

A354BD Bolts Testing and Evaluation Meeting: June 7, 2013 @ DJV Field Office

Meeting Notes and Action Items

7AM-9:30 AM Meeting:

(In Meeting: B. Maroney, J. Fisher, A. Pense, M. Nader, D. Jang, R. Land, A. Akinsanya, M. Wahbeh, H. Townsend, K. Frank, D. Williams, T. Langill, L. Raymond, B. Brignano, B. Casey, J. Duxbury, H. Tazir and S. Dean (by phone); T. Anziano and F. Seible joined meeting around 8:45am, during "Background and Testing Plan Review".)

1. Introductions
2. Dr. Maroney outlined the main questions to be addressed by the assembled team of experts.
 - a. How much testing is required to achieve a reasonable level of confidence on the data analysis conclusions.
 - b. Whether the current testing program is sufficient or should be expanded and what additional tests are recommended.
 - c. Design Decisions based on tests: Recommendations on how to use the data.
 - d. Upgraded A354BD Rod Specifications
 - i. HRC Range
 - ii. Charpy Tests
 - iii. Other.
3. Dr. Maroney also indicated to the Group that in deciding on the bridge's opening date, it is important to consider the relative safety of the new bridge as compared to the existing bridge.
4. Background and Testing Plan Review (presented by Dr. Nader, please refer to attached file):
 - a. During Design, high strength large diameter bolts were only available as A354BD or from Macalloy (U.K.); Bolts from Macalloy were considered but were not selected as they are a sole source product and would also require a Buy America waiver.
 - b. A354BD Specifications on SAS: Caltrans Corrosion Technology Team and Caltrans Steel Committee approved the use of A354BD galvanized, provided the following is specified and applied:
 - i. Dry Blast Cleaned to SSPC No. 10 (Near White Blast Cleaning)
 - ii. Galvanization within 4 hours of dry blast cleaning and in accordance with ASTM -A123
 - iii. Shall conform to ASTM A-143 "Standard Practice for Safeguarding against Embrittlement of Hot-Dip Galvanized Structural Steel Products and Procedures for Detecting Embrittlement".

- c. It was confirmed (Letter from Tennessee Galvanizing) that the tower anchor rods were flash pickled. Dr. Langill explained that not much hydrogen is generated during this process.
- d. The specified ASTM A143 bend test (or equivalent) was not performed on the high strength large diameter rods (ASTM A354 Grade BD) on the SAS (for both the 2008 and 2010).
The Group agreed that the bend test specified in A143 could have provided valuable information about the manufactured bolts. It was agreed that the bend test must be enforced for the new bolts.
- e. Discussions regarding the ASTM A354BD standards concluded that the ASTM A354 Grade BD specification will likely need be revised due to the failure of the 2008 rods.
It was also noted that while ASTM prohibits galvanizing A490 bolts, it allows it with A354BD bolts, which have essentially the same chemistry and hardness range. The specified bolt strengths for these two specifications are:
 - i. A490: 150 ksi min and 170 ksi max,
 - ii. A354BD: 140 ksi min (for diameters greater than 2.5") with no specified maximum.
- f. It was agreed to review ASTM A193 B7 as a possible specification for new replacement rods.
- g. Review of A354BD on SAS Testing Program and Acceptance Criteria: The test program was presented as well as the proposed methodology to evaluate the stress corrosion resistance based on the test results. The methodology is based on the following:
 - i. Threshold determined by the Stress Corrosion (Townsend) Test;
 - ii. Hardness values based on a statistical evaluation of the field hardness and lab hardness measurements;
 - iii. Sustained stress level for each group of rods;
 - iv. Other criteria such as Charpy results (*fracture toughness*).

It was agreed to review the test program and possibly to add to it (see 9:30-Noon Summary).

- h. A review of the A354 Grade BD rods locations in SAS identified the three (3) dehumidified locations (Tower Base, PWS Anchorage & Tower Saddles) as being at a lower risk for Hydrogen Embrittlement. It was agreed further to consider the following (to ensure there is no moisture)
 - i. Monitor rod temperature as a function of dew point and find a way to ensure the stays above the dew point temperature.
 - ii. Provide and install an automated early warning system in case dehumidification unit malfunctions.
 - iii. Install a back-up dehumidification system.

- i. Comparison of 2008 vs. 2010 Rod test results to date: Destructive tests performed on two 2008 rods and four 2010 rods were compared:
 - i. Chemistry was shown to be similar.
 - ii. Hardenability was improved on the 2010 rods vs. 2008 rods.
 - iii. Charpy values show the most dramatic difference between the two sets:
 1. 2008 rods: 13.5 to 17.5 ft-lb at 40F
 2. 2010 rods: 36.8 to 38.3 ft-lb at 40F.

It was agreed that Charpy values were an important indicator of the fracture toughness of the specimen. It was also agreed that more tests on the 2008 rods would be required to better differentiate them from the 2010 rods. It was confirmed that all the 2008 ends cut as part of the S1/S2 Design Alternatives are available for testing.

