Appendix F –

Borescope Investigation of Pier E2 Rods Holes, SMR Reports (2011 and 2013)

PROJECT INFORMATION

04-0120F4
Self-Anchored Suspension Bridge

SUBJECT

Borescope Observation of Pier E2 Rod Holes – 2011

BACKGROUND

The purpose of this report is to document the 2011 borescope assistance provided by a Materials Engineering and Testing Service (METS) inspector to onsite Structure Construction personnel. This action was not in response to a formal inspection request. Construction inspectors were having difficulty determining if the contractor's efforts to remove water from the anchor rod ducts was successful and asked a METS inspector in the field to assist with the assessment. The borescope was used as a visual aid to view the bottom of the Pier E2 Shear Keys S1 and S2 anchor rod holes. As this was not a formal METS inspection, a report was not written at that time. The borescope information taken was provided to construction personnel for their evaluation and was also later provided to the Bay Area Toll Authority's consultant support group, Bay Area Management Consultants (BAMC), for their information.

A total of 288 ASTM A354 Gr. BD bearing and shear key anchor rods have been installed in Pier E2, per the contract requirements; 96 of these 3-inch hot-dip galvanized rods are shear key anchor rods that were embedded in concrete at Pier E2. The shear key anchor rods were fabricated in 2008 and assembled inside pipe sleeves in Shear Keys S1 and S2 after release to the jobsite. The locations of the shear keys (S1 and S2) are highlighted in **Figure 1**.

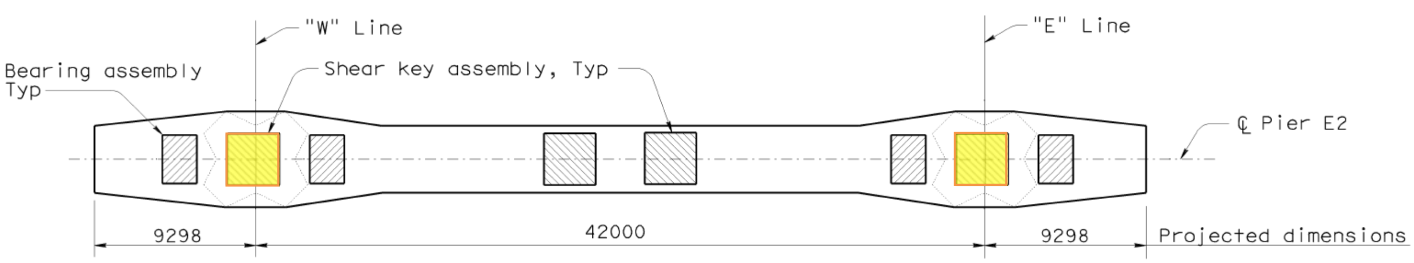

Figure 1: Locations of Shear Keys S1 (left) and S2 (right) on Pier E2

As shown in **Figure 2**, the details of the rods in S1 and S2 are different from the details for the bearing anchor rods. The embedment of the shear key E2 rods in concrete prevents access from below. Prior to installation of the shear keys, the rods had to be flush with the Pier E2 top surface; therefore, pipe sleeves were installed below the bearing plate to allow for the rods to be temporarily lowered **(Figures 3 and 4)**. The area inside the temporary pipe sleeve was to be grouted after the rods were raised to their final position during installation of the shear key.

