminations were identified by sounding of the concrete with a hammer. Figure S-88 shows typical pedestal and wall cracking at the southeast pivot. The pedestal at the northeast pivot could not be reviewed due to the presence of debris. Cracked and delaminated concrete was also observed in the concrete seating area adjacent to the northeast pivot. Typical localized corrosion of the steel pivot assemblies and adjacent structural steel was observed at all pivot locations, as shown representatively in Figure S-89.

S.18.3 Recommendations

Based on our observations, we recommend the following repairs be performed at all four pivot locations to address the existing conditions and to reduce future deterioration:

- Sandblast and recoat corroded sections of the steel pivot assemblies and adjacent structural steel.

- Rout-and-seal cracks observed on the concrete pedestals and walls to prevent water from infiltrating to the level of the steel reinforcement and cause future spalling.

- Demolish the round concrete base section directly below the steel pivot assembly and reconstruct a larger base with additional steel reinforcing to prevent cracking of this section during moving of the stands.

S.18.4 Figures

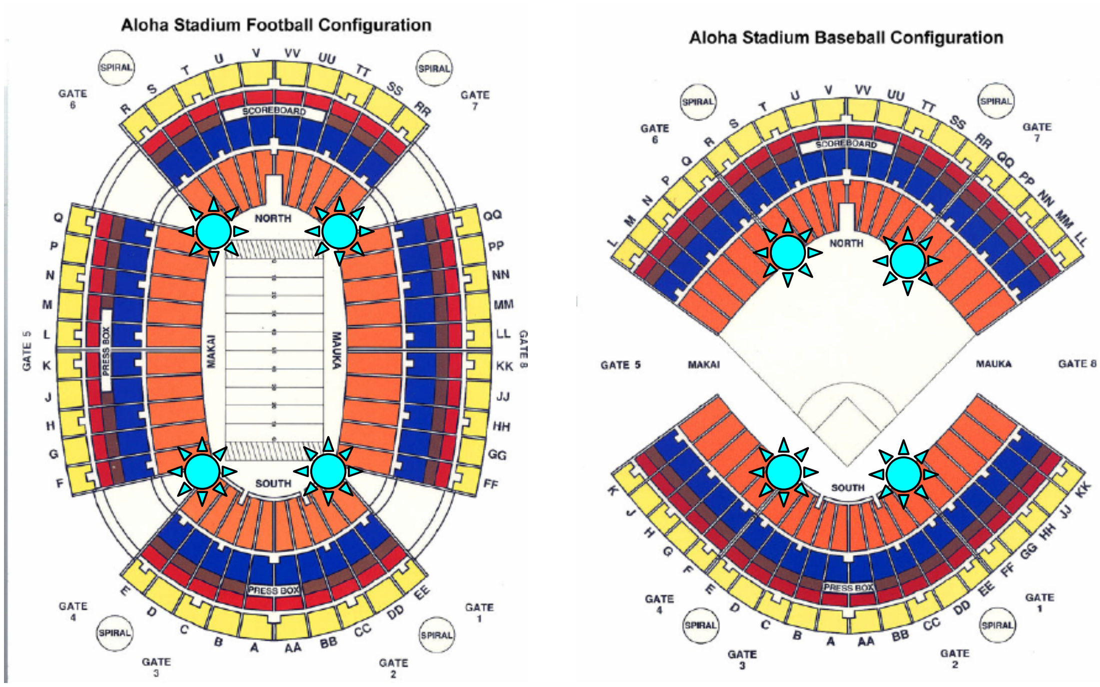


Figure S-83. Locations of pivot pins

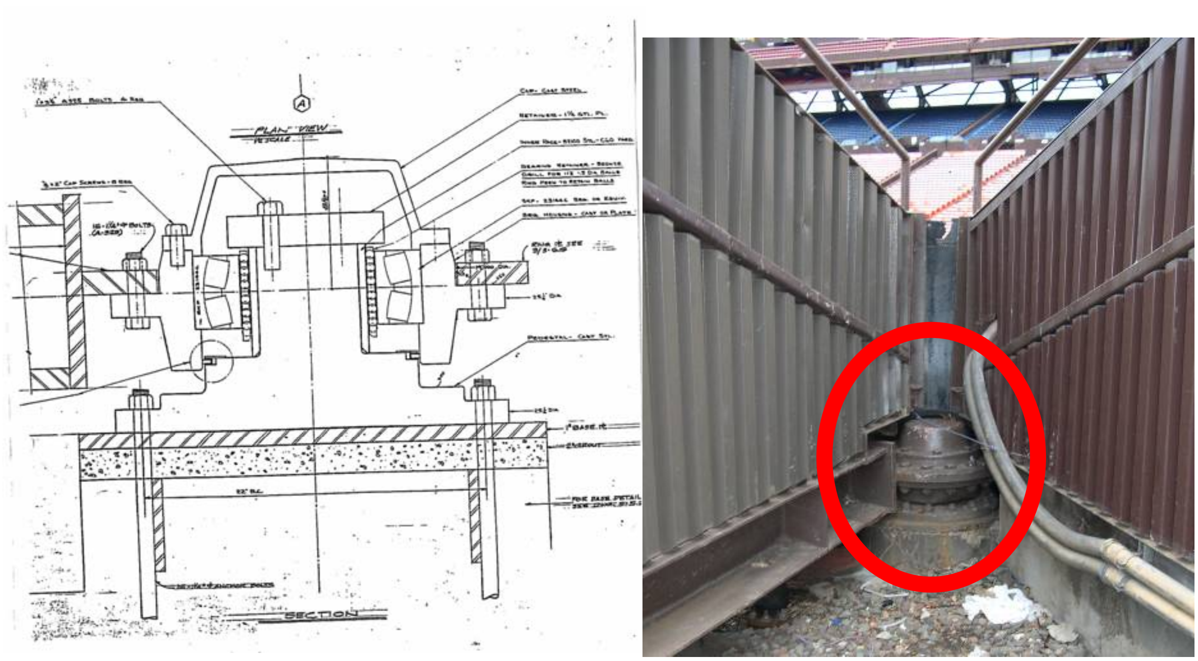


Figure S-84. Section through pivot pin assembly and view of representative pivot assembly

Figure S-85. Thickened wall section at southwest pivot point as indicated by arrow

