ALOHA STADIUM
Structural and Safety Evaluations:
Weathering Steel and Decking Corrosion Assessment

DAGS Job No. 12-10-0651
99-500 Salt Lake Boulevard
Halawa, Honolulu County, Hawaii

VOLUME 1 OF 2 VOLUMES

Final Report
December 12, 2018
WJE No. 2014.6720.1

Prepared for:
State of Hawaii, Department of Accounting and General Services, Public Works Division, Planning Branch

Prepared by:
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EXECUTIVE SUMMARY

This report summarizes findings related to "Aloha Stadium - Structural and Safety Evaluations: Weathering Steel and Decking Corrosion Assessment" [DAGS Job No. 12-10-0651]. The primary objective of this project is to perform interim assessments related to structural safety evaluation while the State of Hawaii considers possible replacement of the existing stadium. This 2018 assessment is the second of an anticipated series of interim assessments; the first interim assessment was performed in early 2016, with findings presented in the report "Aloha Stadium - Structural and Safety Evaluations: Weathering Steel Corrosion Assessment," Final Report, October 26, 2016.

The present interim assessment is limited to two major safety-related aspects:

- An assessment of corrosion-related damage to weathering steel primary structural members in areas of the stadium where the original protective coating systems, installed in the 1980s and 1990s, have not yet been replaced or otherwise maintained in the recent health and safety improvement projects at the Aloha Stadium; and
- An assessment of corrosion-related damage to the lightweight concrete-and-metal decking systems, some of which were installed at the time of original stadium construction in the early 1970s, and some of which were installed in the 1980s and 1990s as replacements for original lightweight decking installed in the 1970s.

The findings from this 2018 interim assessment are used to prioritize recommended repairs. The steel seating tread-and-riser plates were surveyed under different projects, with the results of those surveys included in this report. Structural steel members that were recoated since 2007, composite concrete-and-metal decking installed since 2015, partitions, paneling, siding, stairs and stairwells, and other miscellaneous steel at the stadium were not included in the scope of this interim assessment.

The assessment methodology consisted of a visual survey that assigned a condition state to each structural steel member and lightweight floor decking panel, including a consideration of the structural connections related to the steel member or the bearing conditions of a lightweight decking panel, as follows:

- Condition State 1 (CS1) – No discernable coating failure on steel members or the visible surfaces of the lightweight decking; no corrosion is assumed. These members and decking panels pose no known immediate concern for health and safety of occupants of the structure.
- Condition State 2 (CS2) – Visual signs of localized coating failure with only minor surface corrosion on steel members or the visible surfaces of the lightweight decking. Section loss is assumed to not be appreciable. Health and safety implications of CS2 members include the eventual progression of observed deterioration into Condition State 3, and the potential for corrosion products and debonded coatings to displace from the surface of the steel member or the decking, becoming a nuisance and a relatively minor safety concern, to a lesser degree than for members classified as Condition State 3.
- Condition State 3 (CS3) – Visual signs of coating failure and noticeable corrosion on steel members or the visible surfaces of the lightweight decking. There appears to be notable corrosion-related section

losses in the steel member or the decking. Health and safety implications of CS3 members include corrosion products and debonded coatings that have the potential to displace from the surface of the steel member or decking, becoming a nuisance and a relatively minor safety concern.

- Condition State 4 (CS4) – Visual signs of coating failure on the steel member or the decking accompanied by pronounced corrosion of the steel member or the decking itself. Corrosion-related section loss in the steel member or decking is not only visibly apparent, but appears to be so pronounced that the structural performance of the steel member or its structural connections, or the decking or its support bearing conditions, is called into question.

Based on the observed condition state, expected levels of work to address identified concerns are as follows:

- Condition State 1 (CS1) – Remediation of concerns with steel members classified as CS1 involves an application of maintenance overcoats onto the topcoats of the corrosion mitigation coatings within the window of maintenance overcoating feasibility, estimated to be 10-15 years from the application of the corrosion mitigation coatings that are in place. The undersides of the lightweight decking system panels that are classified as CS1 should be recoated with corrosion mitigation coatings and the pedestrian traffic coatings on the concrete walking surface should be replaced, along with repairs to the concrete substrate; however, in lieu of maintenance-type repairs, it may be more cost-effective over the long term to replace the lightweight decking system with a thicker, conventional composite metal decking system.
- Condition State 2 (CS2) – Remediation of concerns with steel members classified as CS2 involves entire removal of existing protective coating systems and installation of new corrosion mitigation protective coating systems. Areas of lightweight decking system classified as CS2 should be replaced with a thicker, conventional composite metal decking system.
- Condition State 3 (CS3) – Remediation of concerns with steel members classified as CS3 involves complete removal of existing protective coating systems and installation of new corrosion mitigation protective coating systems. High priority CS3 steel members have active corrosion concerns that should be considered for mitigation in the near-term, but not necessarily needing intervention in the next 24 months. Similarly, high-priority areas of metal decking classified as CS3 should be replaced with a thicker, conventional composite metal decking system in the near-term, but not necessarily needing intervention in the next 24 months.
- Condition State 4 (CS4) – Remediation of concerns with steel members classified as CS4 requires structural modifications to strengthen affected components of the member or to eliminate construction details that inadvertently result in accelerated corrosion. CS4 steel members identified as “Immediate” priority have concerns over structural performance that should be addressed immediately; and CS4 steel members identified as “24 month” priority have concerns over structural performance that should be addressed within 24 months. High-priority areas of metal decking classified as CS4 should be replaced with a thicker, conventional composite metal decking system within the next 24 months.

Repairs are recommended to be undertaken for the corrosion related issues summarized in Table 1, which is generally organized by groups of members as described in Appendix A, and further subdivided by condition state. The current status of the repairs that were previously-recommended for repair in our 2016 corrosion assessment report is summarized in Table 2; incomplete repairs and unaddressed items in Table 2 continue to be recommended for repair. For groups where the configuration of all members and their connections within the group are identical, or nearly identical, the entire group is assigned the most severe condition state.

Suggested time frames are provided under "Priority", which relates to the observed condition state; the indicated time frames are relative to the inspection date of August 2018. Repairs to CS4 members, connections, and decking are urgent and are recommended to be completed within, at most, 24 months from the inspection date of August 2018.

Due to their criticality to continued structurally-safe operations of the existing stadium, particular members classified as CS4 are identified to be repaired immediately. If these repairs cannot commence immediately, the members identified for immediate repair should be monitored for on-going deterioration during the delay period; the delay period should not exceed 1 year. The intent of the monitoring would be to generally assess that the stadium can be occupied for continued operations during the delay period. The nature of the monitoring program, and the frequency of monitoring, remain to be developed.

The timing of repairs to CS3 High Priority and CS2 Medium Priority members, connections, and decking will be contingent on planning and funding decisions pertaining to the facility. It is advisable to consider undertaking projects to address all of these items as soon as practical, to mitigate the adverse effects of corrosion that is progressing at an accelerating rate with time (Page 33).

The 2018 survey revealed noticeable corrosion-related losses, classified as CS4, in particularly critical groups of structural members in the stadium. More detailed assessments, including physical measurements of section losses and detailed investigations, are recommended for these particularly critical members as described later in this report (Page 38).

In addition to the repairs of deteriorating steel members, metal decking, and connections, a one-year interval between inspections is recommended (Page 38). The round of inspections summarized in this report were performed during July and August 2018. Therefore, the next recommended inspection date is August 2019. Future recurring inspections should take place on an annual basis.

At the time that the recommended 2019 inspection is anticipated to be performed, the renewed protective coating systems that were installed under construction contracts completed in 2009 through 2011 will have been in service for an average of 10 years. It is therefore recommended that weathering steel members which received coatings under construction contracts that were completed prior to and in 2011 be included in the 2019 inspections.

Table 1. Summary of Recommended Repairs - 2018 Assessment

Priority (Relative to August 2018)	2018 Condition State	Group (App. A)	Group Description (2018 Assessment) (Consult Appendix A for further information)	Group Status
Immediate	CS4	02	Pronounced section losses at flanges and web at base of inclined bracing member in endzone stands at concrete barriers along Grid Line F.9	Pending
		N/A	Severe corrosion at multiple locations in the roof structure over pedestrian entry Gate 1 (refer to summary memo in Appendix B)	Pending
24 Month	CS4	01	Pronounced section loss in top flanges of beams in the cantilevered raker assemblies supporting Red (lower tier) and Brown (loge) Seats	Pending
		04	Pronounced section loss in web of radial truss bottom chord at plate connection to horizontal truss diagonal member; or bolt head or nut lost to corrosion at the connection; or both	Pending
		06	Severe corrosion of sub-decking hat channels, at lower concourse restroom plumbing	Pending
		06	Severe corrosion of sub-decking hat channels, at locations on lower concourse and upper concourse, away from bathrooms	Pending
		10	Some section losses at wide-flange girders that frame out escalator openings, at both escalators	Pending
		11	Section losses within connection of wind girt to radial truss bottom chord member	Pending
		Several	Pronounced section losses at flanges of various spandrel and edge beams, throughout stadium	Pending
		N/A	Severe corrosion at multiple locations in the roof structures over pedestrian entry Gates 5, 6, 7, 8 (refer to summary memo in Appendix B)	Pending
Medium	CS3	06	Limited section losses in sub-decking hat channels or in decking itself, at scattered across all seating stands	Pending
		10	Some section losses at top flanges of beams that frame out the field-level floor landings at the bottom of the escalators, at both escalators	Pending
		Several	Some section losses at flanges, webs, or connections at various beams, at locations scattered across all seating stands	Pending
		N/A	Severe corrosion at multiple locations in the sheet metal cladding and roofing for the structures over vehicular entry Gates 1, 2, 3, 4 (refer to summary memo in Appendix B)	Pending
	CS2	N/A	Moderate corrosion of the structural steel framing of the roof structures over vehicular entry Gates 1, 2, 3, 4 (refer to summary memo in Appendix B)	Pending

Table 2. Updated Summary of Previously-Recommended Recommended Repairs - 2016 Assessment

Updated Priority (Relative to August 2018)	2016 Condition State	Group (App. A)	Group Description (2016 Assessment) (Consult Appendix A for further information)	Group Status
Immediate	CS4	03	Connections between girder and raker column, Line F at top of Blue seating section	Pending: Anticipated for H&S5
		05	Fiberglass angle falling hazard mitigation, longer term	Pending: Anticipated for H&S5
		06	Floor deck short-term stabilization beneath a vomitory ramp	Pending: Anticipated for H&S5
	CS3	09	10 Selected Rows of Seating Plate Repairs, various Orange seating rows in NWSL	Pending: Anticipated for H&S5
Completed	CS4	05	Fiberglass angle falling hazard mitigation, short term	Performed In-House by Stadium
		06	Electrical Room Lightweight Decking Floor Slab short-term Stabilization	Included in H&S4
		09	59 Selected Rows of Seating Plate Repairs, various Orange and Yellow seating rows; also all aisles with step boxes	Included in H&S4
High	CS3	09	Seating Plate Repairs, all remaining Orange seating rows for both sideline stands and all remaining northeast sideline stand Yellow seating rows not addressed in H&S4 and H&S5	Pending
		Various	Corrosion mitigation at CS3 members identified in Appendix C of the October 26, 2016 corrosion assessment report.	Pending
Medium	CS2	09	Seating Plate Repairs, all Brown (loge) seating rows, northeast sideline stand Red seating rows, and north endzone Red seating rows in Sections U, V, UU, and VV	Pending
		N/A	Corrosion mitigation at CS2 members (all remaining members and connections that are presently painted brown)	Pending

INTRODUCTION

The Planning Branch of the Public Works Division (PWD) of the Department of Accounting and General Services (DAGS), State of Hawaii, requested that Wiss, Janney, Elstner Associates, Inc. (WJE) perform a limited study regarding corrosion of weathering steel members and floor slab lightweight decking systems at Aloha Stadium. The intent of this study is primarily to identify and prioritize recommended repairs of these aspects of the Aloha Stadium to maintain health and safety.

BACKGROUND

Description of Stadium

The Aloha Stadium (Figure 1) is comprised of six structurally independent seating stand modules. These seating stand modules are referred to under the following titles and abbreviations in the present report:

- North Endzone (NEZ) (formerly identified as North Fixed)
- South Endzone (SEZ) (formerly identified as South Fixed)
- Northeast Sideline (NESL) (formerly identified as Northeast Moveable)
- Southeast Sideline (SESL) (formerly identified as Southeast Moveable)
- Northwest Sideline (NWSL) (formerly identified as Northwest Moveable)
- Southwest Sideline(SWSL) (formerly identified as Southwest Moveable)

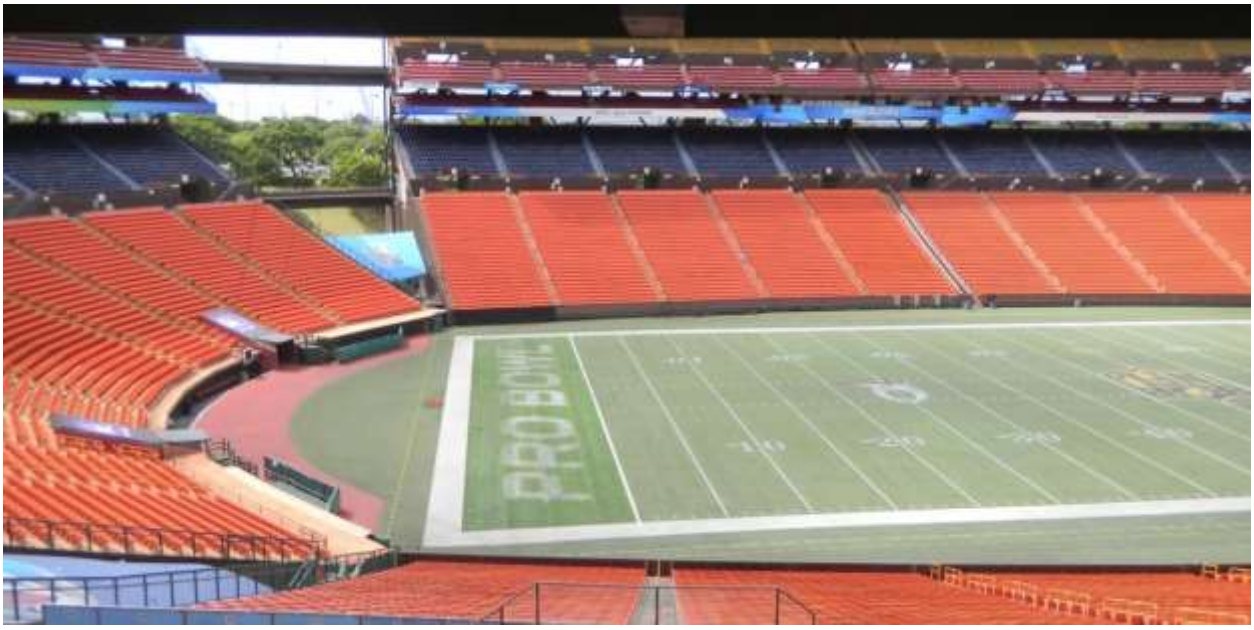


Figure 1. Aloha Stadium, as viewed from a vantage point on Gridline 17 in the Blue seating section on the southeast sideline seating stand. The south endzone seating stand is on the left side, southwest and northwest sideline seating stands are visible across the field, and the southeast sideline seating stand is in the foreground.

The seating stand modules have previously been referred to as moveable or fixed, referring to the historical capability to relocate the sideline modules between baseball and football configurations. However, based on findings from our 2005 planning study, a policy decision was made by the Aloha Stadium Authority to no longer host baseball events. Consequently, the stadium now remains in the football configuration.

The structural and architectural plans for the stadium utilize numbered gridlines in a radial pattern aligned with the raker frames and lettered gridlines oriented parallel to the edges of the field (Figure 2). These gridline identifiers were established on the original design documents for Aloha Stadium.