5. Review of the Upgraded A354BD Rod Specifications to be applied to the replacements for the 2010 -3" rods from Shear Keys S3/S4 and Bearings B1 through B4 removed for testing. This set will be called the 2013-Rods.

(T. Hall, A. Cavendish-Tribe, J. Gorman joined the meeting)

- i. Hardness Range: It was agreed by the Group (including Peer Review Committee Members) to maintain HRC 31-35 as in the original CCO 312 letter.
- ii. Charpy-V-Notch Test: It was agreed to require the steel to meet 50lb-ft at 40°F.
- iii. 90% Martensite transformation: This requirement was stated in the Department's Letter No. 05.03.01-011715 to the Contractor. Dyson (Rod Supplier) took exception to this requirement. It was noted that this requirement was specified by Salim Brahim, the current Chair of ASTM International Committee F16 on Fasteners. It was agreed that the Department/METS will verify that this requirement is met.
- iv. MT of the threads: The Group was informed that the 2008 Rods had not been MT tested, while the 2010 rods were. It was also noted that the fabricator revised the fabrication process to include "vacuum degassing" after the MT requirement was specified. It was agreed to add this requirement to CCO 312 order (similar to CCO 91).
- v. Thread Making: Rods with cut threads and rods with rolled threads are used in the SAS. It was noted that after the MT requirement was enforced, the fabricator elected to cut threads after heat treating (while for the 2008 rods, the threads were cut before heat treating). After discussing the pros and cons, there appeared to be no clear benefit to specifying the thread

making process or its sequencing with respect to heat treating; therefore the Group agreed not to specify the thread making type or sequence.

- vi. ASTM A143 Bend test The Group agreed that the (bend test) embrittlement tests in A143 shall be performed for the new rods. It was also agreed that if Dyson does not agree to perform the test (or take responsibility for it) the department will perform this test.
- vii. Order size for the 2013 rods: It was agreed to order a total of thirty (30) - 3" diameter A354 Grade BD rods with supplemental requirements, of which twenty (20) are galvanized and ten (10) are black. *(Note that the Department later decided to order 40 rods.)*

9:30-Noon Meeting:

Some attendees left for the SSPRP meeting, while the remaining attendees continued to discuss the details of the testing program.

(In Meeting: H. Townsend, K. Frank, D. Williams, T. Langill, L. Raymond, A. Pense, S. Dean (phone), A. Cavendish-Tribe, J. Gorman, J. Duxbury, H. Tazir)

- 6. Testing on 2008 (failed) bolts. The Group agreed that the testing program must include the following:
 - a. Tests I and Test II for all available 2008 rods (in-situ or cut samples). The tests include:
 - i. Field Hardness
 - ii. Lab Hardness
 - iii. Charpy
 - iv. Chemistry
 - b. It was agreed that Incremental Load Step tests by Dr. L Raymond would be performed on a few samples (these test require sample lengths of approximately 6 inches) to study the embrittlement of the 2008 rods.
 - c. Dr. Townsend noted that in his brief examination of a broken end of a 2008 rod (removed by the Contractor) he noted white, hard powder between the threads. He suggested that the powder residue's chemistry be analyzed and x-rayed for fluorescence. The objective is to determine whether the powder is grout or the product of corrosion.
 - d. It was also suggested and agreed to test the top grout pad of the 2008 rods for aluminum content.
- 7. Testing program for the 2010 rods (Attached Table):
 - a. The test plan was reviewed with focus on items 2, 7, 12 and 13.

- b. The test plan was agreed to, and supplemented with the Incremental Step Loading method similar to ASTM F1624 and performed at *Lou Raymond & Associates (LRA)*.
 - c. A. Cavendish-Tribe requested verification that the number of heats for PWS strand is 17.
 - d. Stress Corrosion Test Details Discussion:
 - i. A. Cavendish-Tribe conjectured that for the Stress Corrosion Cracking (SCC) test to provide an indication of the material susceptibility, it should be started with a breach in the galvanizing (exposing bare metal to create the differential in potential).
 - ii. Dr. Langill indicated that the galvanized surface was not likely to crack sufficiently to expose bare steel under load.
 - iii. It was agreed that while testing a worse scenario had merit, it was also necessary to perform SCC testing for bolts in the in-situ coating condition.
 - iv. It was agreed to create a breach (holiday) in the wet portion of threads at the dead ends of two (2) of the of four (4) E2-2010 test samples. Please note that at a later meeting it was agreed to have a breach (holiday) in all 4 samples at the dead end while the live end itself was to represent the as-built condition.
 - e. Repairing the coating on the top rod surface (after completion of grinding and testing): It was agreed that the surface will be repaired by means of multiple coats of zinc paint. Flame spray metalizing was discussed, but was not pursued due to the in-situ conditions.
8. Stress Corrosion Test Overview (by Dr. Townsend)
- a. Dr. Townsend summarized the Stress Corrosion Test that will be performed for the 2010 rods in a saline solution, and described how the stress results will be used to determine a stress intensity factor threshold.
 - b. Dr. Townsend also showed, based on his 1975 research, how stress intensity threshold can be determined for process hydrogen by performing a similar step-loading test, but in air rather than in a salt solution.
9. Incremental Step Loading Technique (Dr. Raymond)
- a. Dr. Raymond explained his test, which is an accelerated stress corrosion test that was shown to provide results consistent with long duration stress corrosion tests.
 - b. It was agreed that this test will be added to the 2010 testing program (as Test V). This test can be done on more samples than Test IV (the full size Stress Corrosion Test), which is limited by available sample lengths, and it can be used to provide a measure for quality assurance.
10. Recent developments in Hydrogen Embrittlement Study Of Galvanized High-Strength Bolts (Dr. Langill):