Figure 86. Cracking in base at southeast pivot point

Figure 87. Cracking in base at northeast pivot

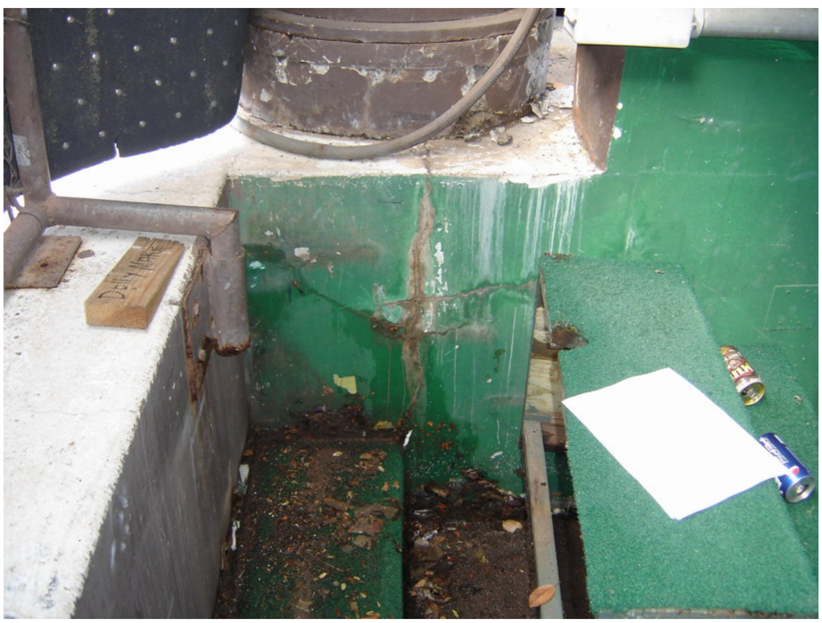


Figure 88. Cracking in pedestal and dugout wall at southeast pivot

Figure 89. Typical spot corrosion of steel pivot assembly at southwest pivot

Part II – Condition Survey

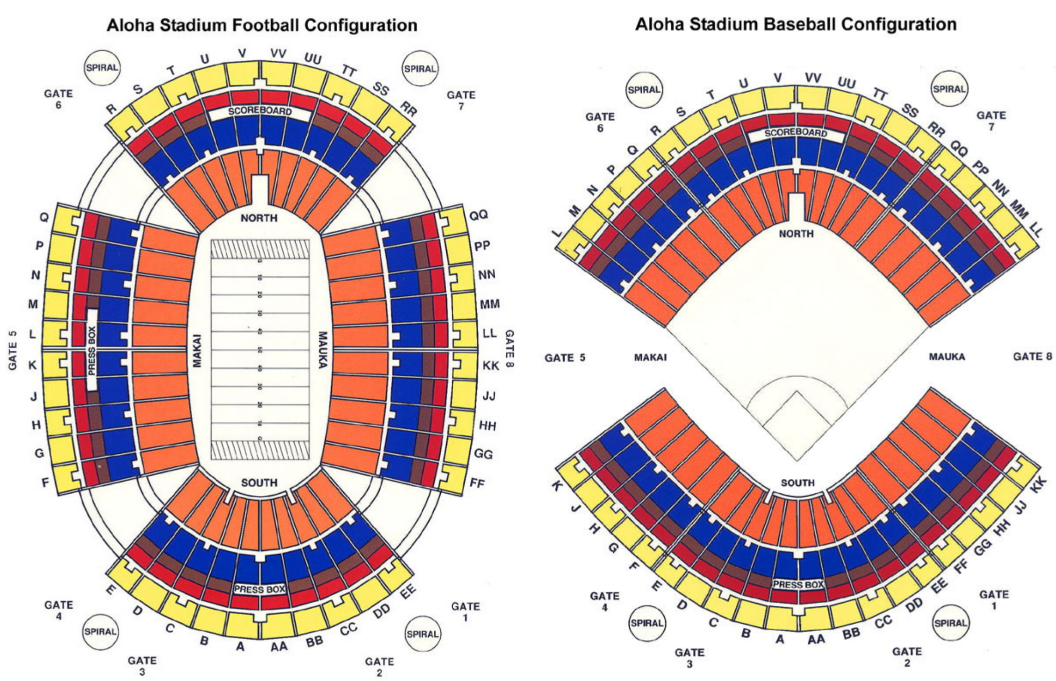
Section T - Transport Systems for Moveable Stands

T.1. Background

As described previously, Aloha Stadium is a reconfigurable stadium that can accommodate football, baseball, and concert layouts. Stadium plans showing the stands positioned in football and baseball configurations are provided in Figure T-1. There are four moveable stands, commonly identified by their relative compass locations (northeast, southeast, southwest, northwest).

To be reconfigurable, the stadium requires a transport system to accomplish the movement of the seating stands from one configuration to another. One corner of each moveable stand is anchored by a pivot fixture, so that when being moved from one configuration to another, the stand rotates about the pivot point. The locations of the pivot points are identified with labels in Figure T-2, which shows the stadium in the football configuration.

The existing transport system dates from the original construction of Aloha Stadium during the first half of the 1970s. An industry publication from the time of construction (*Compressed* Air,



(a) Football Configuration (b) Baseball Configuration

Figure T-1. Expanded plans of Aloha Stadium: (a) Football configuration; (b) Baseball configuration.

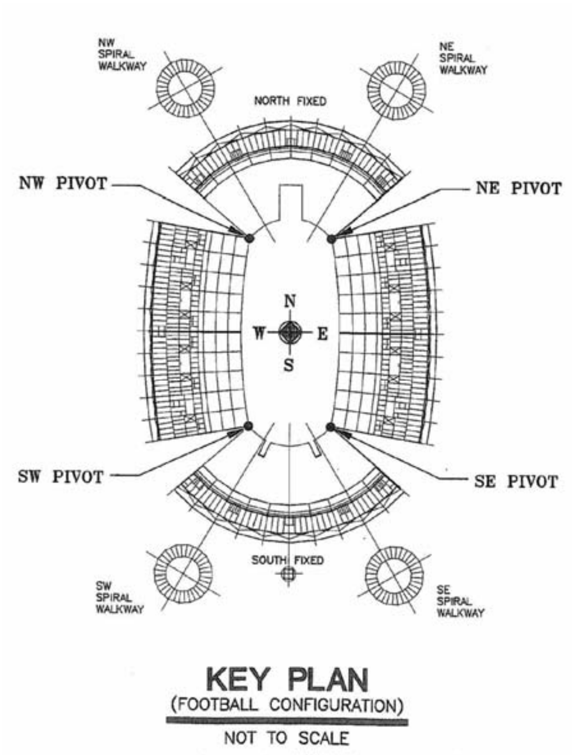


Figure T-2. Stadium plan (football configuration) showing locations of pivots.