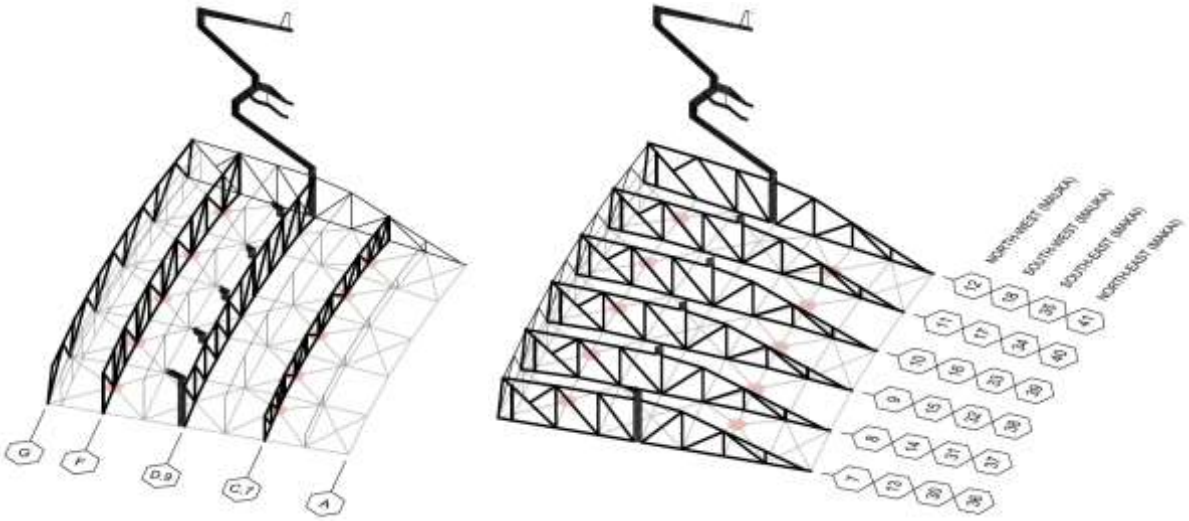


Figure 2. Schematic illustrations of the base truss system, located beneath the sideline seating stands, showing trusses along lettered transverse gridlines (left) separately from trusses along numbered radial gridlines (right).

Because of their prominence at the stadium, seating section identification letters are used to reference many features at the stadium, Figure 3. Each lettered seating section spans between numbered radial gridlines. The seating sections on the west half of the stadium are identified with single letters. Seating sections on the east side of the stadium are identified with double letters, corresponding to the single-lettered sections on the opposite side of the north-south line of symmetry.

Each of the structurally independent stand modules extend from ground level up to a high roof structure that is cantilevered over the yellow seating sections, Figure 4. Seating sections are differentiated vertically by colors, from lowest level (Field Level) proceeding upwards:

- Orange (Lower Field Level)
- Blue (Upper Field Level)
- Brown (Loge Seats or Box Seats)
- Red (Lower Tier Level)
- Yellow (Upper Tier Level)

The seating sections are step-like, tread-and-riser systems that form a seating bowl. Typically the seating sections are constructed of 1/4-inch steel plate tread-and-risers, with the exception of the Orange seating level at the endzones, which utilize a reinforced concrete tread-and-riser construction. The framing that supports the tread-and-riser is typically structural steel, with the exception of the lowest level of the endzone stands, where the reinforced concrete tread-and-risers are supported by reinforced concrete framing.

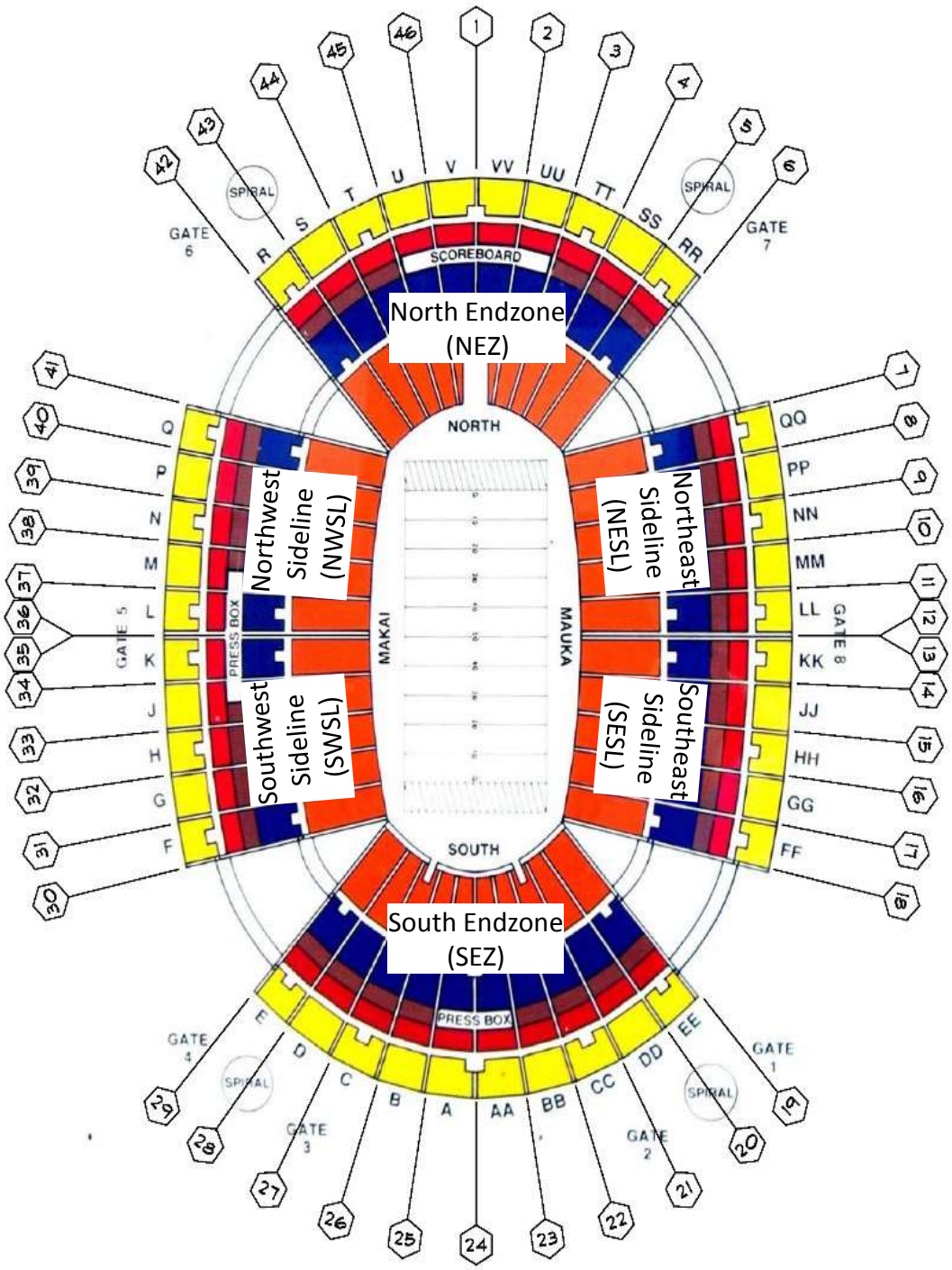


Figure 3. Exploded (colored sections not vertically stacked) plan view of the Aloha Stadium, indicating seating section letter identifiers and radial gridline numbering scheme.

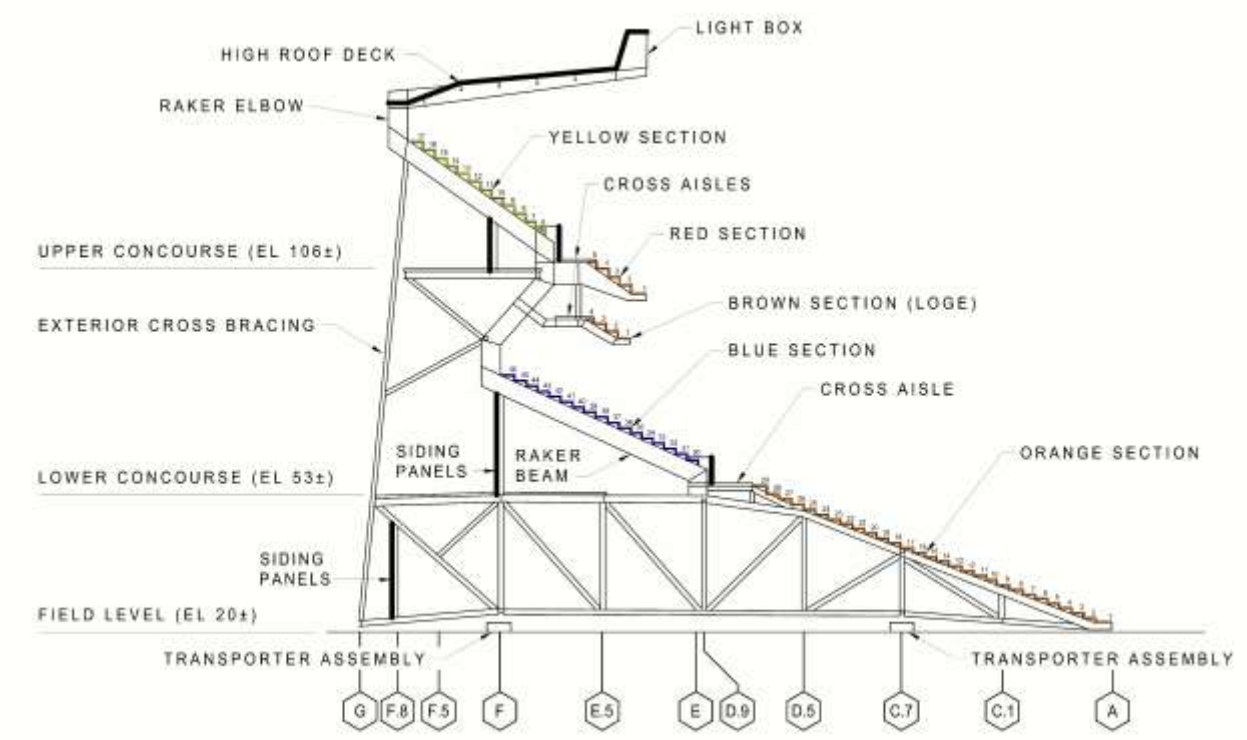


Figure 4. Schematic section through Aloha Stadium sideline seating stand structure.

Access to the seating sections is accomplished via two main concourses. The lower concourse is located approximately at the elevation of the top of the Orange seats, providing access to the Orange and Blue seating sections. The upper concourse is located at the top of the Red seating level, providing access to the Brown, Red, and Yellow seating sections. The structural floor slab systems that support the two concourse levels and other horizontal traffic bearing surfaces, such as the cross-aisles and vomitory ramps, are typically constructed of concrete material of various construction detailing. The various floor slab systems will be described in detail in a later section of this report.

Four spiral ramp structures exist to provide pedestrian access to the upper concourse level from the lower concourse level. The original spiral ramp structures, which had been constructed using weathering steel, were replaced in their entirety with hot dipped galvanized and painted mild steel framing in the 1990s.

Corrosion Mitigation Coatings

The primary structural systems at the Aloha Stadium are constructed using weathering steel, which requires a protective coating system (high-performance paint) to prevent corrosion in the chloride-laden, Hawaiian environmental conditions. As originally constructed during the early 1970s, the weathering steel at the stadium was uncoated. However, by 1980, significant corrosion developed in primary structural members throughout the stadium, causing concern for the integrity of the structure.

A corrosion mitigation program was developed during the 1980s, and a protective coating system was applied to the weathering steel throughout the stadium structure during an approximately 10- to 12-year long period between the mid-1980s and 1995. The protective coating system applied in this time period is

comprised of three parts: an organic zinc-rich primer, an epoxy intermediate coat, and an aliphatic urethane topcoat.

Since originally applied, no major maintenance of the coating system is known to have taken place prior to corrosion mitigation efforts that commenced in 2009. At the present time, corrosion mitigation remains ongoing, with the circa 1980s-1990s protective coatings in some areas of the stadium having aged beyond 30 years.

Prior Condition Survey of Existing Coating Systems

As part of Phase 2 of Structural Certification, a comprehensive field examination of the protective coating systems of Aloha Stadium was conducted by WJE during the fall of 2007. Over 1,100 individual field tests were performed on the existing coating systems at over 220 discrete locations throughout Aloha Stadium. An analysis was performed on the collected data. Information regarding the condition study and recommendations can be found in the report Aloha Stadium, Structural Certification Task 2.2, Condition Survey of Protective Coatings, Final Task Report, October 31, 2008, WJE No. 2007.4596.2 [DAGS Job No. 12-10-0374].

The conditions of the coating systems were tested or rated in accordance with accepted standards for adhesion, thickness, degree of corrosion present, degree of corrosion undercutting, and the degree of chalking. Other coating defects such as peeling, blistering, and cracking were visually evaluated along with additional coating related concerns such as limited resistance to water ponding, erosion of coatings, pinholes in coatings, and questionable coatings selected for maintenance painting. Samples of coatings were removed from selected stadium surfaces and tested in the laboratory for identification of the coatings' generic binder and for the presence of hazardous metals content. The results of the field and laboratory tests were analyzed, and field observations were assessed. It was generally found that the ageing coatings were experiencing localized failure at various locations throughout the entire stadium and were reaching the end of their serviceable life, if not beyond serviceability.

An Overcoating Acceptance Criteria was developed on the basis of commonly-accepted industry practices for acceptable levels of adhesion, thickness, and degree of corrosion in combination with our own experience with coating systems and exercise of our professional judgment. When the Overcoating Acceptance Criteria was applied to the field test results, it was found that the coatings of a significant portion of the coated components at Aloha Stadium were not suitable for overcoating. At the time of the study in 2007-2008, all of the existing protective coatings at Aloha Stadium had aged more than 10 years, and some had been in service for 20 or more years. The field testing revealed that deterioration of the coatings, as measured by adhesion testing, was increasing with age (Figure 5). For the generic type of existing coating system, original degree of surface preparation, and the given environment, industry references for service life indicated 10 years to be the ideal age at which to apply a maintenance overcoat to the generic type of existing coating system utilized at the stadium, and that practical service life was fully exhausted at 16 years.

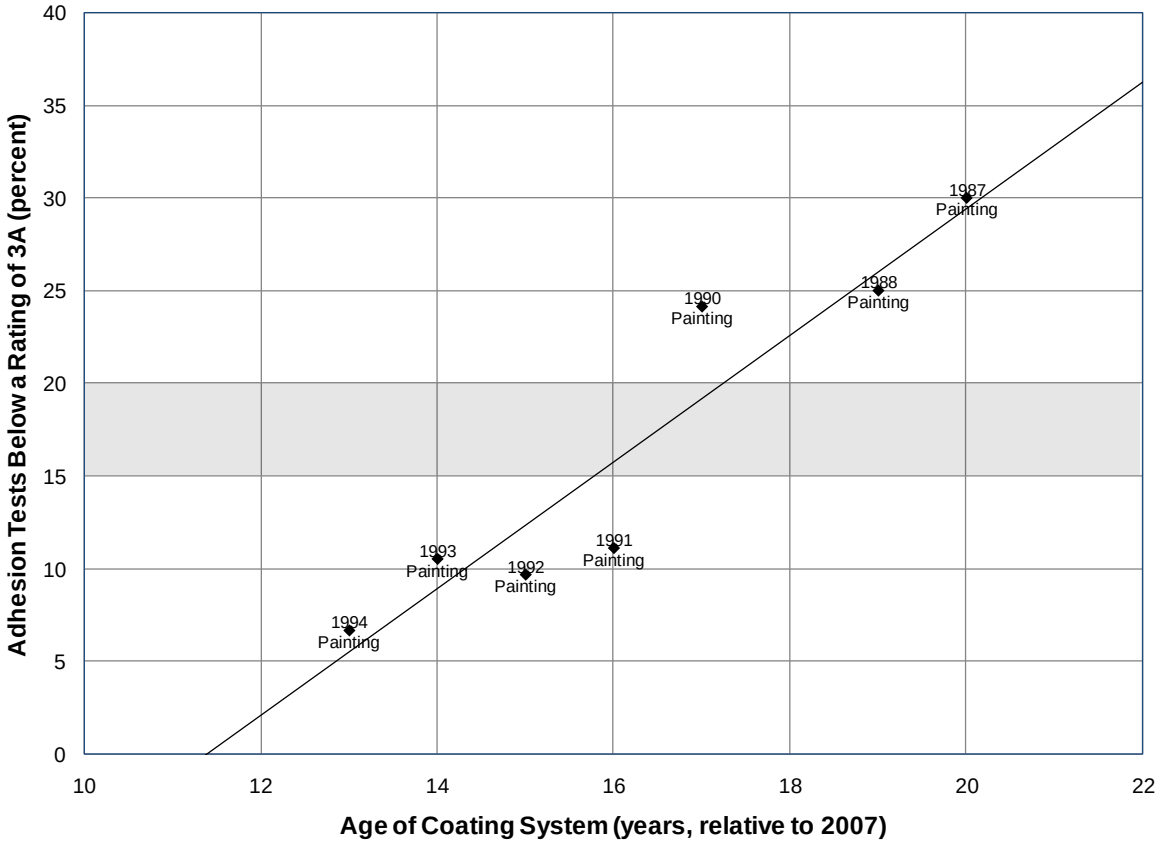


Figure 5. Age of the coating system (relative to 2007) versus the proportion of low adhesion results determined for certain members tested in 2007. The linear trend line of the plotted data is shown. The shaded band in the range of 15 to 20 percent of adhesion tests having poor ratings represents the starting point where any economic benefit that may be realized by overcoating may be offset by costs of surface preparation. Since the time that this data plot was prepared in 2007, the coatings applied during 1991 to 1994 have reached ages of at least 24 years(as of 2018) and older, suggesting that adhesion test results on these coatings would likely fall above the shaded band if these coatings were retested at this current age.