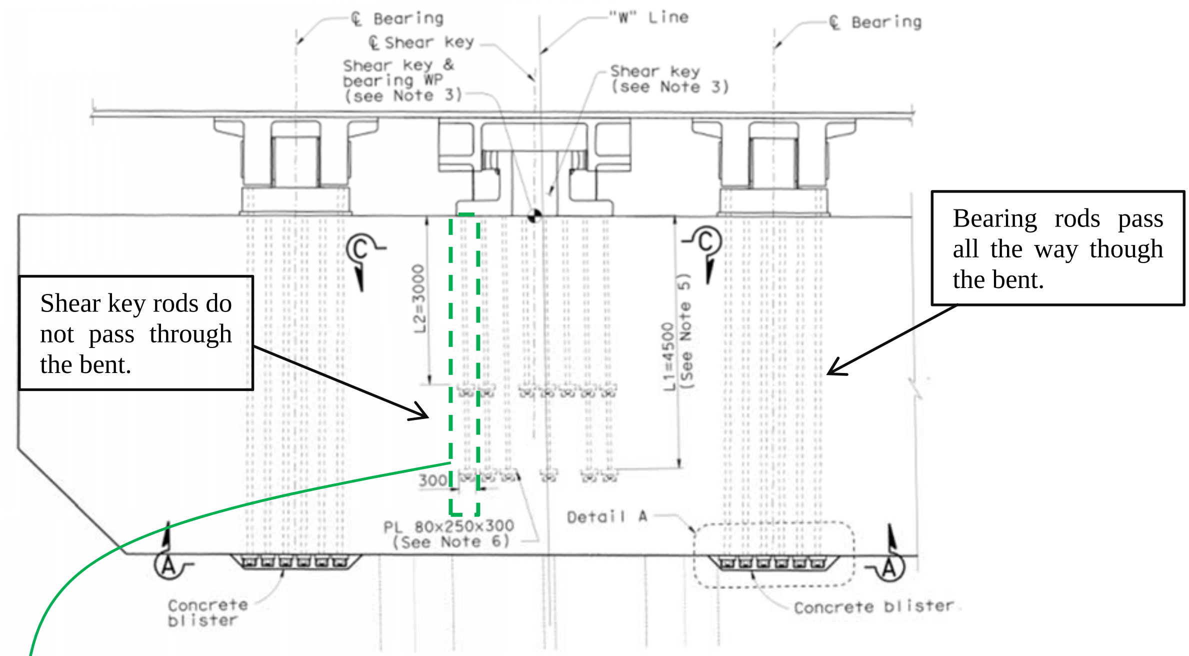

Figure 2: Cross-sectional view of shear key and shear key anchor rods setup

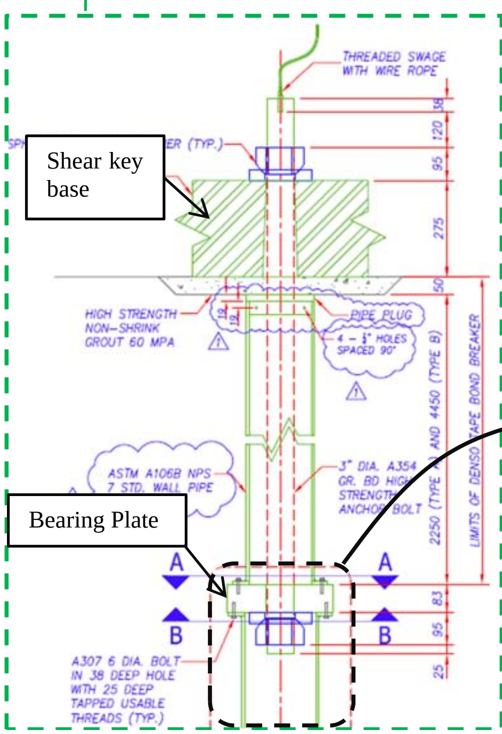

Figure 3: Anchor rod setup

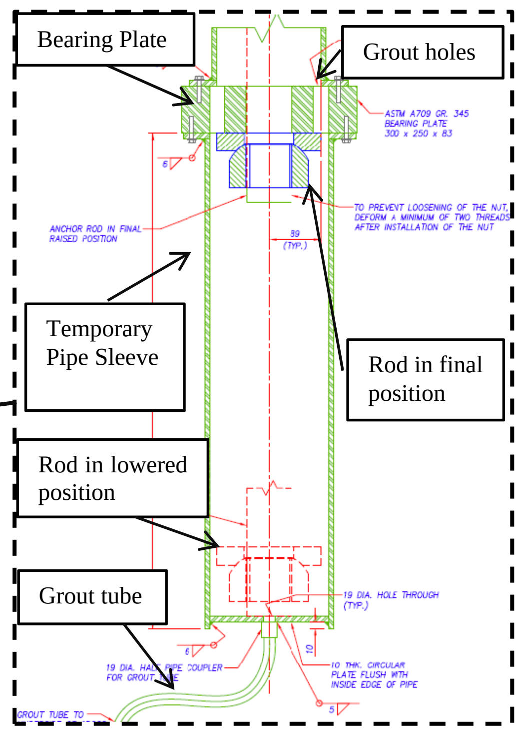

Figure 4: Temporary Pipe Sleeve Detail

After the Pier E2 concrete pour, the rod holes were left open, exposing them to atmospheric conditions and accumulation of debris. The Contractor extracted the water and used compressed air to remove debris. In order to prevent future water and debris intrusion, the Contractor covered the holes with plywood. See **Figures 5** and **6**.

Figure 5: Extraction of water

Figure 6: Capped Rod Holes

Construction requested METS assistance to view the interior of the rod holes to help assess water and debris removal at the bottom.

DISCUSSIONS

A Quality Assurance Associate Steel Inspector utilized a GE XL Go Videoprobe Borescope at various rods in Shear Keys S1 and S2 in August 2011.