December 1975, pp. 6-9) attributes the original design and construction of the transport system to Rolair Systems, Inc. The stadium transport systems are based on air film technology, whereby a series of air film bearing assemblies provide a thin film of air as a lubricant between the load and the supporting surface to eliminate friction. The bearing assemblies at Aloha Stadium travel across paved concrete runways as the stands are moved.

In football configuration, the stadium layout includes eight (8) curved pedestrian bridges that connect the moveable stands to the fixed stands. The bridges span the pie-shaped gap between the fixed and moveable stands at each quadrant or corner of the stadium. At each of the four corners of the football-configured stadium, Figure T-1a, there are two bridges, one bridge located at each of the lower and upper concourse levels, depicted in Figure T-3. When the stadium is positioned in baseball configuration, the two bridges from each quadrant are demounted and lowered to the ground, stacked upper bridge on top of the lower bridge, and then moved into storage beneath the adjacent fixed stand. In addition to having a horizontal transport system based on air film technology, the bridges also have a hydraulic piston lifting mechanism to raise the bridges from ground level to the appropriate vertical position in the stadium.

T.2. Transport for Moveable Seating Stands

There are eight steel-framed structural pedestals located beneath each moveable stand, with either two or four air film bearing assemblies at a pedestal. The typical pedestal layout plan for a moveable stand is given in Figure T-4. A structural pedestal and its bearing assembly are shown in Figure T-5. The bearing assemblies are supported by a paved concrete runway, both when in motion and when at rest.

Compressed air is used to inflate four flexible doughnut-like diaphragms that comprise each individual bearing assembly. The diaphragm inflation process lifts a seating stand by approximately 1 inch. Pressurization causes controlled leakage of air around the perimeter of each diaphragm, creating the air film that supports the stands and provides the air lubrication over which the stands are moved. The compressors that supply the pressurized air are located remotely, beneath the fixed stands. Permanent piping delivers the pressurized air to the moveable stands, and distributes the air within the stands.

Lateral movement of a stand is accomplished by a transporter drive assembly, shown in Figure T-6. The assembly is permanently attached to the structural frame of the moveable stand. The drive assembly includes a mechanism that grips a curved steel guide rail mounted to a concrete slab, and a hydraulic ram system that reacts against the grip to move the transporter along the guide rail. As the transporter drive assembly moves along the rail, the stadium stand moves with the transporter. The transporter assembly includes a control console for adjustment of the air pressure provided to the air bearing assemblies. The ram is operated by using compressed air to pressurize a hydraulic oil reservoir.

T.3. Moveable Bridges

There are two different movement systems related to the moveable bridges: a vertical lifting system and a horizontal transport system.

T.3.1 Bridge Lift Mechanism

The vertical lift mechanism is a large hydraulic piston, approximately 30 inches in diameter and 104 ft long, encased by a steel casing and embedded into the ground. The mechanical principle is similar to that of a hydraulic piston passenger elevator. The ram is operated by using compressed air to pressurize a hydraulic oil reservoir. Figure T-7 is a schematic illustration showing operational concepts for the bridge lift mechanism, reproduced from the original structural design drawings.

T.3.2 Bridge Transport Mechanism

When at ground level, the bridges are supported on air film bearings of the same type as used for transport of the moveable stands. When the air bearings are inflated, fork lifts are used as tugs to move the bridges into and out of storage. There are bridge storage areas located at each of both the north and south fixed stands, providing a total of four bridge storage areas.

T.4. Existing Conditions

WJE made limited observations on the existing conditions of the various operating elements of the transport systems. WJE also relied in part on the prior condition report prepared in 1990, and on limited interview of stadium personnel, using our observations and interviews to assess the continued validity of the 1990 assessment. The 1990 assessment of the transport systems is presented in Chapter III and Appendix B of the report “Aloha Stadium Master Plan Update,” February 1990, by Pacific Planning and Engineering (PPE).

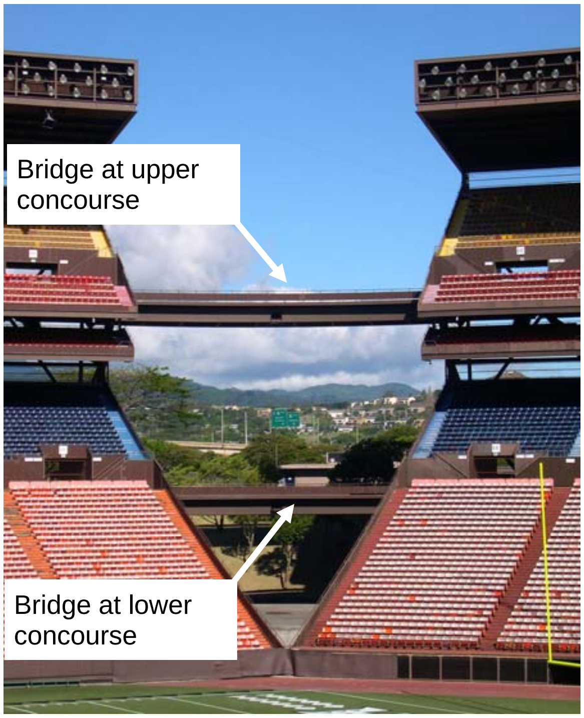


Figure T-3. View of moveable, curved pedestrian bridges. (Southeast moveable stands at left, and south fixed stands at right.)

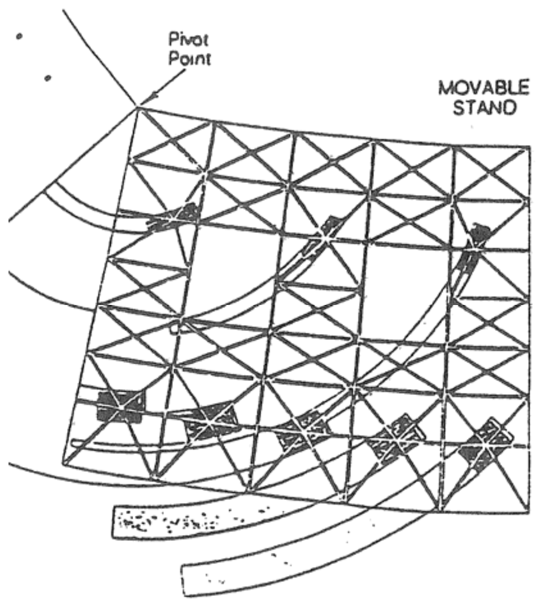


Figure T-4. Plan showing layout of air transport pedestals at one moveable seating stand (pedestal assemblies are shown as solid rectangles).

Figure T-5. Representative structural pedestal with air bearing assembly (typically tarp-covered for protection)

Figure T-6. Transporter drive assembly and steel guide rail.