Application of the Overcoating Acceptance Criteria identified a limited proportion of components at the stadium, at the time of the 2007-2008 condition survey, which were marginally eligible for overcoating. Even though some initial construction cost benefit may have been realized by judiciously overcoating these components as compared to repainting, the economic benefit was not certain over long-term life cycle financial analysis, given the deteriorated coating conditions and the difficult access to many of the steel components for future maintenance and repairs. This is because overcoating of these components will come with a reduced service life as compared to the service life of a repainted component where existing coatings are removed and new coatings are applied. In addition, a higher risk of failure of the overcoat was anticipated where existing coatings in their 2007-2008 condition would be overcoated without regard to the presence and proportion of coatings with poor adhesion. Furthermore, it was unlikely that coating manufacturers would provide a long-term warranty, if any warranty at all, for the overcoating application even if areas of poor adhesion were to be addressed.

At the time of the 2007-2008 condition survey, WJE provided options to selectively remove areas of poorly adherent existing coating to reduce the risk of failure of an overcoat, or to otherwise remove and replace the existing coating systems. For the overcoating option, investigative trial installations and assessment would be required to demonstrate whether an overcoated system could achieve a reasonable performance. The factors related to overcoating supported the State's decision at that time to completely remove and replace the existing coatings and forgo investigative trial installations related to the overcoating approach.

Recoating as Part of Corrosion Mitigation

On this basis, the State of Hawaii began a phased program for renewal of the protective coatings system over a series of construction projects, commencing in 2009, and continuing to the present. The renewal program consists of complete removal of the original coating system and replacement with a new coating system.

Based on the results of the field survey testing, and with no provision made to pursue options for overcoat trial installations, it was recommended that the stadium should be recoated. Recoating is defined here as the complete removal of any existing protective coating system to bare metal followed by application of a new protective coating system. Various projects at Aloha Stadium, completed to date since 2009 and including current projects (H&S4, nearing final acceptance, and H&S5, pending award), have included removal of existing protective coatings and installation of new protective coatings as part of corrosion mitigation of structural steel at the Aloha Stadium. The replacement protective coating system applied commencing in 2009 is comprised of three parts: an organic zinc-rich primer, an epoxy intermediate coat, and fluoropolymer topcoat.

The protective coatings have been renewed in several critical areas of the stadium, including:

- The main high roof and its supporting cantilever columns, throughout the stadium
- The diagonal bracing frame (at the rear of the seating stands), and the hub assemblies within this bracing, throughout the stadium
- Inclined braces between bracing frame hubs and raker frame knee joints, on sideline seating stands
- Main stairs on sideline stands
- Framing in direct contact with new, replacement lower (main) level concourse decking, northeast and northwest sidelines

The scope of recoating corrosion mitigation is described generally for each project in the following itemization; for specific locations of demising lines between the various projects, the individual project documents should be reviewed. Projects completed since 2009 to date, and projects that are currently active, are listed below:

Roof Replacement Projects

The corrosion mitigation work, including both recoating and repairs to or replacement of structural steel members, was performed at the main high roof cantilever beams, girders, purlins and light-box framing.

- Roof Phase 1: ["Aloha Stadium, Replace Metal Roof Deck and Transformers (Sections FF to KK and RR to VV) DAGS Job No: 12-10-0518] - Completed 2009
- Roof Phase 2: ["Aloha Stadium, Replace Metal Roof Deck and Transformers (Sections LL TO QQ, R & S, & L TO Q) DAGS Job No: 12-10-0598] - Completed 2010
- Roof Phase 3: ["Aloha Stadium, Replace Metal Roof Deck and Transformers (Sections AA TO EE, & A TO K) DAGS Job No 12-10-0620] - Completed 2011

Structural and Various Health and Safety (H&S) Improvements

The corrosion mitigation work, including both recoating and repairs to or replacement of structural steel members, was performed.

- H&S Phase 1 (H&S1): [DAGS Job No. 12-10-0605] - Exterior cross bracing, from ground to roof, all stands - Completed 2013
- H&S Phase 2 (H&S2): [DAGS Job No. 12-10-0636] - North Concourse Waterproofing - No corrosion mitigation work - Completed 2013
- H&S Phase 3 (H&S3): [DAGS Job No. 12-10-0736] - Bracing between upper and lower concourse (sidelines), coating of areas below the lower concourse directly affected by structural upgrades - completed 2016
- H&S Phase 4 (H&S4): [DAGS Job No. 12-10-0797] - Primarily seating plate corrosion mitigation work and isolated corrosion mitigation on structural members, connections, and decking - currently constructed and nearing final acceptance
- H&S Phase 5 (H&S5): [DAGS Job No. 12-10-0865] Primarily seating plate corrosion mitigation work and isolated corrosion mitigation on structural members, connections, and decking - currently pending award

Areas of Stadium not yet Recoated

However, the original coatings systems have not yet been replaced in significant areas of the stadium, including:

- The structural base truss systems that support all four sideline seating stand structures: northwest, southwest, southeast and northeast sideline stands
- The seating plates that support the Orange, Blue, Brown, Red and Yellow seating areas, throughout the entire stadium
- The girts and struts that support the cladding that enclose the base trusses of all four sideline seating structures
- Inclined braces between bracing frame hubs and raker frame knee joints on both end zone seating stands
- Raker frame members in all areas of the stadium
- Structural steel framing directly supporting all upper level concourses
- Structural steel framing directly supporting the lower (main) level concourses at the southeast and southwest sideline stands
- All curved pedestrian passage bridge structures
- Elevator tower structure and bridges to the main stadium structure
- Spiral ramp structures and bridges to the main stadium structure

Lightweight Metal Decking Floor Slabs

Both levels of concourse slabs and other horizontal traffic-bearing surfaces, such as the cross-aisles at the tops of the Orange, Brown and Red seating areas, the slabs supporting the concession stands and restrooms, and the slabs of the vomitory ramps, are typically constructed of concrete materials with metal decking substrates of various construction detailing.

At both of the endzone seating stands, the slabs of lower concourse, the concession and bathroom areas that adjoin the lower concourse, and concourse vomitory ramps, and the cross aisle at the top of the Orange seating area are comprised of reinforced-concrete slabs supported by reinforced-concrete framing systems.

For all of the remaining areas of the Aloha Stadium seating stands, the original, circa 1970s floor slabs were constructed using a unique system of light-gage hat channels ("sub-decking") supporting a light-gage, galvanized, corrugated metal deck ("decking") topped by a thin concrete slab that is nominally 1 inch thick including the depths of the flutes of the corrugated metal deck and the concrete (Figure 6), collectively identified as a "lightweight decking system." The durability of this circa 1970s lightweight decking system was poor, and as a result, after less than 6 years of service life, the circa 1970s lightweight decking components were replaced with a nearly-identical lightweight decking system that also used galvanized steel components, with the further addition that a waterproof traffic coating was applied to the walking surface of the thin concrete slab to improve the durability of the replacement system components. Replacement of the circa 1970s lightweight decking system commenced in 1981, taking place in phases over the course of the 1980s.

Re-Decking with Conventional Decking System as Part of Corrosion Mitigation

Even with the addition of a waterproof traffic coating to the walking surface, the service life of the circa 1980s replacement lightweight decking system proved to be on the order of 20 to 25 years. This means that in many areas of the stadium, the circa 1980s replacement lightweight decking system is nearing the end of its service life.

Therefore, some limited re-replacement of the circa 1980s replacement lightweight decking system occurred in 2015, at selected areas of the northeast and northwest sideline seating stands. The circa 1980s lightweight decking system was replaced with a more conventional composite concrete-and-metal deck system (Figure 7), including application of a waterproof traffic coating to the walking surface. This re-replacement decking system is anticipated to have improved durability and longevity as compared to the existing lightweight deck system, even though the conventional composite deck system will have a larger self-weight.

The installation of the conventional decking system was completed under the following construction project:

- Aloha Stadium, Structural and Various Health and Safety Improvements, Phase 3 [DAGS Job No. 12-10-0736] - Completed 2016

The specific areas where conventional decking system has been installed include:

- NESL, at the rear of the lower concourse level, from the line of columns along Grid Line F to the outside edge of the concourse slab at Grid Line G;
- NESL, the cross aisle at the top of the Orange seating section;
- NWSL, at the rear of the lower concourse level, from the line of columns along Grid Line F to the outside edge of the concourse slab at Grid Line G; and
- NWSL, the cross aisle at the top of the Orange seating section;

The H&S4 and H&S5 projects do not include any large areas where conventional decking was installed, although H&S5 is anticipated to include installation of replacement conventional decking at relatively limited areas of the cross aisles at the top of the Orange seating sections of the southeast and southwest sideline seating stands. Instead, for the most part, the H&S4 and H&S5 projects provide supplemental support to selected, deteriorated areas of the existing lightweight decking rather than replacement of the deteriorated lightweight decking. The supplemental support should be considered an interim measure, intended to stabilize the deteriorated lightweight decking until such time as conventional decking can be installed in the affected area.

Areas of Stadium not yet Re-Decked

General locations in the stadium where the lightweight decking systems remain in place include the following:

- Upper concourse walkways and vomitory passages, all seating stands throughout the stadium
- Cross aisles at the top of the Red seating section, all seating stands throughout the stadium
- Cross aisles at the top of the Brown (loge) seating section, all seating stands throughout the stadium
- Cross aisles at the top of the Orange seating section, SESL and SWSL
- Lower concourse concession, restroom, and back-of-house areas, along with vomitory passages, all sideline seating stands
- Lower concourse outer walkways, SESL and SWSL

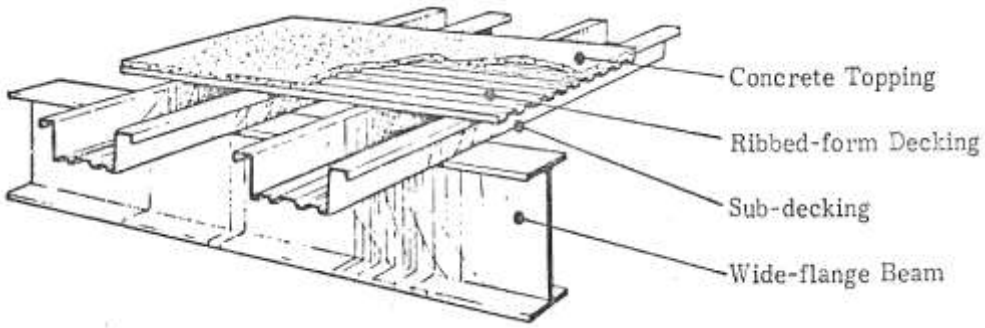


Figure 6. Schematic illustration of existing lightweight decking system at Aloha Stadium.

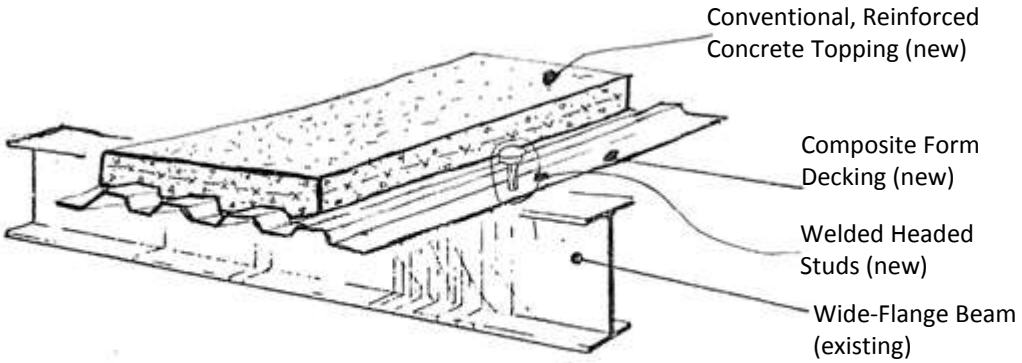


Figure 7. Schematic illustration of circa 2015 replacement decking system at Aloha Stadium.

CORROSION ASSESSMENT METHODOLOGY

Basis for Corrosion Assessment Work

WJE has been informed by DAGS that evaluation for construction of a separate new stadium to replace the existing Aloha Stadium is in progress. Therefore, maintaining health and safety at the existing stadium should recognize the possibility for replacement of the stadium. Such maintenance should be anticipated over an estimated eight-year period while a new stadium is funded, designed, and constructed. The anticipated eight-year duration commences from the time that a firm decision is made by the State to pursue construction of a new stadium.

A plan of action was discussed in 2016 with DAGS to perform structural safety inspections and evaluations modeled on similar inspections that are performed on highway bridge structures. Safety inspection and evaluation only considers the effect of dead and live loading; lateral loading effects (wind, earthquake) and effects of occupant-induced vibrations are not considered. The corrosion assessment reported herein includes not only safety inspections, but also collects condition information about coatings, structural members, and floor slab metal decking; this condition information can be used to identify structural steel members and areas of floor slab decking having conditions in need of attention, and to prioritize the necessary work related to these members and decking.

Structural Members and Floor Slabs Selected for Inspection and Evaluation

Weathering Steel Members with Protective Coatings

Our efforts related to safety inspection and evaluation focus on those areas of the existing stadium where the original protective coatings system installed circa 1980s and 1990s have not yet been replaced. These members received a brown top coat or did not receive any top coat, leaving the white epoxy intermediate coat visible. Members where the original protective coating systems have been removed and replaced are not in the present safety assessment because these protective coatings were recently installed and are presumably performing well. A green top coat has been applied to members that received a new coating system, allowing these members to be readily-distinguished from members that still have the original brown or white protective coating system in place. The first of the replacement coatings were installed in 2009, and are nearing 10 years of service life at the time that this report is written.

There is an ongoing concern that the original protective coatings may have completely failed in some locations, thereby exposing the underlying structural members to the possibility of renewed corrosion. Consequently, those portions of members where we believe that the original protective coatings have failed are selected for assessment whether further corrosion damage has occurred, in addition to the corrosion damage that occurred prior to application of the original coatings in the 1980s and 1990s.

The base truss systems beneath the four sideline seating stand structural modules represent one-third to one-half of the total number of weathering steel members in the entire stadium. Additionally, these base truss members support more than one-half of the total number of seats in the stadium. Given that the original coatings on these base truss members have not yet been replaced, and that these are the oldest of the original protective coatings applied, these members were selected for assessment under the present safety inspection and evaluation efforts.

Other structural members where the original protective coating system has not yet been replaced and were therefore selected for assessment in this project consisted of the mainframe welded plate girders that

comprise the raker frames which support the Blue, Brown, Red and Yellow seating areas, and the framing members that connect the raker frames to the diagonal bracing frames at the rear of the stadium.

Lightweight Metal Decking Floor Slabs

A visual survey of the underside of the original lightweight decking systems that are older than 5-years are selected for assessment in this project. General locations in the stadium where the lightweight decking systems remain in place were summarized earlier in this report.