As shown in Figures 7 through 12, the following issues were observed:

- Some grouting holes were clogged by debris. (**Figures 7 and 8**)
- Initially, as stated in Revision 0 of this report, some of the rods indicated oxidation of the bottom portion of the rod. This was based on a recent review of borescope imagery associated with the report being prepared regarding all A354BD rods on the bridge in 2014. Upon further review of the contract documentation, the portion of the rod visible in Figure 8 is coated with grease and then Denso tape. The Denso tape does not allow for the examination of the condition of the galvanized rod. It is not possible to determine the source of the white residue as it could be debris from the surrounding environment. It should not be characterized as oxidation. **Figures 8A and 8B** show the rods were wrapped in Denso tape prior to assembly and installation. [Revision 1]
- Objects such as cigarette butts, U-bolts, and wood chips were found at the bottom of the holes, on top of the bearing plate. (**Figures 9 and 10**)
- Standing water was observed in some rod holes (**Figure 11**) and below the bearing plate (**Figure 12**)

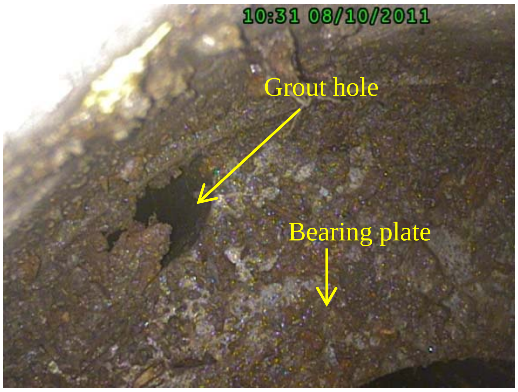

Figure 7: Grout Hole Blocked

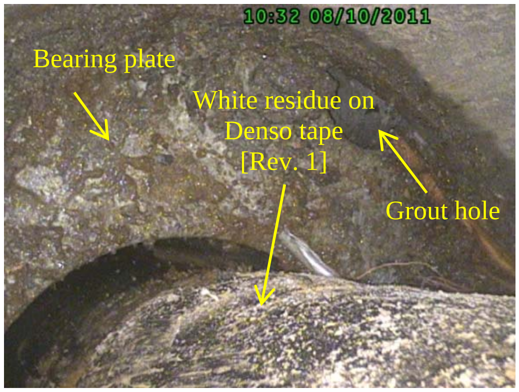

Figure 8: Debris on the Bearing Plate

Figure 8A: Rods wrapped with Denso Tape

Figure 8B: Rod Assembly

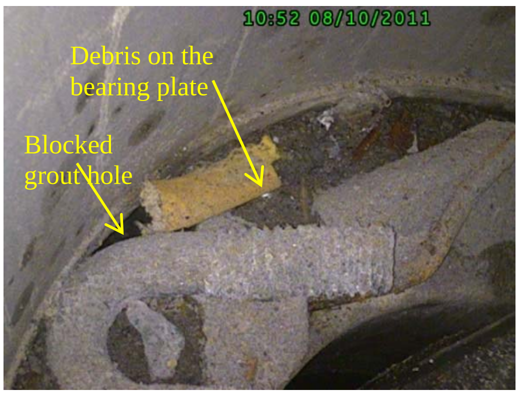

Figure 9: Various Debris on the Bearing Plate

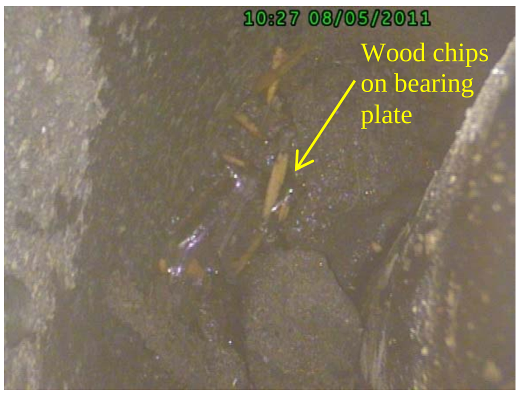

Figure 10: Various Debris on the Bearing Plate

Figure 11: Standing Water in the Rod Hole

Figure 12: Various Debris on the Bearing Plate

SUMMARY OF OBSERVATIONS

The borescope assistance provided for the E2 anchor rod holes performed in August, 2011 identified several holes with standing water present. In addition, debris (wood chips, bolts, cigarette butts) and a white residue on the Denso Tape was identified in many of the areas inspected. Because the rods are wrapped in Denso tape, the white residue is not thought to be oxidation of the anchor rods as previously reported, and could simply be debris from the surrounding environment.

This report is to document, in 2014, these above-mentioned observations, and field assistance provided by METS to construction personnel in 2011. This report was not intended to perform a corrosion investigation of the rods. The borescope observation was to provide tools to construction staff inspecting the dewatering and debris removal operation performed by the Contractor.