The present equipment mostly dates from the time of original construction, ca. 1974 and 1975. This includes the piping, controllers, valves, bearing assemblies, transport tug equipment, and bridge lift mechanical equipment. We understand that some maintenance type upgrades and limited equipment replacement have been made throughout the years. The inflatable diaphragms are routinely replaced at regular intervals.

The 1990 assessment of the transport system included the following specific issues and complaints:

1. Pivot points are not secure
2. More compressed air required for moving the stands
3. Stands movement is labor and time intensive
4. Air bearing efficiency needs to be improved
5. Design loads were underestimated
6. Debris under the air bearing assemblies causes problems
7. Poor seal of the bearing with the runway
8. Poor control and monitoring of the compressed air system
9. Poor performance and reliability of the air compressors
10. Bearing assemblies are difficult to inspect and maintain
11. Inefficient operations to move bridges to and from storage
12. Inefficient and unreliable bridge lifting operation
13. Dangerous bridge lifting operation
14. Difficult inspection and maintenance of lift ram

While the routine replacement of the inflatable diaphragms has resulted in some operational improvements, many of the system-wide issues identified in the 1990 assessment are generally applicable today. For example, the lack of complete pavement beneath the moveable stands permits a ready source for dirt that accumulates beneath the bearing assemblies. The pivot points exhibit structural distress (see Part II, Section S). The pressure control systems, transport drive mechanism, air piping, and bearing assembly structures all remain as original equipment. Stadium personnel informed us that the performance of the equipment is variable, and remains prone to occasion breakdown that can be time consuming to rectify. WJE concludes that there has been little operational improvement gained since 1990. Consequently, for detailed

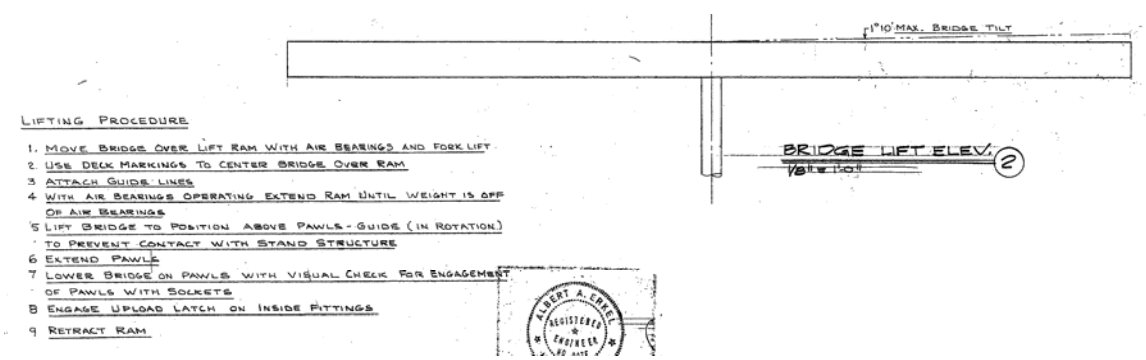


Figure T-7. Elevation from original structural drawing, illustrating bridge lift procedure.

discussions on these issues, the reader is referred to the 1990 report by PPE.

T.5. Alternative Transport Systems

T.5.1 Moveable Stadium Stands

Besides the air film bearing and transport system, other technologies exist that are capable of transporting large and massive structures such as the moveable stands at Aloha Stadium. WJE corresponded informally with representatives of Uni-Systems, LLC, Minneapolis, Minnesota, a designer and manufacturer of movement systems for retractable roofs and retractable fields at several of the "new generation" athletic stadiums. Based on the dialogue between WJE and Uni-Systems, the following alternative transport systems were identified:

- **Water Bearing System –** This is similar in principle to an air bearing system, but uses pressurized water. Water bearings operate under a higher pressure than air bearings, and thus have a significantly greater lift capacity than air bearings. Water bearings are significantly less sensitive to debris under the bearings than are air bearings. Lateral movement of the stands would be accomplished by electrically powered traction wheels.

- **Steel Wheel-and-Rail System –** This is similar to a railroad wheel and rail. The necessary rails can be installed flush to the paved surface of the ground and would not represent a tripping hazard to pedestrians. Lateral movement of the stands would be accomplished by electrically powered traction wheels.

- **Heavy Duty Roller Bearing System –** This is similar to roller bearings used to move massive industrial equipment. This system would also require a rail system to guide movement. Lateral movement of the stands would be accomplished by electrically powered traction wheels.

Each of these three alternative systems is sensitive to the levelness and stiffness of the foundation for the runway or guide rail upon which the system would be supported as it travels. The present air film technology bearing system is also sensitive to these same runway issues, where differential settlement of the existing runways may be contributing to current operational problems.

Based upon the dialogue between Uni-Systems and WJE, the informal conclusion was reached that a water bearing system was the most likely candidate as a replacement for the air film bearing system. This is because loads would be distributed to both structure and foundations in a manner similar to the current system. Frictional forces during lateral movement would also be comparable to that of the air bearing system, if not somewhat less. The traction drive wheels would be significantly more reliable and easier to operate than the existing air-powered hydraulic drive system.

T.5.2 Moveable Bridges

Alternative systems also exist for lifting and horizontal transport of the moveable bridges. As was identified by PPE and described in some detail in their 1990 report, one viable alternative system would include a cable hoist system for bridge lifting and a wheel-and-rail system for lateral bridge movement.

T.6. Recommendations

If the State decides to indefinitely maintain the ability to reconfigure the stadium stands, it is our opinion that the air film bearing systems and air-driven hydraulic systems should be replaced in their entirety with different technology, including the lifting and transport systems for the moveable bridges. One candidate replacement technology for stadium movement is a water bearing system with electric-powered traction drive wheels. The cost for a replacement system is informally estimated by Uni-Systems to be on the order of $10,000,000. This cost remains to be verified.

Alternatively, the air bearing system could be thoroughly rehabilitated and modernized much along the lines as was recommended in 1990 by PPE. When the PPE cost estimates from their 1990 report (having 1989 dollars) are adjusted to 2005 dollars, the costs for a thorough modernization of the existing air systems are estimated to be on the order of $10,000,000. In light of this apparent cost, it is our opinion that modernization of the existing system is a less desirable solution as compared to replacement with an alternative technology for the same estimated cost.

If the State decides to maintain the ability to reconfigure Aloha Stadium, WJE recommends that a detailed engineering study be performed on the existing transport system, and that the available alternative technologies also be evaluated in detail, prior to selecting any alternative transport technology for a replacement transport system. These alternative studies should include rigorous construction cost estimates. These same recommendations would apply if the State should instead decide to modernize the existing air film technology systems.