Areas in the stadium where the lightweight decking system have been replaced by a conventional composite metal decking system during the H&S3 project are not expected to exhibit deterioration at this time, and as a result, spans of conventional composite metal decking are not included in the present assessment.

Other Structural Features

Portal structures constructed from structural steel and sheet metal of uncertain date of construction exist at the vehicular entry gates that lead into the Aloha Stadium site. The vehicular entry gate structures have not been surveyed for corrosion in any recent survey or repair efforts. Therefore, the vehicular entry gate portal structures are selected for assessment.

Similarly, canopy structures constructed from structural steel and sheet metal of uncertain date of construction exist at several of the pedestrian entry gates that lead into the main concourse at the rear of the Aloha Stadium. The pedestrian entry gate structures have not been surveyed for corrosion in any recent survey or repair efforts. Therefore, those pedestrian entry canopy structures that are constructed of structural steel and sheet metal are selected for assessment. Some pedestrian entry canopy structures are constructed of reinforced concrete; the concrete canopy structures are not included in the present assessment.

Because the current spiral ramp structures are replacement structures constructed in the 1990s using galvanized mild steel, maintenance of corrosion protection for the ramp structures is a lower priority. As a result, the spiral ramp structures are not included in the present assessment.

The lower portions of both endzone seating stands (the lower concourse floor slab, the Orange seating areas, and the structures supporting these areas) are constructed of reinforced concrete structural systems. As a result, these lower portions of the North and South Endzone seating stands are not included in the present assessment.

Survey Methodology

The primary methodology used was visual assessment of the selected weathering steel members and lightweight floor decking as summarized above. Due to access limitations and obstructions, it was not possible to observe all surfaces of every structural steel member with original coatings from the 1980s and 1990s, or every panel of lightweight floor decking. It is estimated that less than 20 percent, cumulatively, of the surfaces of the structural steel members with original coatings that were assessed in this survey were concealed or inaccessible. For the lightweight decking, it is estimated that less than 10 percent of the lightweight decking panels were concealed or inaccessible.

The visual survey assigned a condition state to each member and decking panel, as follows:

- Condition State 1 (CS1) – No discernable coating failure on steel members (Figure 8) or the visible surfaces of the sub-decking hat channels or the decking itself; therefore, no corrosion is assumed. These members and decking panels pose no known immediate concern for health and safety of occupants of the structure.
- Condition State 2 (CS2) – Visual signs of localized coating failure with only minor surface corrosion on steel members (Figure 9) or paint loss with corrosion observed or corrosion likely on the visible surfaces of the sub-decking hat channels or the decking itself. Section loss is assumed to not be appreciable. Health and safety implications of CS2 members include the eventual progression of observed deterioration into Condition State 3, and the potential for corrosion products and debonded coatings to displace from the surface of the member or the decking, becoming a nuisance and a relatively minor safety concern, to a lesser degree than for members or decking classified as Condition State 3.
- Condition State 3 (CS3) – Visual signs of coating failure and noticeable corrosion on steel members (Figure 10) or the visible surfaces of the sub-decking hat channels or the decking itself (Figure 11). There appear to be notable corrosion-related section losses in the steel member or decking. Health and safety implications of CS3 members include corrosion products and debonded coatings that have the potential to displace from the surface of the member or decking, becoming a nuisance and a relatively minor safety concern.
- Condition State 4 (CS4) – Visual signs of coating failure on the steel member (Figure 12, Figure 13), sub-decking or decking (Figure 14), accompanied by pronounced corrosion of the member, sub-decking or decking itself. Corrosion-related section loss in the member, sub-decking, or decking is not only visibly apparent, but appears to be so pronounced that the structural performance of the member, its structural connections, sub-decking or decking, or the bearing supports for the decking, is called into question.

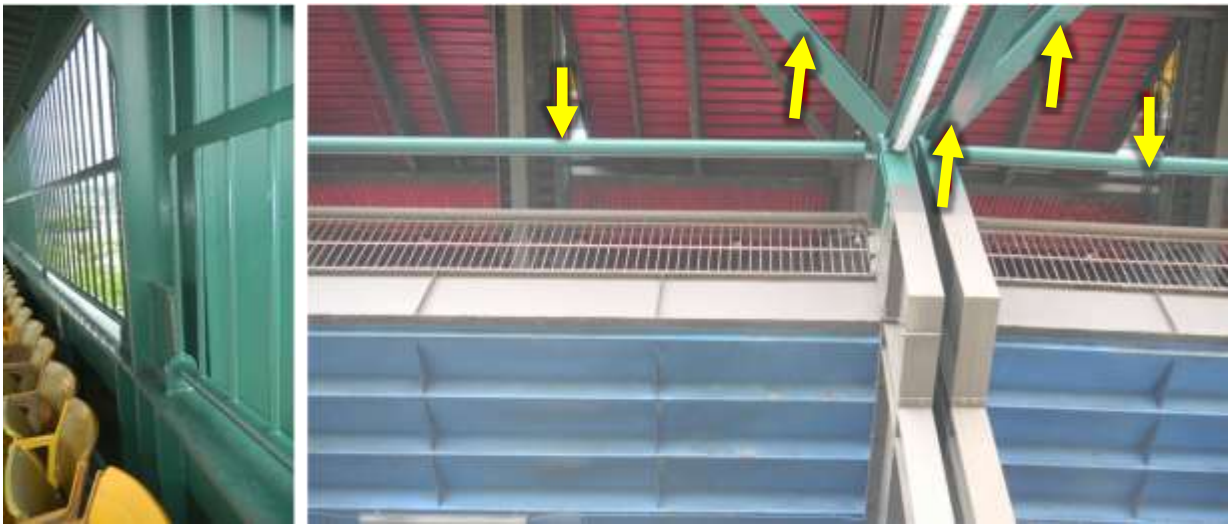


Figure 8. Examples of structural steel members classified as Condition State 1

Figure 9. Example of structural steel member classified as Condition State 2

Figure 10. Example of structural steel member classified as Condition State 3.

Figure 11. Example of lightweight floor slab decking classified as Condition State 3.

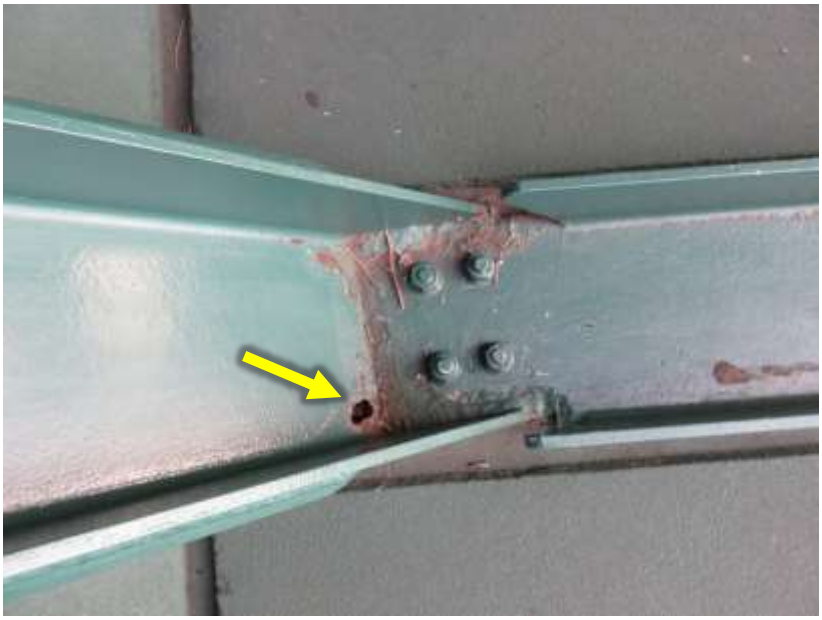


Figure 12. Example of structural steel member classified as Condition State 4. The yellow arrow points to a hole completely corroded through the thickness of the web of the steel member.

Figure 13. Additional example of structural steel member classified as Condition State 4.

Figure 14. Example of lightweight floor slab decking classified as Condition State 4.

SURVEY RESULTS AND DISCUSSION

The field work for the visual assessment of corrosion took place primarily during July and August 2018. Detailed findings are given in a series of appendixes, as follows:

Appendix A – Representative photographs of selected steel members and decking panels classified as CS3 or CS4, including narrative regarding assessment of apparent causes of observed corrosion, along with additional descriptive notes
Appendix B – Memos summarizing detailed findings for supplementation assessments of selected groups of members and ancillary structures (distributed electronically in report Volume 2 of 2)
Appendix C – Orientation drawings showing the locations within the stadium of steel members and lightweight decking panels classified as CS3 and CS4 (distributed electronically in report Volume 2 of 2)
Appendix D – Results of the member-by-member survey for the entire stadium (distributed electronically in report Volume 2 of 2)

Appendix A is organized into groups of members, based on the corrosion observed in similar types of members, as follows:

Group 01 - Raker Cantilever Assemblies on End Frames: Flange Corrosion
Group 02 - Endzone Exterior Diagonal Braces on Line F.9: Corrosion of Brace at Concrete Barrier
Group 03 - Plate Girders on Line F at Top of Blue Seating Section: Corrosion and Cracked Welds at Connections to Raker Frames
Group 04 - Lower Chord Horizontal Truss at Field Level: Corrosion at Connection of Acutely-Skewed Horizontal Truss Diagonal Brace to Bottom Chord of Radial Truss at End Frames
Group 05 - Fiberglass Angles: Overhead Falling Hazard and Corrosion at Attachment to Raker Frame Members above Concourses
Group 06 - Lightweight, Thin-System Floor Decking: Corrosion of Metal Deck
Group 07 - Orange Cross Aisle End Frame Beams: Corrosion at Beam Top Flange Supporting Deck Edges
Group 08 - Lower Concourse End Frame Beams: Corrosion at Beam Top Flange Supporting Deck Edges
Group 09 - Seat Plate Tread-and-Riser Rows: Corrosion at Seat Plates
Group 10 - Escalator Framing: Corrosion of Girders at Lower Concourse and of Beams at Field Level Landing
Group 11 - Radial Truss Framing Members: Corrosion at End Frame Radial Trusses
Group 12 - Upper and Lower Concourse Levels, Outer Perimeter Edge Beams: Corrosion at Beams
Group 13 - Red Seats Field-Fronting Beam: Flange Corrosion at Seat Plate Edges
Group 14 - Field -Fronting Framing Members along Grid Line A: Corrosion at Seat Plate Opening for Utilities
Group 15 - Sideline Stands Siding Girt Connections at End Frame Walls: Missing Bolts at Connections
Group 16 - Press Box Floor Framing Member Connection: Corrosion at Connection
Group 17 - Radial Trusses Supporting Orange Seats: Isolated corrosion at connections
Group 18 - Raker Frame at Box Seats Level: Corrosion at Raker Plate Welded Connections

As part of these assessments, each structural steel member and lightweight decking floor panel in the stadium is given a unique member identifier (Member ID). The member identification scheme is described in detail on Pages C-1 and C-2 of Appendix C.

Findings and discussion for various groupings of structural steel members, including the lightweight decking system, follow.

General Findings

The findings from our 2018 survey indicate that approximately 200 weathering steel members and approximately 85 panels of lightweight decking are presently observed to exhibit severe corrosion (cumulative of members and decking panels classified as CS3 and CS4). Our visual assessment found that essentially all of the original protective coatings, typically having a brown-colored top coat, at the observed weathering steel members have deteriorated. Corrosion to varying degrees has resumed at almost every weathering steel member having original coatings that we observed. The degree of resumed corrosion was observed to be highly variable, ranging from mild to severe. Severe corrosion (CS 3 and CS 4) is taken to be readily-observed, unabated corrosion on the weathering steel member that has resulted in pitting of the steel surface, pronounced corrosion scale accumulation (exfoliation), or both, either of which may represent a sufficient loss of steel that causes a reduction in the structural capacity the member or connection.

With respect to the lightweight floor decking, our 2018 visual assessment is the first time that the lightweight floor decking has been included in a comprehensive manner in any of the recent interim assessments for corrosion. Based on observations made of the underside of the lightweight floor decking, large extents of the lightweight decking do not exhibit severe corrosion. Nonetheless, severe corrosion (CS 3 and CS 4) was observed in the lightweight decking at isolated locations throughout the stadium. As described later in this report, the severe corrosion typically consists of section losses in the sub-decking hat channels, which can lead to a reduction in the structural capacity of the decking system in the area where the severe corrosion occurs.

Expected levels of work to address the steel members and decking panels classified as CS3 and CS4 are described later in this report.

Descriptions of particularly prominent or particularly extensive deterioration on members and decking panels classified as CS3 and CS4 follow below. Member group identifiers are as summarized above, and are the same as the member grouping scheme utilized in Appendix A. Additional information on member groups not described below can be found in Appendix A.

Beam Flanges in Raker Cantilever Assemblies (Group 01)

At each radial grid line throughout the stadium, there are cantilevered raker frame assemblies that structurally support the Red and Brown seating areas (Figure 15). The primary components of the raker assembly include a deep, structural steel, welded raker beam that directly supports the seat plates and cross aisle of the Red seating area (upper cantilevered beam), a more shallow, structural steel, welded raker beam that directly supports the seat plates and cross aisle of the Brown (loge) seating area (lower cantilevered beam), and a weathering steel wide flange member that appears to be a “column” but instead serves as a tension tie to transfer structural loads from the structural framing at the Brown seating level up to the structural framing at the Red seating level.

At several end raker frame locations, severe corrosion losses (CS3 and CS4) have been visually observed in the top flange of the deep raker beam supporting the Red seating level (Figure 16). Severe corrosion losses have also been observed in the top flange of the raker beam supporting the Brown seating level. There are a total of twelve end raker frames at the stadium, resulting in a total of twenty-four weather steel raker beams that potentially exhibit notable corrosion losses. There are similar cantilevered assemblies at the interior raker frames, but the beams of the interior cantilever assemblies do not exhibit corrosion to the same extent as do the beams on the end frame cantilever assemblies.

It appears that, over the years, rainwater has entered into operable access hatches in the floor deck at the ends of the cross aisles servicing the Red and Brown seating areas. The access hatches are located immediately above the subject raker beams in the end raker frames. The rainwater appears to have leaked directly onto the top flanges of the raker beams, resulting in notable corrosion to the top flanges of the raker beams due to relatively persistent wetness.

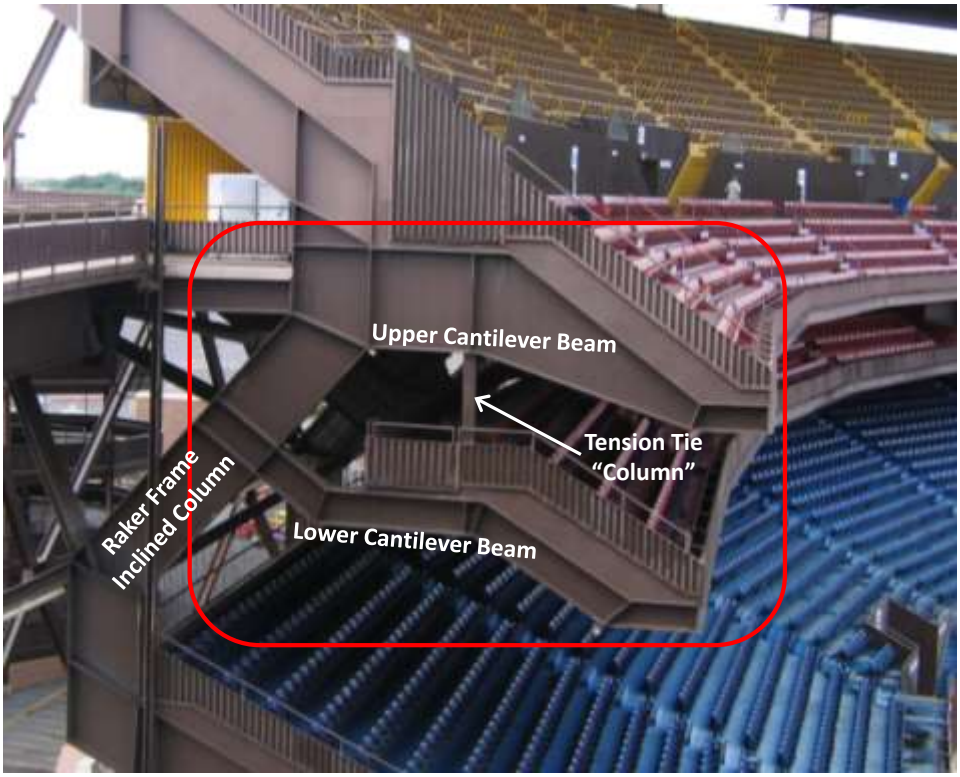


Figure 15. View of a typical end-bay raker frame, with cantilevered raker assembly highlighted by red box. Annotations indicate various features of the cantilevered assembly.