For any comments or questions, please contact the undersigned at 510-610-9054.

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Structural Materials Representative
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cc. Keith Hoffman, Gary Thomas, Mazen Wahbeh

PROJECT INFORMATION

04-0120F4
Self-Anchored Suspension Bridge

SUBJECT

Borescope Investigation of Pier E2 Rod Holes – 2013

BACKGROUND

A total of 288 ASTM A354 Gr. BD bearing and shear key anchor rods have been installed in Pier E2. 96 of these 3-inch hot-dip galvanized rods are shear key anchor rods that were embedded in concrete. The rods were fabricated in 2008 and assembled inside pipe sleeves in Shear Keys S1 and S2. The area around the pipe sleeves was grouted five years later, in 2013.

Once the grouting was complete, in Mar. 2013, thirty-two (32) of the shear key anchor rods fractured shortly after tensioning. The specific rods are highlighted in **Figure 1**. The top portions of the rods were extracted in segments for fracture analysis. It was not possible to retrieve the bottom fracture surfaces. The Department requested that METS investigate the interior of the rod holes with a borescope to evaluate the in-situ conditions and provide images of the fracture region.

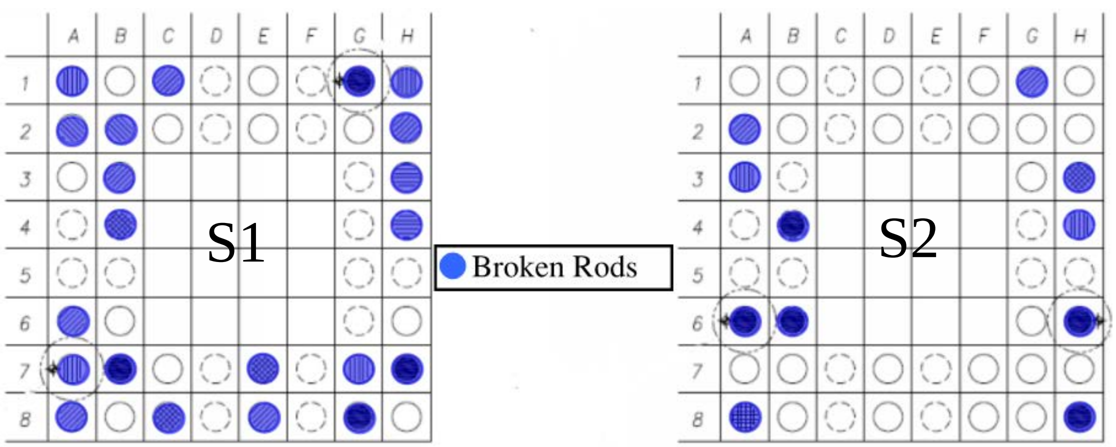

Figure 1: Locations of Failed Rods in Shear Keys S1 & S2

As shown in **Figure 2**, the details of the rods in S1 and S2 are different from the details for the bearing anchor rods. The embedment of the shear key rods in concrete prevents access from below. Prior to installation of the shear keys, the rods had to be flush with the pier E2 top surface. Temporary pipe sleeves were installed below the bearing plate to allow for the rods to be installed in a lowered position **(Figures 3 and 4)**. After the shear keys were installed, the rods were raised to their final position where the bottom nut was against the bearing plate and the top of the rod was tensioned against the shear key base. The area inside the temporary pipe sleeve was grouted after the rods were raised to their final position.