The State may also decide to fix the stadium into a single configuration. Should the State decide to do this, there will be costs associated with decommissioning of the existing systems, including necessary structural modifications to permanently connect the moveable structures to the existing foundations. Additionally, there will still be the need to pave the open ground and improve drainage beneath the stands, as these measures are needed for corrosion protection (see Part II, Section R).

Part III – Structural Safety Evaluation

Section A - Introduction

On 20 April 2005, the State of Hawaii, Department of Accounting and General Services (DAGS), issued the request for qualifications (RFQ) “Aloha Stadium, Planning Study,” DAGS Job No. 12-10-0374. The scope of work established in the RFQ included an evaluation of structural systems, or an “update based on existing studies.” On this basis, therefore, the structural safety review for the 2005 Aloha Stadium Planning Study was to assess whether prior structural certifications remain applicable at the present time (November 2005).

The need for a structural safety evaluation of Aloha Stadium arose because of the corrosion problems that developed with the weathering structural steel. Investigations performed during the 1980s identified that the weathering steel was not performing as intended. Instead of forming a protective patina of dense and stable rust, the weathering steel at Aloha Stadium was continuing to corrode at an unexpectedly high rate. The corrosion had progressed to the extent that probable structural damage had developed at numerous locations throughout the stadium. A corrosion abatement program was developed to address the corrosion issues. The corrosion abatement program included assessment of the physical extent of corrosion damage, repair or replacement of corroded structural steel members on an as-needed basis, and the application of a protective coating system (“paint”) to the weathering steel to prevent further corrosion.

Numerous structural analyses were implemented to determine which structural steel members required repairs. These analyses evaluated the Aloha Stadium structure on both an “as-designed” basis (i.e., assuming no corrosion-related damage) and on an “as-is” basis, where the load capacities of the structural members were adjusted on a member-by-member basis to account for the extent of corrosion damage, as determined through field observations of structural members. The analyses of the “as-designed” structure, however, revealed that certain structural elements had inadequate strength as originally designed, without any corrosion-related damage. Consequently, in addition to corrosion-related structural repairs, structural strengthening repairs were also implemented to address identified deficiencies in the “as-designed” structure.

Upon substantial completion of the corrosion abatement program in 1994, the State commissioned a structural engineering consultant to prepare a final report on the abatement program. The final report was to include a statement regarding the then-current structural condition of Aloha Stadium.

Section B - Structural Certification from 1995

The most recent structural safety evaluation was completed in 1995, as documented in the report "Final Report and Structural Certification," contained in 14 volumes, by Robert Englekirk Consulting Structural Engineers, Inc. (also identified in their report as Robert Englekirk, Inc., or REI), Honolulu, Hawaii, October 1995. Our review of the REI "Structural Certification" is based on the narrative (Volume 1 of 14) of the report and Appendix A (Volume 2 of 14), "Aloha Stadium Seismic Analysis," 14 March 1995. Appendix A was prepared by REI's sub-consultant, Forensic Technologies International Corporation (FTI), Annapolis, Maryland.

The 1995 REI structural certification report included the following main components:

- A summary of analyses, studies, construction projects, and other work preceding their report, including: reports by REI and others predating the 1995 report; a summary of the corrosion abatement program; a summary of construction projects related to the corrosion abatement program; and a review of prior structural studies and analyses.
- A site survey to confirm that the constructed repairs were in conformance with the established corrosion abatement program.
- Evaluate the stadium for seismic loading and make recommendations based upon the evaluation.
- Issuance of a final statement regarding the structural integrity of the Aloha Stadium.

B.1. Physical Condition of the Stadium in 1995

The 1995 REI structural certification reported the following significant items related to the physical condition of Aloha Stadium at the time of their 1995 report. Their comments typically apply to conditions throughout the stadium.

- Weathering steel members had been painted with a protective coating system.
- For the primary steel members observed by REI, it appeared further deterioration of the members had been mitigated at the time of their report.
- New roof decking, roof gutters, and light enclosure decking had been installed.
- A new coating system was applied at concourse walkway decks.
- New siding had been installed and included modified details. Modified end details on the siding appeared to alleviate the build-up of debris and moisture. The then-new siding at the upper and lower vomitories, however, appeared to be corroding: "the rapid corrosion of the new, painted steel siding raised some concern" (REI Volume 1, page 19).
- Steel seat plates were repaired and sloped for positive drainage. However, rust on top of the seat plates was noticed, particularly in the orange seating sections of the moveable

stands. Paint was blistering at limited locations on the underside of the seat plates, primarily at the loge and lower tier levels.

- Numerous details to mitigate corrosion had been implemented, including: water and rubbish deflectors installed on main steel members; certain pockets at connections of wide-flange steel members had been filled with epoxy; new floor drains and drain holes had been installed; caulking and flashing had been installed; and other items.
- All four spiral walkways had been replaced in 1995 and were in new condition.

Other conditions were noted by REI, but are not summarized here. REI's complete comments on the physical condition of the stadium at the time of their 1995 certification can be found in Volume 1 of 14 of the 1995 REI report.

B.2. Structural Analyses from the 1995 REI Certification

In their 1995 report, REI divides the analytical studies and physical condition examinations that they relied upon into two categories: 1) those performed between 1982 and 1994 by REI, FTI, and others, or "pre-1995" studies; and 2) those performed by REI, FTI, and others as a direct part of their 1995 certification work. The most significant of the structural analyses relied upon by REI are summarized in this section of this report. Significant condition-related issues were summarized in Subsection B.1, immediately above. Further narrative description of the analyses by REI and others may be found in Volume 1 of 14 and Volume 2 of 14 of the 1995 REI report.

B.2.1 Moveable and fixed stadium seating stands

The pre-1995 analytical studies examined both the "as-designed" structure and the circa 1989 "as-is" structure. The 1989 "as-is" analyses took into account the corroded state of the structural members as they existed in 1989. This was accomplished by conducting a detailed survey of the corrosion damage in the structure, and then modifying the "as-designed" strength evaluation calculations according to the extent of corrosion damage or section loss observed in the "as-is" structure. REI also makes mention (1995 REI Report, Volume 1, pages 11 and 12) of a litigation-related "as-is" structural analysis that was completed in approximately 1992 for the Attorney General's Office, but this particular analysis is not described in detail.

Several of these pre-1995 analyses identified certain structural "concerns." The major pre-1995 structural concerns summarized by REI in their 1995 report were as follows.

- The upper concourse diaphragm deck was overstressed in the "as designed" condition. REI reports that this condition was repaired in the summer of 1988 by the installation of pipe bracing beneath the upper concourse.