Figure 16. Corroding top flange of deep raker beam supporting the Red seating area. This location is in an end frame of the northeast sideline stands. The deep beam is one component of the cantilever raker assembly that supports the Red and Brown seating areas.

Because the structural configuration of the raker assemblies is cantilevered in nature, these assemblies in general lack structural redundancy, which in turn means that the probable consequences of structural failure of an assembly will likely be more severe than that of a structural member with redundancy. Consequently, the top flanges of the upper and lower cantilevered beams in these assemblies at several end-bay locations in the stadium were assessed in the field through physical measurements that estimated the extent of member cross-section lost in the top flanges due to corrosion. The field-measured section losses were used to estimate the remaining structural capacity of the as-corroded members. Structural demands, determined using current building code requirements, were then calculated for these members and subsequently compared to remaining structural capacities; the results of such comparisons are typically expressed numerically in terms of demand-to-capacity ratios.

Based on our field measurements and subsequent structural analyses, we find that the current structural capacities of the as-corroded cantilevered raker assemblies are such that demand-to-capacity ratios are less than 1.0, which means that even after accounting for the adverse structural effects of corrosion-related section losses, enough structural capacity remains such that the existing, as-corroded structural section satisfies the structural strength requirements of the building code.

In any event, the affected structural members in the cantilevered assembly will almost certainly continue to corrode, and if repairs are not implemented in a timely manner to mitigate the effects of continued corrosion and to restore structural capacities, the remaining structural capacities of the corroding members will likely reduce with time to structural capacities below those required by the building code. As summarized later in this report, it is recommended that the affected portions of the cantilevered raker assemblies be structurally repaired within a 24-month time period. Further details regarding our assessment of the affected cantilever raker assemblies is given in a memo included in Appendix B of this report.

Endzone Diagonal Braces at Concrete Barriers (Group 02)

A diamond-configuration, diagonal bracing frame exists at the rear of each of the two endzone seating stands. The structural members of the diagonal bracing frames are weathering-steel wide-flange structural shapes. At the main concourse level, concrete barriers are present where the lowest level of diagonal structural steel braces connects to the reinforced concrete substructure of the endzone seating stands (Figure 17). Although these concrete barriers are referred to as "thrust blocks" on the original architectural drawings, a review of the original structural drawings indicates that the barriers are lightly-reinforced, and as a result, the concrete barriers do not appear to serve a structural function. Instead, it is presumed that the concrete barriers are present as a measure to prevent vehicles from impacting the diagonal braces. The original, crica 1990s protective coatings on these particular weather steel braces have been removed and renewal protective coatings (green paint topcoat) have been applied within the past 10 years. While green-painted members are generally excluded from the approved scope of the present corrosion assessment, the corrosion-related losses were readily-noticed at some of these members, and as a result, green-painted members of this particular type were included in the present assessment.

During our August 2018 corrosion survey field activities, along with follow-up visual observation of these braces during September and November 2018, WJE observed severe corrosion losses (CS3 and CS4) in almost every brace, at the bottom end connections in the vicinity of the concrete barrier, where the structural steel brace connects to the reinforced concrete substructure of the seating stand. A representative location classified as CS4 is shown in Figure 18; a total of four braces were categorized as CS4. The locations on the braces where noted corrosion losses occurred are locations where, due to physical interference with the concrete barriers, it is difficult to apply protective coatings to the weathering steel brace member; these locations also are configured in a manner that tends to retain water and debris. As a result, despite having been re-coated within the past 10 years, corrosion of the weathering steel member is apparently on-going at a relatively accelerated rate at these locations because the protective coatings are locally failing.

Because of the severity of the observed corrosion losses (CS3and CS4), which included complete loss of section through the entire thickness of the web or the flange of some of the brace members, six brace members in the endzone seating sections of the stadium were selected for further assessment in the field through physical measurements that estimated the extent of member cross-section lost due to corrosion. The field-measured section losses were used to estimate the remaining structural capacity of the as-corroded brace members, specifically at the location where the brace member penetrates into the concrete barrier. Structural demands, determined using current building code requirements, were then calculated for these members and subsequently compared to remaining structural capacities; the results of such comparisons are typically expressed numerically in terms of demand-to-capacity ratios.

Based on our field measurements and subsequent structural analyses, we find that the current structural capacities of the as-corroded brace members are such that demand-to-capacity ratios are only slightly below 1.0. This means that the remaining structural capacity of the as-corroded brace member only marginally satisfies the structural strength requirements of the current building code.

Figure 17. Representative concrete barrier at base of structural steel braces that make up the diagonal bracing frame at the rear of the endzone seating stands (South endzone shown). The red arrow indicates viewing position for the photo of Figure 18.

Figure 18. Annotated photo showing severe corrosion conditions at base connection of steel brace member to the concrete barrier (South endzone).

In any event, the affected braces in the endzone seating stands will almost certainly continue to corrode, and if repairs are not implemented to mitigate the effects of corrosion and to restore structural capacities, the remaining structural capacities of the corroding endzone brace members will almost certainly be reduced to less than the structural capacities required by the building code. As summarized later in this report, it is recommended that the affected endzone braces be structurally repaired commencing immediately.

Because we have assessed only six out of a total of 40 brace-to-concrete barrier interfaces in both endzones, later in this report we recommend that all remaining endzone braces be examined up-close and subsequently assessed for the effects of corrosion losses, and that the concrete barrier in at least one location be at least partially dismantled to allow for examination of that portion of the structural steel brace that is embedded within the concrete barrier. These supplemental assessments are recommended to commence immediately. Further details regarding our assessment of the endzone braces is given in a memo included in Appendix B of this report.

Blue Seating Section, Line F Girder-to-Raker Connections (Group 03)

The concern with these particular connections was previously identified during the 2016 survey. Although these connections are anticipated for repair as part of the pending H&S5 project, at the time of this writing, the contract has not been awarded and so the connections have not yet been repaired. As a result, we continue to identify these connections as conditions to be addressed in a health and safety project.

Connections at the top of the blue sections are present at each numbered gridline. A structural steel angle connects the top flanges of two abutting girder ends to the vertically-oriented flange of the adjacent raker column (Figure 19).

Water becomes entrapped between the vertical leg of the angle and flange of the raker column. The entrapped moisture is causing corrosion on the connection angle and the flange of the raker column. The expansion of the corrosion products between the connection angle and the flange of the raker column applies a prying force to the connecting pieces that has resulted in partial or complete failure of the weld between the connection angle and the raker column flange at many of these connections (Figure 20 and Figure 21). Continued corrosion at these connections will result in further cracking of the affected welds. At the time of our survey, the welds have failed to various degrees at approximately 75 percent of these angle connections.

Figure 19. Typical location of problematic Blue seating section connection between girder and raker frame column.

Figure 20. The indicated weld line between connection angle and raker column flange has completely fractured.

Figure 21. The weld between the connection angle and raker column flange at this location has partially fractured.

Lightweight, Thin-System Floor Decking (Group 06)

Lightweight decking is included in the 2018 survey; the lightweight decking floor slabs have not otherwise been systematically included in any of the recent assessments for corrosion. Visual surveys were conducted from beneath for the lower (main) concourses of the sideline seating stands, for the upper concourse of all seating stands, and for cross aisles comprised of lightweight decking in all seating stands.

Severe corrosion was typically observed at locations where entry of water into the decking system is unmitigated, such as along the end bay radial trusses at the lower concourses of the sideline seating stands (Figure 22). Other locations where severe corrosion of the lightweight decking was observed also typically involved water leaks, such as at plumbing penetrations associated with toilet facilities (Figure 23). Unmitigated rainwater leaks through the sidewalls of the vomitory ramps of the main concourses in the sideline seating stands have been previously identified as affecting the lightweight decking floor slabs of the electrical rooms (Figure 24). These unmitigated rainwater leaks have also affected the lightweight decking of the vomitory ramps themselves and the lightweight decking at "back of the house" facilities such as maintenance rooms and concession storage areas.

As mentioned above, the severe corrosion in the lightweight decking at vomitory ramps and the electrical rooms had been previously identified as locations where the bearing of the floor span was determined to be unreliable at these locations. Installation of the supplemental support beams to stabilize these conditions at the electrical room is included in the H&S4 project; the other noted locations are anticipated to be addressed by the H&S5 project that is presently pending award. Provision for improved water control at the apparent leak source are also included in the H&S4 and H&S5 projects.

Figure 22. Representative severe (CS4) corrosion conditions observed in decking and hat-channel sub-decking of the lightweight floor system of the lower concourse of a sideline seating stands. Location shown is where the decking is supported by the end bay radial truss (at bottom of photo) of the sideline seating stand.

Figure 23. Deteriorated decking and sub-decking at plumbing penetrations servicing a toilet facility in a sideline seating stand.

Figure 24. Corrosion has occurred through the lightweight sub-decking hat channel that supports an electrical room floor at the Northeast Sideline seating stand.

Seat Plate Tread-and-Riser Rows (Group 09)

The concern with the seating plates was previously identified during the 2016 survey and in field surveys related to several of the health and safety construction projects. Some seating plate repairs were carried out during the H&S4 project, and additional seating plates are anticipated for repair as part of the pending H&S5 project. Furthermore, even after completion of seating plate repairs under the anticipated H&S5 project, significant additional extents of seating plates will likely require repair in the future. As a result, we continue to identify the seating plates as conditions to be addressed in a health and safety project.

The seating plates, constructed of conventional mild steel, have not been recoated since the 1980s and 1990s. Areas of these original coatings have failed. This leaves the steel seating plates directly exposed to the chloride-laden atmosphere, and as a result, the seating plates are now corroding. Additionally, some areas of the seating plates include construction details that are vulnerable to corrosion and also do not slope properly to drain, exacerbating the corrosion. The steel seating plate has corroded completely away in some locations, particularly in the Orange seating area of the sideline stands, resulting in holes through steel seating plates.

The seating plates throughout the stadium were visually surveyed on various dates during the period between April 2015 through September 2016, and again in late 2017 and early 2018, for severely corroded conditions as part of the design phase of the H&S4 and H&S5 projects, respectively. Results of these health and safety design-phase investigations are summarized in Table 3.

Table 3. Summary of Seat Plate Findings

Condition State	Location	Notes
CS4	59 Selected Rows, Orange seating; Section PP, Row 16, Yellow seating	Corrosion mitigation included in scope of H&S4
CS4	10 Selected Rows, Orange seating	Corrosion mitigation anticipated to be included in scope of H&S5
CS3	Orange Aisles with Step Boxes (All Sideline Stands)	Corrosion mitigation included in scope of H&S4
CS3	Balance of Orange sideline seating	These areas contain lapped joints, and ineffective drainage, which are accelerators of corrosion
CS3	Yellow Seating, Northeast Sideline Stands only	These areas contain lapped joints, and ineffective drainage, which are accelerators of corrosion
CS2	Brown Seats	These areas contain lapped joints, and questionable drainage, However the seating plates are in relatively less deteriorated condition that other seating areas, with respect to corrosion.
CS2	Red Seats, Northeast Sideline Stands and seating sections U, V, UU & VV in the North Endzone Stands	These areas contain lapped joints, and questionable drainage, However the seating plates are in relatively less deteriorated condition than other seating areas, with respect to corrosion.
CS2	Balance of seating bowl	During prior repair campaigns, lapped joints were fully welded and nominally horizontal portions of the seat plates were re-sloped for improved drainage.

Ancillary Entry Gate Overhead Structures

Limited visual assessments of the overhead structures at vehicular and pedestrian entry gates, which may be commonly described as roof canopies, have not been included in any recent assessment for corrosion at the Aloha Stadium. Given the limited size of the typical overhead structure at an entry gate of either type, a condition state was holistically assigned to an entire overhead structure, as opposed to assigning a series of condition states to individual structural members within an overhead structure. Our assessment included two vehicular entry gate overhead structures and six pedestrian entry gate overhead structures. The structural steel framing members for the vehicular entry gate overhead structures were categorized as CS2, except that the sheet metal cladding and roofing panels were classified as CS3. The six pedestrian entry gate overhead structures were categorized as CS4. The corrosion damage at pedestrian entry Gate 1 was found to be so severe that it is recommended to immediately repair or immediately dismantle the structure at this particular entry gate. Further details regarding our assessment of both types of entry gate overhead structures are given in two separate memos included in Appendix B of this report.

Rate of Corrosion

The rate of corrosion of weathering steel exposed to a high-chloride environment such as Hawaii can be approximated as an exponential relationship that increases with time. However, the rate of corrosion is also dependent on factors that are not readily quantifiable for the conditions encountered at Aloha Stadium. Therefore, it is not feasible to forecast the rate at which structural weathering steel members with deteriorating original coatings applied in the 1980s and 1990s will corrode at the Aloha Stadium.

Nonetheless, the findings from our 2018 survey when compared to those of the 2016 survey, provide meaningful, quantitative information regarding the actual progression of corrosion at the Aloha Stadium.

The locations where structural steel members have been categorized as CS3 and CS4 are graphically summarized in Figure 25 for the 2016 survey, and in Figure 26 for the 2018 survey; these figures also include locations where metal decking panels and seating plate rows are categorized as either CS3 or CS4, but do not include locations where fiberglass angles were identified as potential falling hazards.

The findings of the 2018 survey indicate that approximately 200 weathering steel members are presently categorized as either CS3 or CS4, which means that these members exhibit severe corrosion. In our 2016 survey, approximately 50 weathering steel members were categorized as either CS3 or CS4. Over the course of approximately two years, the cumulative number of steel framing members categorized as either CS3 or CS4 has *increased* by 300 percent. This is quantifiable evidence that the adverse effects of corrosion at the Aloha Stadium are increasing with time.

The findings of the 2018 survey indicate that approximately 85 panels of the lightweight floor slab decking are presently observed to exhibit severe corrosion (CS3 and CS4). Although lightweight decking was not surveyed in 2016, based on anecdotal reports from stadium staff, the number of maintenance-related concerns involving lightweight decking has generally increased with time in recent years. This is anecdotal evidence that the adverse effects of corrosion at the Aloha Stadium are increasing with time.