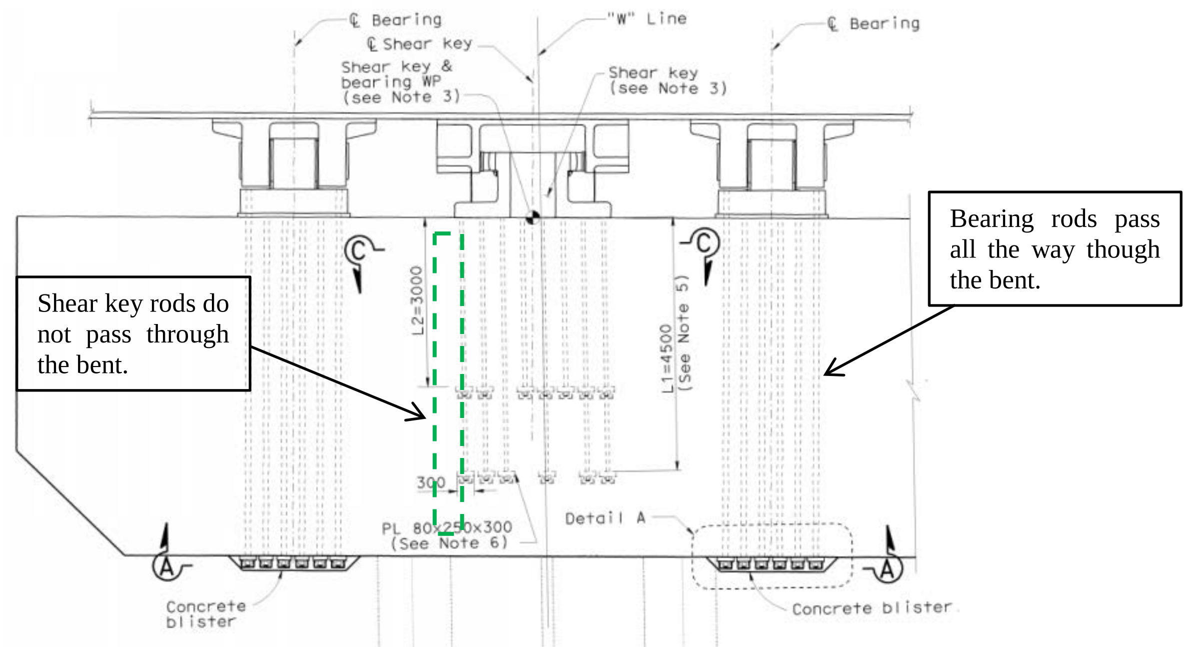

Figure 2: Cross-Sectional View of Shear Key and Bearing Anchor Rods

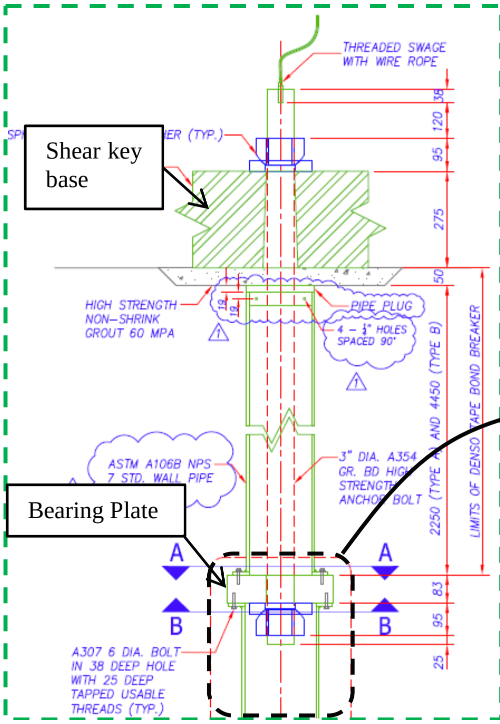

Figure 3: Anchor rod setup

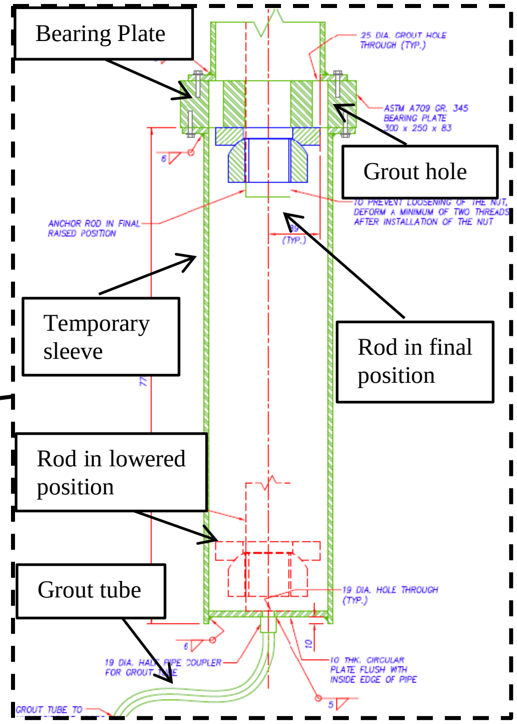

Figure 4: Temporary Sleeve Detail

DISCUSSION

Borescope inspections were performed between Mar. 12 and Mar. 17, 2013 by Quality Assurance Inspectors Jason Gramlick and Scott Croff with a GE XL Go Video probe Borescope (**Figure 5**). The camera at the tip of tube on the borescope was inserted into each of the rod holes while the direction of the camera lens was navigated to observe the in-situ condition of the portion of the rod still in the hole.

Figure 5: GE XL Go Video probe Borescope

Out of the thirty-two fractured rods, only five locations, as highlighted in **Figure 6**, were accessible for borescope inspection: S1A7, S1-G1, S2-H6, S2-A6, and S2-A8.