- The deep plate girder main frame (raker frame) elbows were overstressed due to weak axis bending. REI reports that this condition was repaired in late 1988 and early 1989 by the installation of horizontal pipe bracing between the frame elbows below the loge level.
- In 1987 and 1988, the original weathering steel roof deck was removed, apparently because it created a falling debris hazard. In 1989, REI recommended that bracing of the main roof framing should be installed when the roof decking is replaced. It is unclear whether the need for bracing was based on “as-designed” or “as-is” structural conditions. In 1990 and 1991, new roof deck and bracing were installed throughout the entire stadium.
- The outside slab edge beams at the upper concourse level were identified by the 1992 litigation-related “as-is” analysis to be a concern. The edge beams were repaired throughout the stadium in 1992.
- Certain bracing elements in the moveable stands below the lower concourse level were also identified by the 1992 litigation-related “as-is” analysis to be a concern. These bracing members were generally associated with framing in the vicinity of the structural pedestals at the transporter bearings. The bracing elements were repaired throughout the moveable stands in 1992.

The 1995 REI report states (Volume 1, page 11) that the 1992 litigation-related “as-is” analysis also identified the “hanger-columns at loge level” and the “back truss” to be “highly stressed members”. Additionally, the “elbows of main plate girder frames” were also identified as “highly stressed members,” even though repairs at selected elbows at the plate girders were completed in 1989. Although “highly stressed,” REI did not find these elements to be “of concern.” Consequently, REI did not identify any of these elements for repair. The 1995 REI report does not clearly identify what specific structural members constitute the “hanger-columns at loge level,” the “back truss” structure, or the “elbows of main plate girder frames.”

The majority of the analyses performed in 1995 relied on three-dimensional finite element analyses of the stands, including dead loads, live loads, and seismic loading. The analyses were performed in general accordance with the following assumptions:

- The geometry of the models was based upon the “as-built” drawings from original construction, and it was assumed that these drawings reasonably represented the structure regarding both geometry and sizes of structural members.
- Retrofit members and strengthening repairs that had been added to the fixed and moveable stands were included.
- Loads were generally in accordance with the 1991 Edition of the Uniform Building Code (UBC).

- Live loads in the seating stands and on the concourse slabs were taken to be 100 psf, unreduced, throughout the stadium. Live loads were not reduced because the 1991 UBC does not allow reduction of live load for public assembly occupancies.
- Roof live load was included on the main roof over the fixed and moveable stands.
- Earthquake loading was in accordance with the dynamic lateral force procedures of the 1991 UBC, except that the seismic zone was taken to be Zone 2A in accordance with the City and County of Honolulu Building Department Amendments to the UBC, in effect at the time of the REI analytical work.
- Wind loading was explicitly excluded from the analyses of the fixed and moveable stands.

- Structural load combinations for dead, live, and earthquake loads were in accordance with ASCE 7-88.
- REI states that the stress analyses of the structural steel members were evaluated in accordance with both ASD and LRFD (Allowable Stress Design and Load & Resistance Factor Design) procedures, mentioning specifically the 9th Edition of the *ASD Manual of Steel Construction* and the 2nd Edition of the *LRFD Manual of Steel Construction*, as published by the American Institute of Steel Construction (AISC). WJE interprets the cited references to mean that the member strengths were actually evaluated in accordance with *Specification for Structural Steel Buildings – Allowable Stress Design and Plastic Design,* June 1, 1989, for ASD procedures, and in accordance with *Load and Resistance Factor Design Specification for Structural Steel Buildings*, December 31, 1993, for LRFD procedures.

As noted previously, the 1995 certification analyses explicitly excluded wind loading from the analyses of the moveable and fixed stands. REI reported the reasoning for this as follows:

> *It was decided that a wind load analysis was not required as a hurricane that would produce the high wind loads will be predictable and that the stadium would not be occupied in that event.* (1995 REI Report, Volume 1 of 14, page 13.)

In Volume 1 of 14 and Volume 2 of 14 of their 1995 certification report, REI and FTI provide numerous detailed findings derived from the structural analyses. The more significant "concerns" expressed by REI (Volume 1, pages 23 and 24) regarding the results of the analyses are as follows:

- For both the fixed and moveable stands, web shear stresses in the deep plate girder main frame (raker frame) elements were identified as overstressed for combined live and dead loads under the LRFD stress evaluation, but not under the ASD stress evaluation.

For several reasons identified in their report, REI expressed the opinion that “web shear failure was not necessarily the critical condition for these members…” REI did not recommend any repair for the deep plate girders.

- For the moveable stands, the analyses revealed that several bracing members at the lower horizontal bracing truss, in the vicinity of the structural pedestals at the transport system air bearings, were overstressed. REI recommended repairs to these members.
- The analysis revealed relatively large vertical and lateral displacements under seismic lateral loads, compared to those expected for a conventional structure. REI noted that the vertical displacements at the roof were particularly large. REI argues that the usual deflection limits are a serviceability criteria associated with conventional structures and thus are not applicable to unusual structures, such as stadiums. REI points out that the large roof displacements could, however, dislodge nonstructural elements such as the lighting, thereby indirectly posing a hazard to life during an earthquake.
- The horizontal and vertical loads imposed on the transporter bearings (while at rest, not while in operation) were examined, and found to be at levels reasonably expected to be resisted by the bearings.
- Even though supplemental horizontal bracing had been installed in 1988 at the concourses and in 1990 and 1991 at the roof level, the 1995 analyses revealed large diaphragm stresses at the concourse and roof levels. REI attributed this to an irregularity in how reactive masses were assigned within their seismic dynamic analytical models, causing an overstatement of lateral loads. Although they did not correct this irregularity in their models and re-run their analyses, REI “deemed [the diaphragms] structurally adequate as-is.”
- REI reviewed the appropriateness of the 100 psf live load used in their analyses and concluded that this was “quite conservative.” Because of this conservatism in the applied live loading “… and considering the inherent safety factors built into the design codes, the allowable stress ratios were increased by about 15% when considering safety …”
- REI emphasized (1995 report, Volume 1 of 14, page 24) that their structural certification is contingent on the implementation of a regular preventive maintenance program as outlined in “Aloha Stadium - Master Plan Update - February 1990.”

B.2.2 Spiral Walkways (Spiral Ramps)

The original spiral walkways were repaired on a temporary basis in 1993. Subsequently, as part of the corrosion abatement program, the original spiral walkways were demolished and replaced in 1995 by new spiral walkways of a similar design. The structural analyses for the 1995 REI structural certification therefore modeled the replacement walkway structures. Because the spiral walkways were, in 1995, new construction that did not include any weathering steel, there was no need for any analysis to account for the effects of corrosion at the spiral walkways.