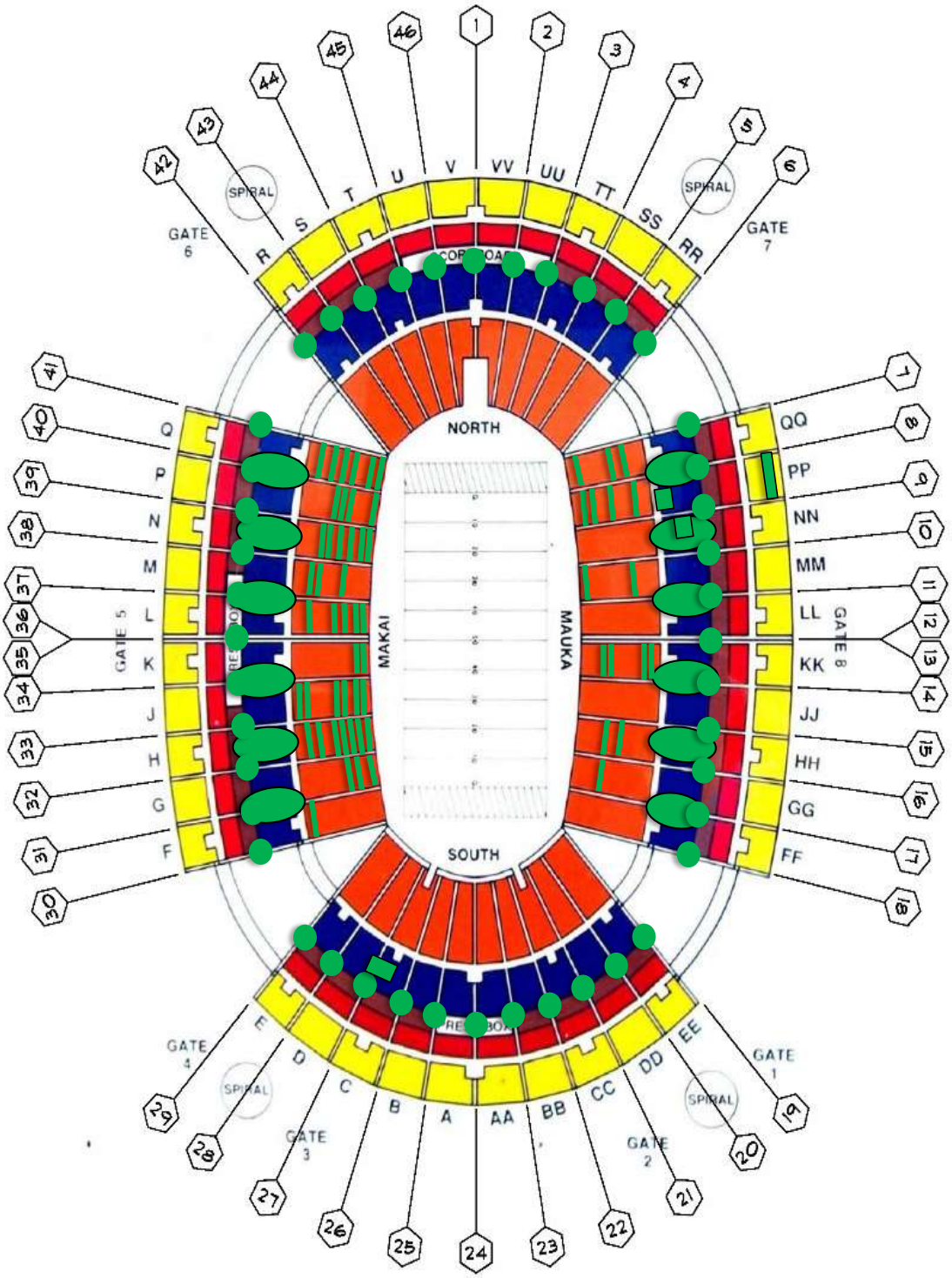


Figure 25. Graphical depiction of locations of recommended repairs: 2016 corrosion assessment

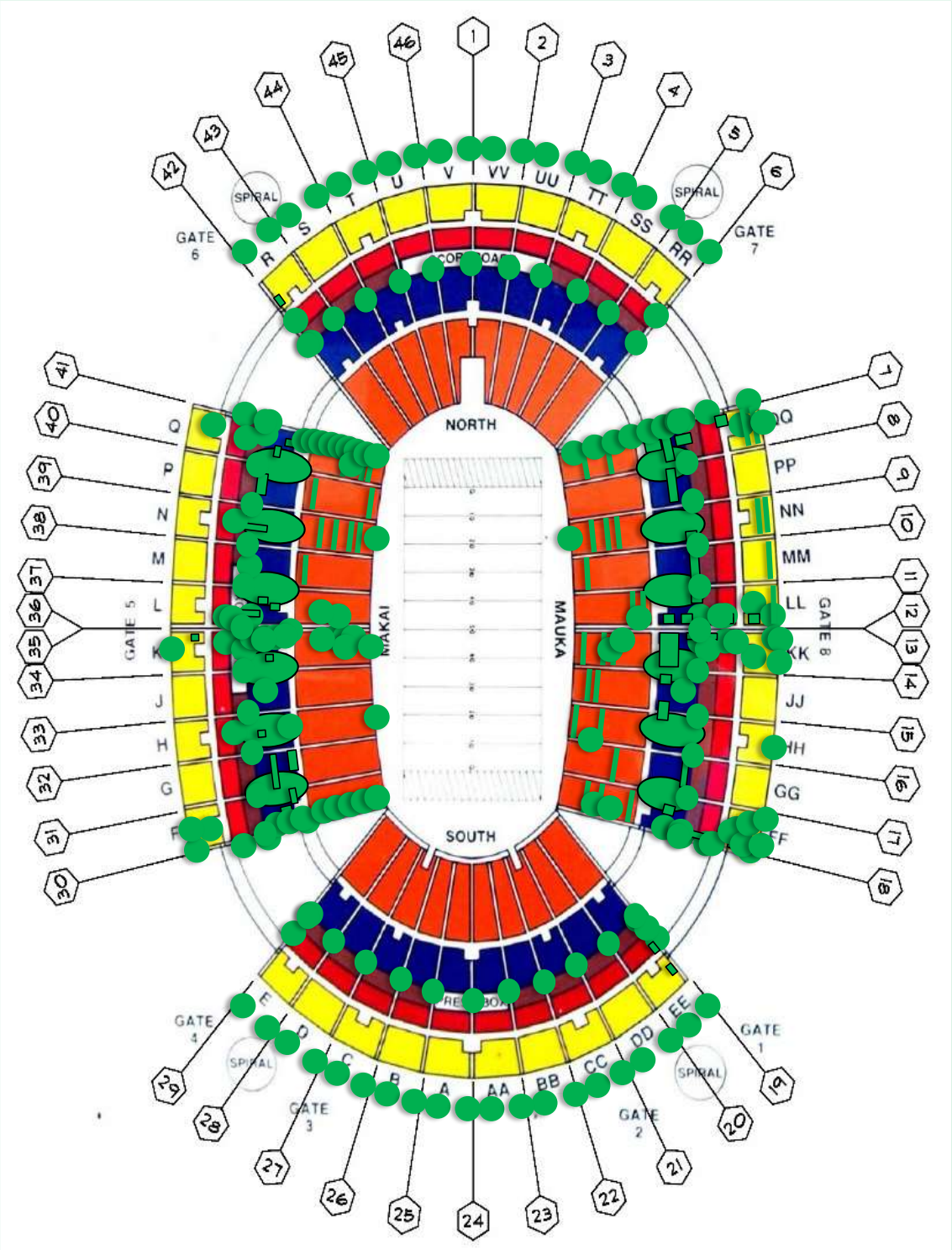


Figure 26. Graphical depiction of locations of recommended repairs: 2018 corrosion assessment

SUMMARY AND RECOMMENDATIONS

The results of the corrosion assessment lead to the following recommendations.

Expected Levels of Work

Based on the observed condition state, expected levels of work to address identified concerns are as follows:

- Condition State 1 (CS1) – Remediation of concerns with steel members classified as CS1 involves an application of maintenance overcoats onto the topcoats of the corrosion mitigation coatings within the window of maintenance overcoating feasibility, estimated to be 10-15 years from the application of the corrosion mitigation coatings that are in place. The undersides of the lightweight decking system panels that are classified as CS1 should be recoated with corrosion mitigation coatings and the pedestrian traffic coatings on the concrete walking surface should be replaced, along with repairs to the concrete substrate; however, in lieu of maintenance-type repairs, it may be more cost-effective over the long term to replace the lightweight decking system with a thicker, conventional composite metal decking system.
- Condition State 2 (CS2) – Remediation of concerns with steel members classified as CS2 involves entire removal of existing protective coating systems and installation of new corrosion mitigation protective coating systems. Areas of lightweight decking system classified as CS2 should be replaced with a thicker, conventional composite metal decking system.
- Condition State 3 (CS3) – Remediation of concerns with steel members classified as CS3 involves complete removal of existing protective coating systems and installation of new corrosion mitigation protective coating systems. High priority CS3 steel members have active corrosion concerns that should be considered for mitigation in the near-term, but not necessarily needing intervention in the next 24 months. Similarly, high-priority areas of metal decking classified as CS3 should be replaced with a thicker, conventional composite metal decking system in the near-term, but not necessarily needing intervention in the next 24 months.
- Condition State 4 (CS4) – Remediation of concerns with steel members classified as CS4 requires structural modifications to strengthen affected components of the member or to eliminate construction details that inadvertently result in accelerated corrosion. CS4 steel members identified as "Immediate" priority have concerns over structural performance that should be addressed immediately; and CS4 steel members identified as "24 month" priority have concerns over structural performance that should be addressed within 24 months. High-priority areas of metal decking classified as CS4 should be replaced with a thicker, conventional composite metal decking system within the next 24 months.

Identified Concerns Requiring Repair

We recommend that the concerns identified as CS3 and CS4 in Table 1 of the Executive Summary section of this report be repaired. Concerns identified in Table 2 of the Executive Summary section that are anticipated for completion within H&S5 or are still pending continue to be recommended for repair. Both tables also list priority for repairs. Please refer to group summaries in Appendix A for additional details regarding the specific concerns listed in the tables.

Structural members and connections that have been rated CS4 are recommended to be structurally repaired within the next 24 months relative to the inspection date of August 2018, as summarized in Table 1 and Table 2. The members and connections identified as CS3 should be given priority for repair after completion of the CS4 repairs. Depending upon the extent of cumulative corrosion damage, there is the possibility that the corrosion damage may have reduced the load capacity of a structural member or its

structural connections. Repair designs for CS4 and CS3 members should evaluate corrosion losses in detail, and should include structural strengthening if the member is overstressed.

Members identified as CS2 are not considered structurally problematic at present time. However, it is financially prudent to perform maintenance on these members with available funding before the corrosion progresses to a CS3, which may involve more extensive repairs or reconstruction in addition to installation of corrosion mitigation protective coating systems.

Supplemental Corrosion Assessments in the Near-Term

A number of locations where members have been identified as CS4 during the 2018 survey warrant detailed, up-close physical inspection to provide for an appropriate final assessment and determination of repairs. In addition to up-close visual observations, measurement of section loss may also be warranted for weathering steel structural members. Recommended supplemental assessments are as follows:

- Systematic, up-close examination for and measurement of corrosion losses of the endzone diagonal braces at the concrete barriers (Group 02 members in Appendix A), for all remaining endzone braces not assessed in the present study. Exploratory investigation into the concrete of at least one barrier at south endzone is also recommended. It would however be preferable to investigate into the concrete of more than one barrier, and to also include concrete barriers in the north endzone.
- Up-close investigation and corrosion loss measurements of the skewed connections in between the horizontal truss at field level and the bottom chords of the radial truss end frames at Grid Line F.9 (Group 04 members in Appendix A).
- Detailed investigation of the lightweight floor decking panels at bathroom plumbing penetrations and chases (a selected portion of Group 06 members in Appendix A).
- Detailed investigation of the decking at end raker frames where curved pedestrian passage bridges connect to lower and upper concourses (a selected portion of Group 08 members in Appendix A).

It is recommended that these additional assessments be completed within 12 months, relative to our inspection date of August 2018, with the exception of the recommended assessment regarding Group 01 and Group 02 members, for which the additional investigations are recommended to commence immediately.

Recurring Structural Inspections

The unpredictability of future corrosion-related structural damage leads to the recommendation that recurring structural inspections take place so that active corrosion can be identified before the extent of corrosion-related damage reduces calculated structural capacity of a member or a connection to a level below structural acceptability. Furthermore, given the undetermined timeline related to possible construction of a new stadium, and thus also an undetermined timeframe for keeping the Aloha Stadium in service to the public, it is also appropriate to identify future necessary structural safety improvements by a program that includes recurring structural inspections.

Given the 300 percent increase over the past two years in the number of members classified as severely corroded (members classified as either CS3 or CS4), a one-year interval between inspections is recommended. This is one-half of the usual interval between inspections for highway bridges (23 CFR 650.311); this reduction is warranted due to the use of weathering steel for primary structural framing members and by the 300 percent increase in the number of severely corroded members observed in 2018 as compared to 2016. Therefore, the next recurring inspection of the Aloha Stadium is recommended to be

completed no later than August 2019, unless conditions come to light that warrant a shorter interval between inspections.

Ageing of Renewed Protective Coating Systems

As summarized earlier in this report, the State of Hawaii began a phased program for renewal of the circa 1980s and 1990s protective coatings system. Renewal protective coatings have been installed over a series of construction projects, commencing with construction projects that were completed in 2009, and continuing to the present, because significant portions of the stadium have yet to receive renewed protective coatings.

Commonly-accepted practice within the coatings industry includes periodic visual assessment of protective coatings systems, prior to the end of their anticipated service life. Based on the anticipated service life of the fluoropolymer top coat material of the renewal coating system, which is 15 years, it is recommended that periodic visual assessments of the renewal coating system commence at 10 years of in-service life of the renewal coating system. It is recommended that the visual inspections commence prior to achievement of the anticipated service life of the topcoat so that coating system performance concerns can be detected in advance of the lapsing of the warranties for the coating system work.

At the time that the recommended 2019 inspections are anticipated to be performed, renewal protective coating systems that were installed under construction contracts where work was completed in 2009 through 2011 will have been in service for an average of 10 years. It is therefore recommended that weathering steel members which received renewed protective coatings under the following construction contracts be included in the 2019 inspections:

- Phase 1 ["Aloha Stadium, Replace Metal Roof Deck And Transformers (Sections FF to KK and RR to VV) DAGS Job No: 12-10-0518] - Completed 2009
- Phase 2 ["Aloha Stadium, Replace Metal Roof Deck And Transformers (Sections LL TO QQ, R & S, & L TO Q) DAGS Job No: 12-10-0598] - Completed 2010
- Phase 3 ["Aloha Stadium, Replace Metal Roof Deck And Transformers (Sections AA TO EE, & A TO K) DAGS Job No 12-10-0620] - Completed 2011

Continued Operations

Due to their criticality to continued structurally-safe operations of the existing stadium, particular members classified as CS4 are identified to be repaired immediately. If these repairs cannot commence immediately, the members identified for immediate repair should be monitored for on-going deterioration during the delay period; the delay period should not exceed 1 year. The intent of the monitoring would be to generally assess that the stadium can be occupied for continued operations during the delay period. The nature of the monitoring program, and the frequency of monitoring, remain to be developed.

Presuming that repairs to the members classified herein as CS4 are completed within two years from the date of our most recent inspections (August 2018), the stadium can be occupied for continued operations.

Projections of suitability for continued service cannot be reliably made beyond a one-year interval due to rates of corrosion that cannot be determined, as evidenced by the 300 percent increase over the past two years in the number of members classified as severely corroded. Suitability for continued operations beyond August 2019 will be determined on the basis of the next recurring inspection, which is recommended to be completed not later than August 2019.

It can be anticipated that previously-unidentified repair design and construction projects may arise from the findings of future annual recurring inspections; therefore, contingency budgets for necessary structural maintenance at the Aloha Stadium should be established, even in the event that a firm decision is made by the State to replace the Aloha Stadium with a new stadium. Structural maintenance remains necessary even after such a decision has been made so that the Aloha Stadium remains structurally safe while it is open to the public during the multi-year period that a new stadium is funded, designed and constructed.