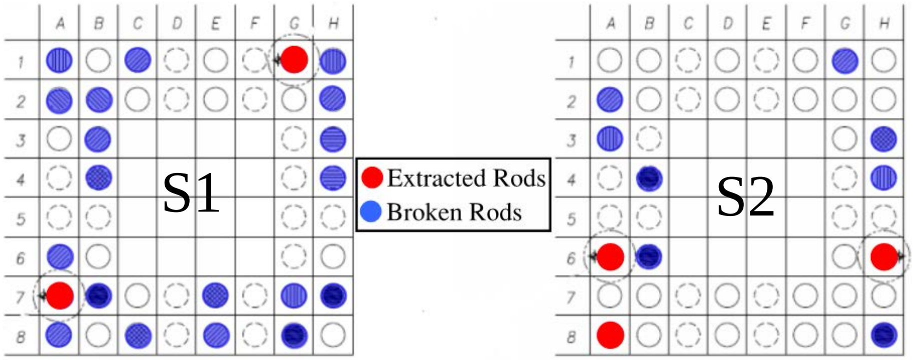

Figure 6: Borescope Inspection Locations in Shear Keys S1 and S2

Rod ID S2-H6 (Mar. 12, 2013)

Standing water was observed as shown in **Figure 7**. The water is right below the bearing plate as shown in **Figure 8**.. A gap appeared to be between the fractured rod and the bearing plate as shown in **Figure 9** suggesting movement of the assembly away from the bearing plate. The views of the borescope images are at cross section A-A of **Figure 3**.

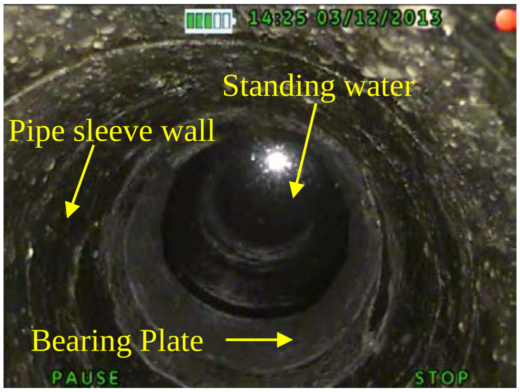

Figure 7: S2-H6 borescope snapshot

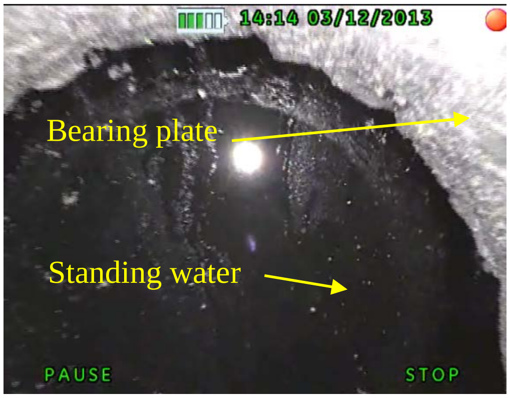

Figure 8: S2-H6 borescope snapshot

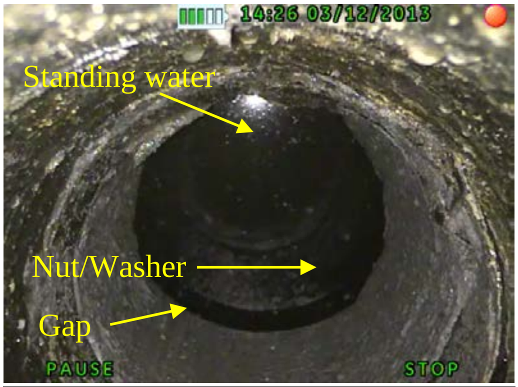

Figure 9: S2-H6 borescope snapshot

Rod ID S2-A6 (Mar. 13, 2013)

Contamination of the borescope lens reduced the range of visibility. The rod's fracture surface was identified and was dry **(Figures 10 and 11**). Corrosion products were visible on the rod fracture surface (**Figure 11)**. The threads exhibited rusting as well **(Figure 12)**. The views of the borescope images are at cross section A-A of **Figure 3**.

Figure 10: S2-A6 borescope snapshot

Figure 11: S2-A6 borescope snapshot

Figure 12: S2-A6 borescope snapshot

Rod ID S1-A7 (Mar. 14, 2013)

Standing water was observed during the inspection. No fracture surface was visible. It appears that the nut had rotated and only the flats of the nut were visible **(Figure 13)**. There are gaps between the bearing plate and the spherical washer edge. The gaps vary in size, further suggesting the rotation of the nut as shown in **Figure 14** and **Figure 15**. The views of the borescope images are at cross section A-A of **Figure 3**.