The 1995 structural analyses of the spiral walkways were carried out under generally the same modeling assumptions and loading parameters as described immediately above for the fixed and moveable seating stands. Unlike the stadium seating stands, however, the spiral walkway analyses also included design wind loads.

REI and FTI identified no structural issue of concern related to the replacement spiral walkways.

B.2.3 Curved pedestrian bridges

When in football configuration, the stadium layout includes eight (8) curved pedestrian bridges that connect the moveable stands to the fixed stands. The bridges span the open gap between the fixed and moveable stands. There are two bridges located at each quadrant or corner of the stadium, with one bridge located at each of the lower and upper concourse levels. Plans showing the locations of the bridges and typical photos of the bridges can be found in Part II Section T of this report. When the stadium is configured for baseball, the bridges are demounted and placed into storage.

Deflection performance of the curved pedestrian bridges has been of note since at least the 1980s, if not before. In 1982, the bridges were structurally analyzed by Mitsunaga ("Investigation of the Structural Adequacy of the Connecting Bridges at Aloha Stadium," for the State of Hawaii, Department of Accounting and General Services, by Mitsunaga & Associates, Inc. and Dr. George T. Taoka, October 1982), who report that their study was prompted by "… comments and reports by the patrons of the stadium on the noticeable movement of the bridges during periods of heavy pedestrian traffic…"

The 1982 Mitsunaga study examined the bridges using a three-dimensional computerized analysis, wherein the bridge members (girders and diaphragm beams) were modeled by frame elements. Loading included the dead loads or self-weight of the bridge structural members, concrete walkway deck, and handrails, a static live load of 100 psf to represent code-specified pedestrian loading on the walkway deck, and dynamic loading intended to simulate moving live loads. Mitsunaga found that the bending stress in the outer main girder in the bridge was overstressed by approximately 5 to 15 percent under static and dynamic live loading, respectively, and that live load deflections for the same girder exceed code recommended deflection limits by an even greater degree. Mitsunaga concluded that "… we believe the connecting bridges presently are structurally sound; however there may be some long term concerns [related to the noticeable movement of the bridges]." Mitsunaga recommended that the bridges be stiffened by any one of several methods to decrease the amount of live load deflection in the bridges.

In a 1989 Master Plan Update report by REI ("Master Plan Update - Structural Study of Corrosion Effects - Part II," by REI, preliminary report dated July 1989), REI performed limited structural analyses by similar methods to confirm the Mitsunaga studies. At that time, REI stated that "No exceptions are taken to the conclusions and recommendations made in the [1982 Mitsunaga] report."

In their discussion about the bridges in their 1995 report (Volume I, pages 13 and 14), REI relies primarily on prior analyses by Mitsunaga in 1982, supplemented by their own 1989 analytical studies. REI also notes that the corrosion-related condition of the bridges was examined in both 1989 and 1992, and that no severe corrosion was found during either examination. REI further notes that the bridges were stiffened in 1993 to address the deflection problem, but that "… the retrofit work was removed due to the inadequacy of the bridge lift system to support the added weight [of the retrofit work]." REI concludes their discussion of the curved pedestrian bridges by stating that "… stiffening of the bridges pedestrian was comfort driven and was not a condition of certification."

Neither Mitsunaga nor REI examined lateral flange bending in the curved girders that support the bridges. This is of concern to WJE because lateral flange bending is known to be a significant issue with curved girders, especially in curved highway bridge construction. Our concern regarding lateral flange bending will be discussed in more detail later in this part of this report.

B.3. "Final Statement" from the 1995 REI Report

REI provides a "Final Statement" regarding the structural certification on Page 24 of Volume 1 of their 1995 report. The following quotations are taken from their "Final Statement."

- "Wind Load Analysis: The certification requires that the stadium … be closed during hurricanes or other similar high-wind conditions. Damage to the steel structure could occur under hurricane-force winds."
- "Elbow Analysis: … Performing a nonlinear analysis [of the elbows on the main steel frames] was suggested… However, since the analysis was not performed, we cannot certify that the main steel frame elbows would continue to perform satisfactorily when subjected to unusual (i.e., earthquake or hurricane) loading."
- "… it is our opinion that in the event of an earthquake, the Aloha Stadium …would not expect major structural collapse. During an earthquake the following could be expected:
    - o "Possibility of large lateral displacements, particularly at the upper levels…

- “Possibility of large vertical displacements, particularly at the roof…
- “Possibility of non-structural damage (i.e., equipment dislodging from supports particularly items attached to the roof structure and loges).
- “Possibility of large force concentration at the bridge/supporting structure connections.
- “Possibility of large force concentration at the moment frame connections.”

Section C - Changes in Structural Conditions Since 1995

Based on condition observations made during our structural condition survey site visit of August 2005, differences in structural condition were observed by WJE, as compared to the condition reported by REI in 1995. The more significant of these changes are summarized below. Our complete structural condition observations are given in Part II of this report.

- For the entire stadium, the first maintenance application of the protective coating system on weathering and galvanized steel is overdue. As a result, limited corrosion of primary structural members has resumed at numerous locations throughout the stadium. To date, the renewed corrosion has caused minor damage, but this damage will increase if the protective coatings system is not adequately maintained. (See Part II Section R.)
- At the main roof over the seating stands, significant corrosion has developed in the ca. 1990 metal roof deck panels and associated structural fasteners, to the extent that localized section loss and isolated fastener failures have occurred. These isolated areas are in need of structural repair. (See Part II Sections R and S.)
- Portions of the concrete-and-metal deck floor system at the upper and lower concourses have corroded away at isolated locations, typically beneath partitions and utility spaces, and part and are in need of localized repair. (See Part II Section S.)
- WJE’s own anecdotal observation of the curved pedestrian bridges finds deflections that seem to be greater than that expected for ordinary pedestrian bridges under foot traffic loading.

Section D - Discussion

D.1. Maintenance of the Protective Coating Systems

Maintenance of the protective coating systems on structural steel elements of all types is an essential condition of the 1995 REI structural certification. Because the protective coatings systems are in need of maintenance, the stadium is no longer in conformance with the assumptions made in the 1995 REI structural certification. Additionally, as a result of the deferral of necessary maintenance, minor corrosion of weathering steel structural members has resumed on a limited basis.

Aditionally, numerous deficiencies in the application of the existing coating systems have been identified by WJE. Some of these deficiencies have led to poor performance of the existing coating systems. Proper maintenance of the existing coating systems, and rectification of deficiencies in the existing coating systems, is essential to preventing any on-going corrosion from progressing further and causing significant structural damage.