- a. Dr. Langill summarized the findings from his recent study of galvanized A490 bolts (note that galvanizing A490 bolts is prohibited by ASTM A490 specifications).
 - i. Dr. Langill tested the hydrogen embrittlement potential of galvanized A490 in 3.5% NaCl solutions following the F1624 protocol at LRA. Testing in air was also performed as well as F606 wedge tests (with 4 degrees).
 - ii. The study concluded that A490 bolts mechanically galvanized under carefully prescribed conditions pass the ASTM embrittlement tests.
 - iii. Dr. Langill will present his findings in ASTM committees.
- b. Dr. Langill also noted that it is common to hot dip galvanize 10.9 bolts in Europe (equivalent to A490).

11. In Situ UT- Testing of Rods (Dr. Frank):

- a. Dr. Frank recommended UT testing of bolts in-situ to identify existing cracks and to establish a baseline for a maintenance program that would involve UT testing at regular time intervals.
- b. UT testing to be performed in the field, at the ends of the rods, around the perimeter. Typically UT can penetrate a depth of 12 inches.
- c. It is understood that FHWA is also requesting UT testing of the rods.

2:30PM-4:40PM Recap

(In Meeting: H. Townsend, K. Frank, D. Williams, A. Pense, T. Langill, L. Raymond, M. Nader, J. Duxbury, H. Tazir)

12. Review 2010 Testing Program with Focus on SCC and additional testing:

- a. It was agreed to add Test V: Incremental Step Loading Technique for Measuring Hydrogen Embrittlement, on reduced-size samples (to be performed by Dr. Raymond). The testing will include:
 - i. Testing in air (to evaluate process hydrogen)
 - ii. Testing in 3.5% NaCl Solutions (with or without holidays)
 - iii. Samples to be tested include:
 - 1. PWS Rods (available samples to be determined)
 - 2. E2-2010 Rods (from Spares or from the 4 tested specimens)
 - 3. Any other available samples (to be verified with CT/METS)
- b. It was also agreed to perform UT testing of all accessible rods (2010) and on all new 2013 rods:
 - i. To identify cracks, if any
 - ii. To provide a baseline for a maintenance program. The maintenance program will include periodic UT testing.

13. Testing of the 2013 Rods: The following list of tests was agreed to:

- a. Stress Corrosion tests:
 - i. 3 full-size galvanized rods
 - ii. 3 full-size black rods
 - iii. 2 full-size, double heat-treated galvanized rods
 - iv. 2 full-size, double heat-treated black rods
- b. Incremental Step Loading Technique: Use 1 full size rod, galvanize half and keep half black
 - i. Test galvanized sample in air
 - ii. Test galvanized sample in 3.5% NaCl
 - iii. Test black sample in air
 - iv. Test black sample in 3.5% NaCl
- c. ASTM A143 test (Section 9.2). Use 1 full size rod, thread both ends for $\frac{1}{4}$ of the rod length, then cut black rod and galvanize one half of the rod.
 - i. Test Samples:
 1. Threaded galvanized
 2. Threaded black
 3. Unthreaded galvanized
 4. Unthreaded black
 - ii. Testing Steps: It was agreed to perform the testing in 15 degree-steps (15, 30, 45, 60, 75, 90), and to perform VT and MT on the surfaces to detect cracks at each step.
 - iii. It was agreed that the minimum sample length should be 15 inches (5t).

Action Items

- a. Update testing Program per above comments (DJV/METS/CT)
- b. Develop Incremental Step Loading Test Proposal for Test V (Dr. Raymond, Dr. Langill)
- c. Procure and ship 3" dummy sample to LRA for testing Calibration/Adjustment (CT)
- d. Update CCO 312 (2013 Rods) Specifications and Rod Order Quantity (CT)
- e. Incorporate UT into in-situ testing of rods (CT/METS/DJV)
- f. Verify number of Heats for PWS rods (CT/METS)