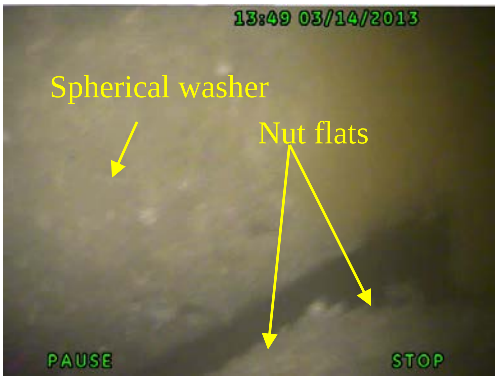

Figure 73: S1-A7 borescope snapshot

Figure 14: S1-A7 borescope snapshot

Figure 85: S1-A7 borescope snapshot

Rod ID S1-G1 (Mar. 17, 2013)

The fractured rod was not submerged in water, but moisture was present (**Figure 16**). The camera lens was rotated to observe the threads on the rod and the nut and as shown in **Figure 17**; the threads exhibited rust deposits. The fracture surface was clearly visible. The nut appeared to be seated within the spherical washer **(Figure 17)**. The views of the borescope images are at cross section A-A of **Figure** 3.

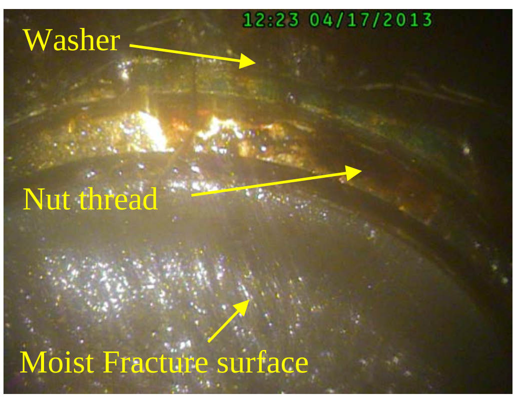

Figure 16: S1-G1 borescope snapshot

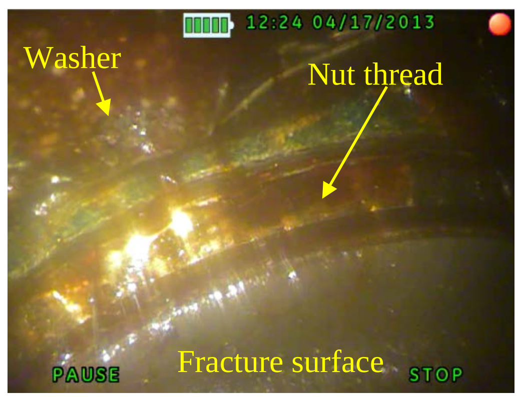

Figure 17: S1-G1 borescope snapshot

Rod ID S2-A8 (Mar. 18, 2013)

Standing water was observed in the hole and the rod was submerged. Particulates in the water reduced clarity and visibility. A gap appeared between the spherical nut and the spherical washer which is indicative of the nut moving away from the spherical washer. The flats of the nut are visible as shown in **Figures 18** and **19**. **Figure 19** also appears to show the fracture surface of the rod. **Figure 20** is a close up of the fracture surface visible in **Figure 19**. The views of the bo-rescope images are at cross section A-A of **Figure 3**.

Figure 18: S2-A8 borescope snapshot

Figure 19: S2-A8 borescope snapshot

Figure 20: S2-A8 borescope snapshot

A water sample was taken for testing from S2-A8. The sample was tested for pH and conductivity, as well as levels of chloride, sodium, calcium, sulfate, nitrate, potassium, magnesium, nitrite, carbonate, bicarbonate, chromium, iron, zinc, aluminum, total dissolved solids, and organic compounds. The results are summarized in **Table 1**. For further details of the tests performed, refer to **Addendum A.**

Table 1: Summary of Water Sample Testing at WJE

Parameter	Result
pH	13.04
Conductivity	31 mS
Chloride	44 mg Cl^-/L
Sulfate	128 mg SO_4^{2-}/L
Nitrate	1.5 mg NO_3^{2-}/L
Nitrite	293 mg NO_2^-/L
Sodium	3940mg Na^+/L
Potassium	990 mg K^+/L
Magnesium	ND
Calcium	96 mg Ca^{2+}/L
Carbonate	2,040 mg/L as $CaCO_3$
Bicarbonate	ND
Organic compounds	ND
Chromium	<1 mg Cr/L
Iron	ND
Aluminum	29.2 mg Al/L
Zinc	32.8 mg Zn/L
Total dissolved solids	11,200 mg/L

ND = not detected

SUMMARY OF OBSERVATIONS

In all but one of the inspected locations, standing water was identified in the bottom of the anchor rod holes. In rod hole S2-A6, where water was not visible, corrosion was evident. In three locations, gaps were discovered between the washer and the spherical nut suggesting the nut had rotated.