As discussed in Part II Section R, WJE recommends that the State of Hawaii immediately prepare to undertake, and the subsequently enact as soon as possible, necessary repairs to restore the protective coating systems.

D.2. Condition of the Main Roof over the Seating Stands

The corroded condition of the metal roof deck and associated failed fasteners are of concern, even though these conditions presently occur on an isolated basis. This is because, throughout the entire stadium roof, there is wide-spread indication that the galvanized protective coating on the deck panels is being consumed. The loss of protective coatings makes the remainder of the metal roof panels and fasteners vulnerable to the types of corrosion damage already observed at isolated locations on the roof structure.

As described in Part II Sections R and S, this degree of degradation of the coatings is so extensive that it is likely to be less expensive to replace the metal deck panels in whole, instead of removing the present coatings on the panels and applying new coatings. Wholesale replacement of roof deck panels would at the same time take care of the needed physical repairs to the corroded roof deck panels and fasteners.

D.3. Wind Loading on Stadium

The 1995 REI structural certification did not examine safety of the stadium under wind loading. Rather, it is a condition of the certification that the entire stadium “be closed during hurricanes or other similar high winds.” In REI’s own words, “Damage to the steel structure could occur under hurricane-force winds.”

Aloha Stadium represents a substantial public investment by the State of Hawaii. As an example, should the stadium be damaged beyond repair, the estimate given in Part VII of this report finds that the cost of replacement with a new stadium would be in the rage of $220 M to $280 M (2005 dollars).

Given this cost of potential loss during high winds, WJE finds it unusual that the 1995 certification did not examine wind loads. Prior to the undertaking of any renovation or repair to Aloha Stadium, or as part of any future structural certification of the stadium, the wind load safety of the stadium should be assessed by appropriate structural analysis of the “as-is” structure. Furthermore, given the unique physical shape and architectural design of the structure (i.e., unlike the generally rectangular configuration of common office, industrial, and residential buildings), wind tunnel modeling should be considered so that realistic wind loads can be established for the stadium. Wind tunnel modeling would consider the stadium location and surrounding terrain to develop these realistic, site-specific and structure-specific wind loading criteria.

D.4. Curved Pedestrian Bridges

During the course of our site visit during August 2005, WJE anecdotally observed that the curved pedestrian bridges seem to deflect more than typical pedestrian bridges under pedestrian foot-fall excitation. Subsequently, as described in Subsection B.2.3, above, WJE reviewed the analytical studies by Mitsunaga (1982) and REI (1989, 1995) regarding the curved bridges. These analyses revealed larger than commonly anticipated deflections for the bridges. These analyses also concluded that, although the stresses in the structure somewhat exceeded the stresses permitted by building code structural provisions, the curved pedestrian bridges were nonetheless “structurally sound” at the time (1982, 1989, 1995) of the analyses.

The WJE review also revealed that the prior analyses by others did not account for the phenomena of lateral flange bending, a structural effect that inevitably arises with curved bridges similar to those at Aloha Stadium. Lateral flange bending effects can be structurally significant. Therefore, WJE undertook a preliminary analysis of these effects. WJE found that, when lateral flange bending is accounted for, there exists structural overstress in the range of 20 to 30 percent when the bridges are exposed to the full live load as prescribed by building code structural design provisions.

It is our professional opinion that overstresses in this range result in a reduction of structural safety to a level below that which would be commonly perceived as acceptable to the public that uses the stadium. Therefore, it is prudent for the State of Hawaii to immediately undertake a more detailed analysis to confirm our preliminary findings, and based upon the results of the more detailed analysis, implement temporary stabilization of the curved bridges as might be necessary.

Section E - Summary and Recommendations

The following summary and recommendations are with respect to the current (November 2005) structural safety of Aloha Stadium. WJE presents the items of greatest concern first.

1. WJE finds that the 1995 REI structural certification has lapsed. This is because the protective coating systems on the weather and galvanized structural steel are in need of maintenance. Additionally, corrosion has damaged the metal deck and fasteners of the high roof over the seating stands. Maintenance of the protective coating systems and the structure itself is a clear prerequisite of the 1995 REI structural certification (1995 REI report, Volume 1 of 14, page 24).

2. WJE has preliminarily identified the curved pedestrian bridges to be overstressed in the range of 20 to 30 percent, according to building code requirements. This overstress is primarily attributed to lateral flange bending, which was not examined in the previous evaluations of the bridges by Mitsunaga or REI. Overstress of this magnitude is typically not acceptable and should be addressed. Further analysis should be immediately undertaken to confirm the preliminary findings by WJE regarding the curved pedestrian bridges. Based upon the results of the further analysis, the need for temporary stabilization can be established, and designed if needed. Subsequently, if appropriate, permanent repairs to the bridges can be designed once temporary stabilization is in place.

3. Significant corrosion has developed on the metal deck that forms a part of the cantilevered roof structure over the stadium seating stands. The metal deck has corroded through at limited, localized areas, and the fasteners that secure the deck to the supporting structure have fractured in some areas due to corrosion. We recommend that the State of Hawaii immediately undertake a more detailed analysis of these conditions to determine the extent of corrosion-related damage, and that appropriate repairs, both temporary stabilization and long-term remedy, be designed and subsequently implemented on the basis of the more detailed study.

4. The structural certification performed by REI in 1995 did not examine wind loads on the structure. Therefore, the structural safety of Aloha Stadium under wind loading is unknown. It is the professional opinion of WJE that this exclusion is unusual, particularly for a public structure that is as prominent as the Aloha Stadium. It is our recommendation that the State commence appropriate structural engineering studies to establish the performance of the stadium under code-required wind loads. This study should be complete before design of any major repair or renovation of the stadium is undertaken. We further recommend that the State consider the use of wind tunnel modeling to establish the wind loads for the recommended studies.

5. Protective coating systems on weathering steel and on galvanized metals are in need of maintenance throughout the entire stadium. Due to the deferring of routine maintenance

of the coating system, limited corrosion has resumed on structural elements at scattered locations throughout the stadium. Additionally, numerous deficiencies in the application of the existing coating systems have been identified. Some of these deficiencies have led to poor performance of the existing coating systems.

Proper maintenance of the coating systems, and rectification of deficiencies in the existing coating systems, is essential to prevent the on-going corrosion from progressing further and causing significant structural damage. We recommend that the State immediately commence a detailed coating study to determine the extent of application deficiencies in the existing coating systems. It is necessary that these deficiencies be systematically identified before design of any coating system reapplication. After establishing the extent of deficiencies, the State should commence preparation of construction documents for repair and maintenance of the coatings system throughout the entire stadium.