APPENDIXES

A. Summaries of Members Rated Condition States 3 and 4
B. WJE Assessment Memos (distributed electronically in report Volume 2)
    - Memo Regarding Pedestrian Entry Gates
    - Memo Regarding Vehicular Entry Gates
    - Memo Regarding Cantilever Raker Assemblies
    - Memo Regarding Endzone Diagonal Braces
C. Orientation Plan and Elevation Drawings Noting Locations of Members Rated Condition States 3 and 4 (distributed electronically in report Volume 2)
D. Tabulation of Corrosion Survey Data (distributed electronically in report Volume 2)

APPENDIX A
SUMMARIES OF MEMBERS CLASSIFIED AS CONDITION STATE 3 OR 4

Group 01 - Raker Cantilever Assemblies on End Frames: Flange Corrosion

CS4 Piece Count: 7

Member(s): A015, B024, B149, D012, D015, E152, F024

CS3 Piece Count: 18

Member(s): A009, A232, A238, B021, B152, C021, C024, C149, C152, D009, D232, D238, E021, E024, = E149, F021, F149, F152

Stand Module(s): All

Nearest Plan Grid Intersection(s): 6,7,12,13,18,19,29,30,35,36,41,42 & E.6

Nearest Seating Section(s): E,F,K,L,Q,R,RR,QQ,LL,KK,FF

Approximate Vertical Position(s): Loge and Red Seats

Apparent Corrosion Accelerator:

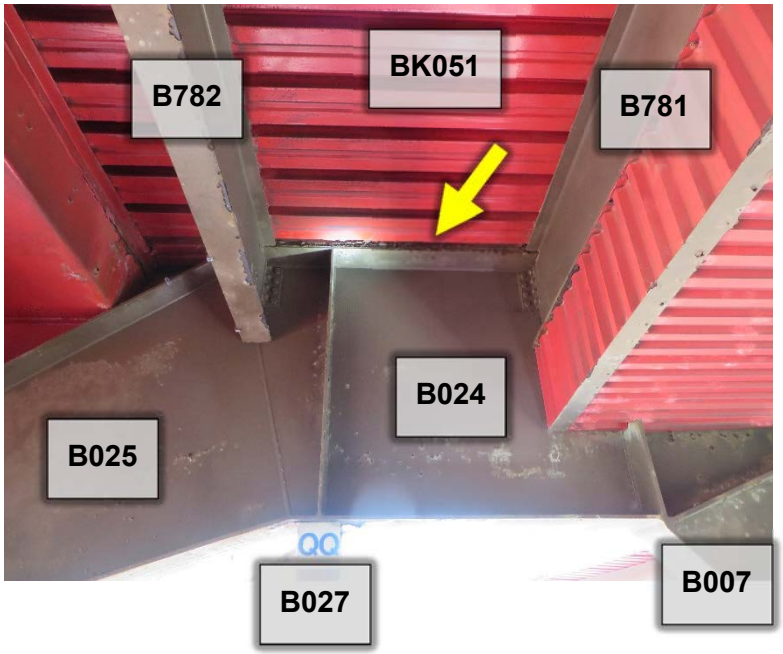
Poor detailing at the edges of the cross aisle decks supported by the cantilever raker assemblies has allowed water to become entrapped on the top surface of the top flanges of the assemblies' beam members, leading to corrosion. At one grid line, corrosion likely due to standing rainwater has been observed at the base of the tension tie ("column") that is used to suspend the Loge seating level from the Red seating level above.

Other Notes:

Corrosion in the tension region of the top flanges of the raker beams in these cantilever assemblies is of particular concern. The significance of this specific condition has been evaluated by field measurement and an analytical evaluation. Findings are be presented in more detail in a memo provided in Appendix B.

Reference, Appendix C Page No(s):
3, 13, 23, 28, 40, 45, 57, 67, 77, 82, 94, 99

Representative Photo(s):



Group 02 - Endzone Exterior Diagonal Braces on Line F.9: Corrosion at Connections to Concrete Substructure at Concrete Barrier

Reference, Appendix C Page No(s):
19, 20, 73, 74

CS4 Piece Count:	4
Member(s):	A305, D291, D292, D293
CS3 Piece Count:	36
Member(s):	A289, A290, A291, A292, A293, A294, A295, A296, A297, A298, A299, A300, A301, A302, A303. A304, A306, A307, A308, D289, D290, D294, D295, D296, D297, D298, D299, D300, D301, D302, D303, D304, D305, D306, D307, D308
Stand Module(s):	North and South Endzones
Nearest Plan Grid Intersection(s):	1-6, 19-29 and 42-46 at F.9
Nearest Seating Section(s):	A-E, AA-EE, R-V, RR-VV
Approximate Vertical Position(s):	Lower (Main) Concourse

Apparent Corrosion Accelerator:

A non-draining pocket where the diagonal brace connects to a cross-tie member and also penetrates into the concrete barrier has retained debris, likely resulting in promotion of corrosion due to prolonged wetness.

Other Notes:

Corrosion has progressed in diagonal brace member webs and flanges to a perforated condition, resulting in loss of load-bearing capacity.

The significance of this specific condition has been evaluated by field measurement and an analytical evaluation. Findings are presented in more detail in a memo provided in Appendix B. It is also recommended that all remaining, similar locations be inspected in greater detail for similar conditions, and further repairs implemented as necessary.

Representative Photo(s):

Group 03 - Plate Girders on Line F at Top of Blue Seating Section: Corrosion and Cracked Welds at Connections to Raker Frames

Reference, Appendix C Page No(s):
3-13, 23-28, 40-45, 57-67, 77-82, 94-99

CS4 Piece Count: 30

Member(s): A029, A183, A205, A227, B033, B058, B083, B108, B133, C005, C033, C058, C083, C108, C133, D029, D051, D183, D205, D227, E005, E033, E058, E083, E108, E133, F005, F033, F108, F133

CS3 Piece Count: 11

Member(s): A004, A051, A073, A117, A161, D004, D073, D095, D161,F058, F083

Stand Module(s): all

Nearest Plan Grid Intersection(s): various

Nearest Seating Section(s): various

Approximate Vertical Position(s): Blue Seating Level

Representative Photo(s):

Apparent Corrosion Accelerator:

A crevice at a faying surface within a connection entraps water, resulting in corrosion. The expansive corrosion has caused weld fractures at the connections at many locations.

Other Notes:

The structural design intent of the angle connection is unknown but these angles appear to stabilize the members involved. Therefore, these connections are recommended to be repaired. The locations of these connections sometimes coincide with locations previously identified for recommended voluntary structural upgrade. Designs to mitigate this condition should consider compatibility, or implementation of the previously identified strengthening concept.

Repair to all locations is anticipated to occur in the H&S5 project.

Group 04 - Lower Chord Horizontal Truss at Field Level: Corrosion at Connection of Acutely Skewed Horizontal Truss Diagonal Brace to Bottom Chord of Radial Truss at End Frames

Reference, Appendix C Page No(s):
29, 46, 83, 100,

CS4 Piece Count: 6
Member(s): B225, B234, C225, C250, E225, E250
CS3 Piece Count: 4
Member(s): B250, B290, C234, F234

Stand Module(s): All Sidelines
Nearest Plan Grid Intersection(s): 7, 12, 13, 18, 30, 36, 36, 41 & G
Nearest Seating Section(s): F, K, L, Q, QQ, LL, KK, FF
Approximate Vertical Position(s): Field Level

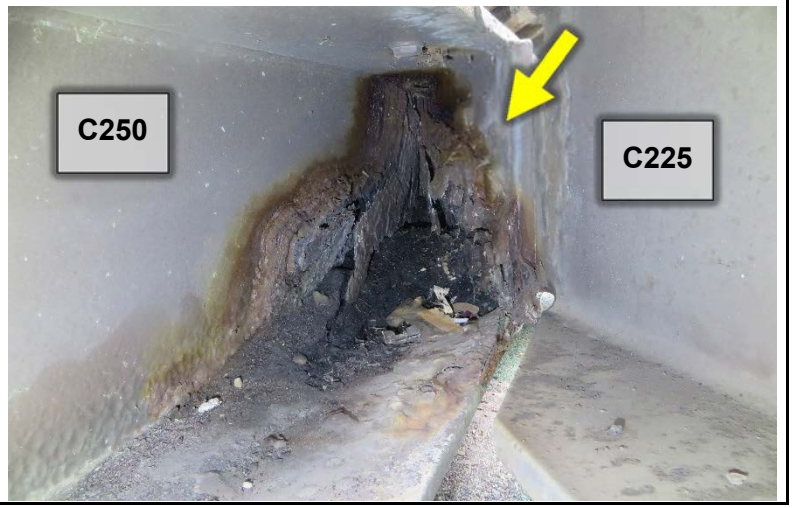
Apparent Corrosion Accelerator:

Non-draining pocket condition at the connection has retained debris, likely resulting in accelerated corrosion due to prolonged wetness.

Other Notes:

Corrosion has affected radial truss bottom chord member webs to a nearly-perforated condition; additionally, some bolt heads in the connection have been essentially rendered ineffective by the corrosion.

Representative Photo(s):



Group 05 - Fiberglass Angles: Overhead Falling Hazard and Corrosion at Attachment to Raker Frame Members Above Concourses

Reference, Appendix C Page No(s):
28, 40, 41, 42, 43, 44, 45

CS4 Piece Count:	0
CS3 Piece Count:	Many
Member(s):	B138, C010, C038, C063, C088, C113, C138, plus others
Stand Module(s):	NESL, SESL
Nearest Plan Grid Intersection(s):	12, 13, 14, 15, 16, 17, 18 & F-G
Nearest Seating Section(s):	Various
Approximate Vertical Position(s):	Yellow Seating

Representative Photo(s):

Apparent Corrosion Accelerator:

Fiberglass angles affixed to the steel beam created a water retaining crevice, which leads to localized corrosion of raker member flanges.

Other Notes:

The fiberglass angles have previously been identified as presenting a falling object hazard. Refer to Appendix D of the October 26, 2016 corrosion assessment report for assessment and recommendations related to the fiberglass angles.

The angles have been removed from throughout the NESL upper concourse, while other angles at locations with relatively advanced corrosion have also been removed at scattered locations elsewhere in the stadium. The falling hazard at locations where the fiberglass angles remain in place are anticipated to be mitigated in H&S5.

Group 06 - Lightweight, Thin-System Floor Decking: Corrosion of Metal Deck

Reference, Appendix C Page No(s):
16a, 30, 33, 47, 50, 70a, 84, 87, 101

CS4 Piece Count: 44

Member(s): BK021, BK120, BK121, BK122, BK123, BK410, BK411, CK010, CK011, CK012, CK321, CK322, CK412, CK433, DK060, DK071, DK077, EK000, EK002, EK003, EK005, EK011, EK012, EK030, EK120, EK121, EK122, EK123, EK220, EK221, EK403, EK411, EK423, EK424, EK464, FK011, FK012, FK321, FK322, FK410, FK411, FK412, FK423, FK424

CS3 Piece Count: 42

Member(s): AK051, AK060, BK011, BK020, BK021, BK022, BK023, BK024, BK051, BK060, BK223, BK224, BK321, BK322, BK323, BK421, BK423, BK424, BK450, BK473, CK000, CK001, CK002, CK003, CK004, CK005, CK030, CK100, CK101, CK103, CK200, CK410, CK451, CK473, EK020, EK021 EK102, EK103, EK420, EK421, FK021, FK221,

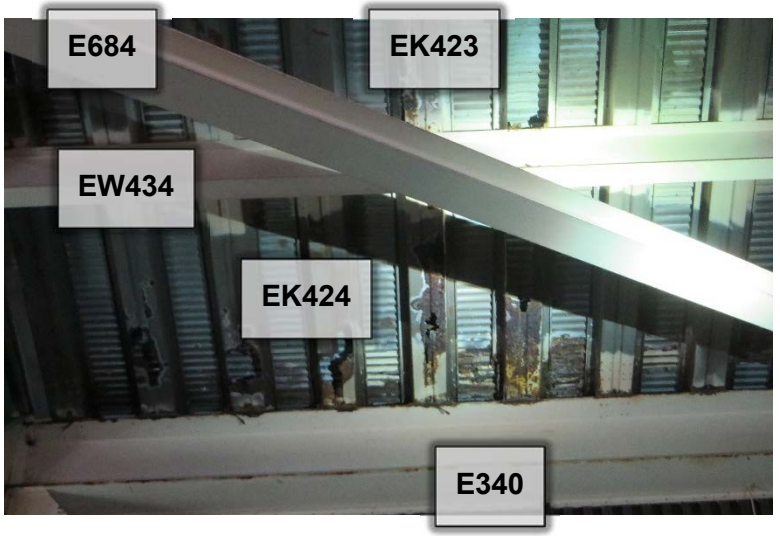
Stand Module(s): All

Nearest Plan Grid Intersection(s): many

Nearest Seating Section(s): many

Approximate Vertical Position(s): concourses

Representative Photo(s):



Apparent Corrosion Accelerator:

Factors that promote corrosion of the lightweight, thin-system floor decking include: crevices at edge and other support detailing, poor water management, deck traffic coatings in use beyond their effective waterproof service life, poor integration of overlying partition walls, and accumulation of debris within the system components.

Other Notes:

The lightweight, thin decking system is prone to corrosion. Patching and localized repairs are regular maintenance tasks for the stadium management. Prior projects have comprehensively replaced the thin decking systems in-kind throughout almost the entire stadium. More recent projects have included replacement of the decking with a more robust, composite concrete-and-metal deck system at the main concourse level in the northeast and northwest sidelines. H&S4 has temporarily stabilized corroded decking systems beneath the electrical rooms at the lower concourse level, and temporary stabilization is anticipated to be installed at some vomitory ramps under H&S5; however the decking at the electrical rooms and vomitory ramps should be completely replaced in a future construction project.

Group 07 - Orange Cross Aisle End Frame Beams: Corrosion at Beam Top Flange Supporting Deck Edges

CS4 Piece Count: 2
Member(s): EW242, EW404
CS3 Piece Count: 1
Member(s): EW001
Stand Module(s): SWSL
Nearest Plan Grid Intersection(s): 30, 35 & D.7 - D.9
Nearest Seating Section(s): F, K
Approximate Vertical Position(s): Lower concourse

Apparent Corrosion Accelerator:

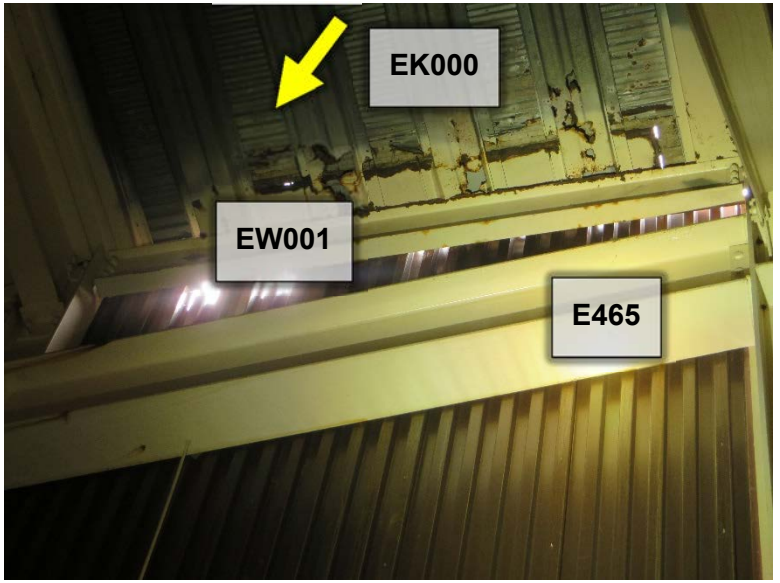
Poor detailing at the edges of the decks has allowed water to become entrapped on the top surface of the top flanges of the weathering steel members that support the decking where the Orange level cross aisle terminates at the raker frame end bay.

Other Notes:

Top flanges of beams supporting the deck assembly are primarily affected, deck replacement projects in the Northeast and Northwest sidelines lower concourses have developed details to mitigate these issues. Repairs for remaining identified locations are anticipated to occur in H&S5.

Reference, Appendix C Page No(s):
77, 82

Representative Photo(s):



Group 08 - Lower Concourse End Frame Beams: Corrosion at Beam Top Flange Supporting Deck Edges

CS4 Piece Count: 4
Member(s): FW042, FW241, FW242, FW442
CS3 Piece Count: 11
Member(s): B341, C301, C304, CW042, CW242, E299, E340, E343, E374, EW042, EW242
Stand Module(s): NESL, NWSL, SWSL
Nearest Plan Grid Intersection(s): Various
Nearest Seating Section(s): Various
Approximate Vertical Position(s): Lower Concourse

Apparent Corrosion Accelerator:

Poor detailing at the edges of the decks has allowed water to become entrapped on the top surface of the top flanges of these members, thereby promoting corrosion.

Other Notes:

Reference, Appendix C Page No(s):
30, 47, 84, 101

Representative Photo(s):

Group 09 - Seat Plate Tread-and-Riser Rows: Corrosion at Seat Plates

CS4 Piece Count: 0

CS3 Piece Count: 35 (Based on seat plate repairs shown on H&S5 drawings)

Member(s): BF011, BF020, BF209, BF212, BF215, BF306, BF426, BF427, BY010, BY012, BY215, BY216, BY315, BY416, CF003, CF010, CF013, CF107, CF108, CF201, CF211, CF317, CF409, CF413, CF427, FF124, FF207, FF208, FF304, FF211, FF215, FF327, FF406, FF407, FF415

Stand Module(s): All Sidelines

Nearest Plan Grid Intersection(s): Various

Nearest Seating Section(s): Various

Approximate Vertical Position(s): Orange Seating, NESL Yellow Seats

Apparent Corrosion Accelerator:

Lapped seams and lack of slope in the steel seating plate tread-and-riser system retain water.