For any comments or questions, please contact the undersigned at 510-610-9054.

Aaron Prchlik, PE
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Addendum A: Water Sample Analysis – Final Test Results

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July 10, 2013

Mr. Mazen Wahbeh
Alta Vista Solutions
6475 Christie Avenue, Suite 425
Emeryville, CA 94608

Re: SFOBB Bay Bridge
Water Sample Analysis - Final Test Results
WJE No. 2013.2796

Dear Mr. Wahbeh:

A water sample labeled S2A8 was received for testing. Parameters requested are: pH, conductivity, chloride, sodium, calcium, sulfide, sulfate, nitrate, potassium, magnesium, nitrite, carbonate, bicarbonate, chromium, iron, zinc, aluminum, total dissolved solids, organic compounds, and bacteria. Sulfide and bacteria were not tested for because the time delay between sample collection and sample receipt was too great for accurate results. Table 1 provides results. A discussion of the test methods follows.

Table 1. Water Test Results

Parameter	Result
pH	13.04
Conductivity	31 mS
Chloride	44 mg Cl^-/L
Sulfate	128 mg SO_4^{2-}/L
Nitrate	1.5 mg NO_3^{2-}/L
Nitrite	293 mg NO_2^-/L
Sodium	3940mg Na^+/L
Potassium	990 mg K^+/L
Magnesium	ND
Calcium	96 mg Ca^{2+}/L
Carbonate	2,040 mg/L as $CaCO_3$
Bicarbonate	ND
Organic compounds	ND
Chromium	<1 mg Cr/L
Iron	ND
Aluminum	29.2 mg Al/L
Zinc	32.8 mg Zn/L
Total dissolved solids	11,200 mg/L

ND = not detected

Discussion of Test Methods

pH - pH was measured using a pH meter with an electrode that had been calibrated with pH 7, pH 13 and pH 4 standard buffer solutions.

Conductivity - Conductivity was measured with an Omega CDH-80 MS conductivity meter. The meter is factory calibrated and was checked with 100µS standard conductivity solution.

Chloride, Sulfate, Nitrate, Nitrite - Anion concentrations were determined using a Dionex ICS 2000 ion chromatograph using hydroxide eluent. Calibration curves were derived using standards for chloride, sulfate, nitrate, and nitrite (as well as fluoride, bromide and phosphate). The sample was diluted as necessary to bring the concentration of each analyte anion into the calibration range. The concentration of a given analyte is determined by comparison to a curve fit of the standards.

Sodium, Potassium, Magnesium, Calcium - Cation concentrations were determined using a Dionex ICS 2000 ion chromatograph using methanesulfonic acid eluent. Calibration curves were derived using standards for sodium, potassium, magnesium, and (as well as lithium and ammonium). The sample was diluted as necessary to bring the concentration of each analyte anion into the calibration range. The concentration of a given analyte is determined by comparison to a curve fit of the standards.

Carbonate and Bicarbonate - Carbonate and bicarbonate concentrations were measured by titration with sulfuric acid. Carbonate and bicarbonate content is calculated after titration to different pH endpoints.

Organic Compounds - Organic compounds were analyzed for by direct injection of a portion of the water sample into a Perkin Elmer gas chromatograph with mass spectrometer detector. This technique, using the Restek 5Sil-MS column with a 1 micron film thickness has proven successful at detecting a wide range of compounds in the past. No compounds were detected after duplicate injections of undiluted water.

Aluminum, Chromium, Zinc - Analysis using atomic absorption of an acidified sample was anticipated. However, upon addition of acid, a precipitate formed. Analysis of the precipitate using scanning electron microscopy with energy dispersive x-ray spectroscopy indicated the presence of aluminum and zinc, but not iron or chromium. For analysis of aluminum, chromium and zinc, dried material remaining from the total dissolved solids test was fused with lithium metaborate to create a specimen that could be dissolved without precipitation. This solution of the fused sample was used for analysis using atomic absorption spectroscopy.

Iron - Analysis using atomic absorption spectroscopy of an acidified sample was performed. A precipitate, which did not contain detectable iron, was filtered from the solution.

Total Dissolved Solids - A portion of the water sample was filtered to remove solids. The filtrate was heated to remove the water, and the total dissolved solids determined gravimetrically.

Thank you for the opportunity to work with you on this project. If you have any questions, please do not hesitate to contact us.

Sincerely,

WISS, JANNEY, ELSTNER ASSOCIATES, INC.

Kimberley A. Steiner
Senior Associate

F. Dirk Heidbrink
Project Manager