Other Notes:

Holes through the seating plates caused by corrosion results in both safety concerns and also leakage through seating plates that is accelerating corrosion in base truss members at certain locations below the Orange seating section. H&S4 has repaired some of the most severely corroded locations. H&S5 is anticipated to repair additional severely corroded locations in the NWSL. However numerous additional seat plate locations throughout the entire stadium will nonetheless require repair in future H&S projects.

Reference, Appendix C Page No(s):
Refer to H&S5 Construction Drawings

Representative Photo(s):

Group 10 - Escalator Framing: Corrosion of Girders at Lower Concourse and of Beams at Field Level Landing

CS4 Piece Count:	2
Member(s):	CW112, EW312
CS3 Piece Count:	2
Member(s):	CM018, EM018
Stand Module(s):	SWSL, SESL
Nearest Plan Grid Intersection(s):	13-14, 34-35 & F-G
Nearest Seating Section(s):	K, KK
Approximate Vertical Position(s):	Field Level

Apparent Corrosion Accelerator:

A poorly detailed interface between the steel plate deck at the escalator landing at field level in the sideline seating stands and the framing beam that supports the steel plate deck creates a crevice that entraps water, thereby promoting corrosion. At the lower (main) concourse level, water draining from the surface of the concourse slab enters into the escalator opening, causing corrosion of the girder members that frame the openings.

Other Notes:

Repairs conducted in H&S3 addressed similar detailing in contiguous areas of the field-level escalator landings. Repairs to these additional noted corroded conditions were included in an alternate design for H&S5, which is not anticipated to be awarded. Similarly for the girder at the lower concourse level, repairs to the girders at the concourse level were to be repaired in H&S5, but that portion of the work is no longer anticipated to be included in the scope of construction to be awarded.

Reference, Appendix C Page No(s):
46, 83

Representative Photo(s):

Group 11 - Radial Truss Framing Members: Corrosion at End Frame Radial Trusses

Reference, Appendix C Page No(s):
23, 28, 40, 45, 77, 82, 94, 99

CS4 Piece Count: 1
Member(s): C543
CS3 Piece Count: 45
Member(s): B001, B253, B255, B256, B257, B464, B465, B515, C251, C290, C291, C293, C296, C449, C465, C514, C518, C685, E254, E255, E256, E257, E290, E291, E292, E294, E464, E465, E468, E515, E516, E544, E690, F129, F171, F290, F294, F295, F296, F297, F343, F465, F514, F515, F516
Stand Module(s): All Sidelines
Nearest Plan Grid Intersection(s): 7, 12, 13, 18, 30, 35, 36, 41 & A - G
Nearest Seating Section(s): QQ, LL, KK, FF, F, K, L, Q
Approximate Vertical Position(s): Field level

Representative Photo(s):

Apparent Corrosion Accelerator:

At numerous locations within the end bay radial trusses of the sideline seating stands, poor detailing at primary and secondary connections and at wall panel supports create crevices, which entrap water and trash. These undesirable features have promoted corrosion.

Other Notes:

Mitigation of corrosion should be prioritized for the end frame radial trusses to prevent continuing progress of the corrosion to CS4. Strengthening of members and connection details to current wind loading requirements should be considered as part of any corrosion mitigation effort.

Group 12 - Upper and Lower Concourse Levels, Outer Perimeter Edge Beams: Corrosion at Beams

CS4 Piece Count:	1
Member(s):	C444
CS3 Piece Count:	7
Member(s):	B717, C435, C436, C440, C734, E435, E443
Stand Module(s):	NESL, SESL, SWSL
Nearest Plan Grid Intersection(s):	Various radial grid lines & Grid F.8
Nearest Seating Section(s):	Various
Approximate Vertical Position(s):	Lower and upper concourses

Apparent Corrosion Accelerator:

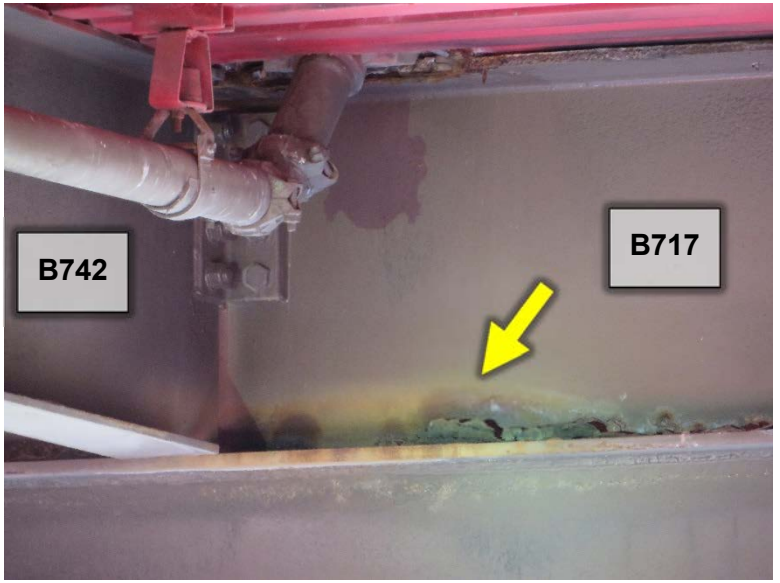
Poor detailing at the edges of the decks has allowed water to become entrapped on the top surface of the top flanges of these members, resulting in corrosion. Drainage at the scuppers that service the gutter along the outside edge of the concourses apparently leak and result in persistent wetness on the top flanges of the edge framing members.

Other Notes:

Top flanges that support the concourse decking assembly are primarily affected. Deck replacement projects in the Northeast and Northwest sidelines lower concourses have developed details to mitigate these issues.

Reference, Appendix C Page No(s):
33, 47, 50, 84

Representative Photo(s):



Group 13 - Red Seats Field-Fronting Beam: Flange Corrosion at Seat Plate Edges

CS4 Piece Count: 0
CS3 Piece Count: 4
Member(s): E789, F709, F789, F795
Stand Module(s): SWSL
Nearest Plan Grid Intersection(s): 32-33, 38-39, 40-41 & E.5
Nearest Seating Section(s): H, N, Q
Approximate Vertical Position(s): Red Seating Level

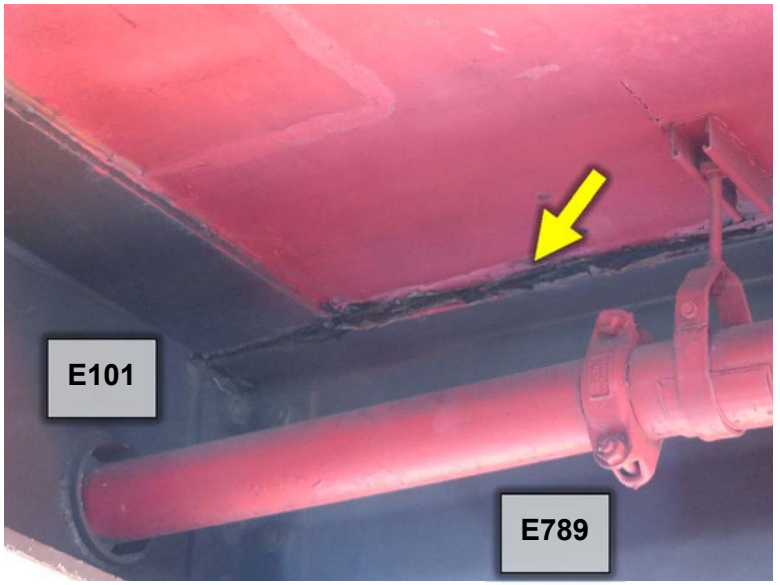
Apparent Corrosion Accelerator:

A poorly detailed interface between the steel plate deck and supporting beam creates a crevice that entraps water, leading to corrosion.

Other Notes:

Reference, Appendix C Page No(s):
87, 104

Representative Photo(s):



Group 14 - Field-Fronting Framing Members along Grid Line A: Corrosion at Seat Plate Opening for Utilities

CS4 Piece Count: 0
CS3 Piece Count: 4
Member(s): B159, E159, E161, F159
Stand Module(s): NESL, SWSL, NWSL
Nearest Plan Grid Intersection(s): 9-10, 32-33, 34-35, 38-39 & A
Nearest Seating Section(s): NN, H, K, N
Approximate Vertical Position(s): Field Level

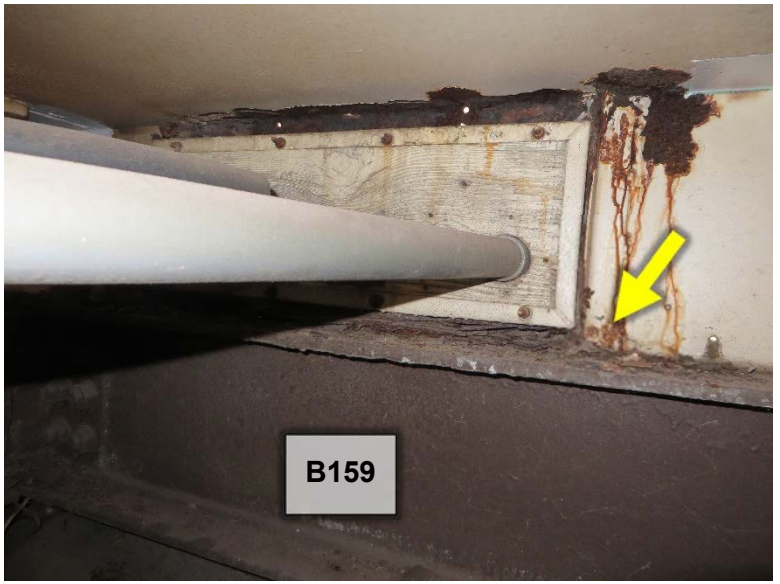
Apparent Corrosion Accelerator:

Poor detailing exists at penetrations that allow utilities to pass from interior to exterior, allowing water ingress and entrapment at crevices created by the penetrations; this has promoted corrosion of the framing members along Grid Line A of the sideline stands.

Other Notes:

Reference, Appendix C Page No(s):
29, 83, 100

Representative Photo(s):



Group 15 - Sideline Stands Siding Girt Connections at End Frame Walls: Missing Bolts at Connections

CS4 Piece Count: 0
CS3 Piece Count: 3
Member(s): ES421, ES441, FS011
Stand Module(s): NWSL, SWSL
Nearest Plan Grid Intersection(s): D.5-E, E.5-F & 35; C.7-D.5 & 36
Nearest Seating Section(s): K, L
Approximate Vertical Position(s): Field Level

Apparent Corrosion Accelerator:

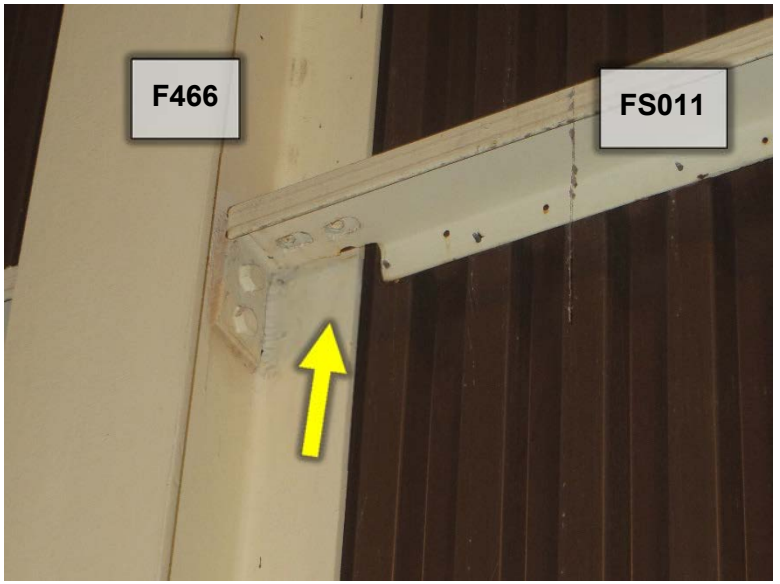
Siding girts with questionable connection detailing have been flagged for assessment of structural capacity.

Other Notes:

Historically, the orientation of the siding girts on the sideline seating stands base truss cladding were inverted to a flanges-down configuration to avoid debris entrapment. The noted connections may have been inappropriately modified during that process.

Reference, Appendix C Page No(s):
82, 94

Representative Photo(s):



Group 16 - Press Box Floor Framing Member Connection: Corrosion at Connection

CS4 Piece Count: 0
CS3 Piece Count: 1
Member(s): F006
Stand Module(s): NESL
Nearest Plan Grid Intersection(s): 11, F
Nearest Seating Section(s): H
Approximate Vertical Position(s): Loge Seating Level

Apparent Corrosion Accelerator:

A poorly detailed connection of a steel tube floor beam to the web of a raker frame column is corroding.

Other Notes:

The steel tube floor beam provides support to the floor decking of the football press box. However, a football press box is not shown on the original architectural or structural drawings, indicating that these floor framing members, their connections, and the decking that they support are additions to the stadium, not original construction.

Reference, Appendix C Page No(s):
94

Representative Photo(s):

Group 17 - Radial Trusses Supporting Orange Seats: Isolated corrosion at connections

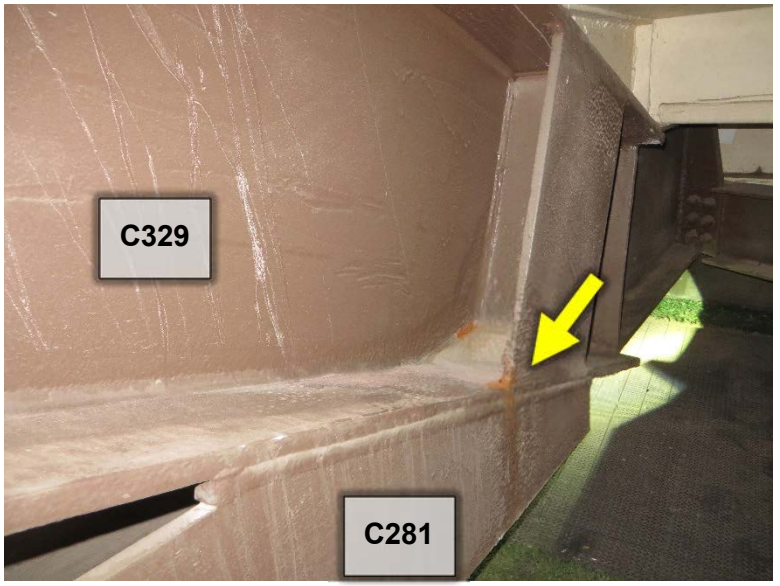
CS4 Piece Count: 0
CS3 Piece Count: 1
Member(s): C329
Stand Module(s): SWSL, SESL
Nearest Plan Grid Intersection(s): 16 & A, 33 & C.1
Nearest Seating Section(s): HH & GG, J & H
Approximate Vertical Position(s): Field Level

Apparent Corrosion Accelerator:
Poor drainage at connections promotes corrosion.

Other Notes:
Drainage Improvements for E280 are anticipated in H&S5.

Reference, Appendix C Page No(s):
43

Representative Photo(s):



Group 18 - Raker Frame at Box Seats Level: Corrosion at Raker Plate Welded Connections

CS4 Piece Count: 0
CS3 Piece Count: 1
Member(s): B135
Stand Module(s): NESL
Nearest Plan Grid Intersection(s): 12 & E.7
Nearest Seating Section(s): LL
Approximate Vertical Position(s): Loge Seating Level

Apparent Corrosion Accelerator:
A water-retaining pocket is promoting corrosion.

Other Notes:

Reference, Appendix C Page No(s):
28

Representative Photo(s):

WJE ENGINEERS ARCHITECTS MATERIALS SCIENTISTS

APPENDIX B

WJE ASSESSMENT MEMOS

NOTE: This appendix is distributed electronically in report Volume 2.

APPENDIX C

ORIENTATION PLAN AND ELEVATION DRAWINGS NOTING LOCATIONS OF MEMBERS CLASSIFIED AS CONDITION STATE 3 OR 4

NOTE: This appendix is distributed electronically in report Volume 2.

APPENDIX D

TABULATION OF CORROSION SURVEY DATA

NOTE: This appendix is distributed electronically in report Volume 2.