Draft Interim Report for Project Entitled:

Corrosion of Residential Fasteners

Performance Period: 10/7/2016 – 6/30/2017

Submitted on

February 15, 2017

Presented to the

Florida Building Commission
State of Florida Department of Business and Professional Regulation

by

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1. Disclaimer

This report presents the findings of research performed by the University of Florida. Any opinions, findings, and conclusions or recommendations expressed in this report are those of the authors and do not necessarily reflect the views of the sponsors, partners and contributors. The appropriate Technical Advisory Committees of the Florida Building Commission will provide a final disposition on the implications for the Florida Building Code.

2. Issues being addressed

- Anecdotal information indicates that corrosion of fasteners has been observed across a range of installations
- The problem is more serious in coastal environments due to presence of chloride ions
- Increased manufacturing of these products outside the United State may be contributing to the problem
- The 2015-2016 corrosion study focused on
    - Electrogalvanized roofing fasteners conforming to ASTM A641 or TAS 114 Appendix E standards
    - Hot dipped fasteners
    - Roof tile fasteners
    - Screen enclosure fasteners
- The 2016-2016 corrosion study identified performance issues that warrant further testing

3. Applicable Sections of the Code and related documents

- 1622.1.2, Florida Building Code—Building
- 1506.4 – 1506.7, Florida Building Code—Building
- 1517.5.1 – 1517.5.2, Florida Building Code—Building
- Guide to Aluminum Construction in High Wind Areas
- TAS 114 Appendix E
- ASTM A90
- ASTM A641
- ASTM A153
- ASTM B117-11
- ASTM G85-11

4. Review of 2015 – 2016 Testing

The 2015 – 2016 experimental study (phase 3) continued the testing roof system fasteners in a corrosion chamber, applying the TAS 114 Appendix E protocol and applying the customized corrosion scoring scale created for phase 2. In phase 3, the emphasis was on testing fasteners that are ASTM A641 compliant (prescriptive) or Miami Dade County approved (performance based TAS 114 Appendix E). Electrogalvanized, electroplated, mechanically galvanized, hot dipped, and stainless steel fasteners were included in the test matrix. Roofing, deck/patio, screen enclosure, and tile screw fasteners were also included. The following summary of findings was reported in the Final Report issued on June 21, 2016:

- It is assumed that Miami-Dade approved EG fasteners had been certified as TAS 114 Appendix E compliant. However, the results did not reveal a single EG sample that passed that standard's criterion of < 5% surface corrosion. Each of the 30 such fastener samples tested had a score of at least 3 (partial light surface corrosion) on both the head and shaft, and most samples displayed significant heavy corrosion. Each of the three EG specimen types marked as Miami-Dade approved only referenced ASTM A641, not TAS 114 Appendix E.
- The hot dipped, mechanically galvanized and stainless steel ceramic coated specimens demonstrated little or no corrosion.
- The corrosion resistance of hot dipped specimens does not appear to be influenced (damaged) by installation. However, due to a relatively small sample size and the inclusion of only two specimen types, this conclusion is indicative rather than definitive.
- Testing on ceramic coated stainless steel screen enclosure fasteners revealed some degradation to the ceramic coating on the stainless steel specimens. The exposed stainless steel did not exhibit significant corrosion. However, unlike metal reactions due to loss of the coating barrier were not evaluated since these specimens were tested out of the box and not in an installed configuration.

5. Statement of Work for 2016 - 2017

The current 2016 – 2017 experimental study (phase 4) continues the testing of residential fasteners in a corrosion chamber, applying the TAS 114 Appendix E protocol and applying the customized corrosion scoring scale created for phase 2. The testing plan is described as follows:

- The 2015 - 2016 study revealed that the ceramic coating on stainless steel masonry screws (commonly used for screen enclosures) peeled during the corrosion testing. This may create issues with unlike metal reactions when these fasteners are used in aluminum enclosures. The testing will install ceramic coated SS screws in aluminum prior to corrosion testing in order to investigate the implications of loss of coating with respect to corrosion at the unlike metal interface.
- Additional tile fastener testing will be conducted to add multiple commonly used products to the limited results from the 2015-2016 study.
- Hot dipped roofing fasteners performed much better than electrogalvanized fasteners in the 2015-2016 study. Fasteners conforming to the ASTM A153 hot dipped standard and the ASTM A641 minimum coating standard will be tested for relative performance.
- HVAC and metal panel clips and fasteners will be included in the 2016-2017 test matrix

The test protocol includes the following:

- Apply TAS 114 Appendix E testing (Section 2.6.1) to evaluate the degree of corrosion resistance
- Testing will be conducted on both new and installed fasteners to determine the influence of installation on corrosion resistance
- Testing will include multiple samples of each specimen configuration

This interim report presents the results of testing on 150 specimens to date (denoted test-1).

6. Description of 2016 – 2017 testing completed to date (Test-1)

Test-1 includes 10 samples from each of 15 groups. These 15 groups include sheet metal and masonry screws commonly used for screen enclosures, as well as roofing tile screws.

This section includes a description of the test specimens, specimen conditioning, test protocol, the corrosion scoring performance metric, results and discussion.

6.1. Description of test specimens in test-1

Table 1 summarizes the specimens in test-1. Groups 1 – 10 are masonry, SDS and SMS ceramic coated stainless steel screen enclosure fasteners. Groups 11 – 13 are mechanically galvanized and electroplated tile screws. Groups 14 and 15 are nylon capped ceramic coated case hardened steel masonry and SDS fasteners. Each of the 15 groups included 10 samples. All samples were tested for 1000 hours (500 cycles).

Table 1: test-1: 15 specimen types, 10 samples each
5 samples out-of-the-box, 5 samples installed in substrate
Status: completed 1000 hours (500 cycles)

Group number	Product type	Use	Certification	Coating
1	Hex 3/8 x 5 304 Stainless white	Masonry	MDC Approved	Ceramic
2	Hex 3/8 x 7 304 Stainless white	Masonry	MDC Approved	Ceramic
3	Hex 1/4 x 3 ¼ 304 Stainless silver	Masonry	MDC Approved	Ceramic
4	Hex 1/4 x 2 ¼ 304 Stainless silver	Masonry	MDC Approved	Ceramic
5	Hex 1/4 10 x 2 SMS 316 Stainless bronze	Screen enclosure	MDC Approved	Ceramic
6	Hex 1/4 12 x ¾ SDS 316 Stainless white	Screen enclosure	MDC Approved	Ceramic
7	Hex 5/16 14 x 1 SDS 316 Stainless bronze	Screen enclosure	MDC Approved	Ceramic
8	Hex 3/8 14 x 1 SDS 316 Stainless bronze	Screen enclosure	MDC Approved	Ceramic
9	Hex 5/16 12 x 2 SDS 316 Stainless bronze	Screen enclosure	MDC Approved	Ceramic
10	Hex 1/4 10 x 2 SDS Stainless white	Screen enclosure	MDC Approved	Ceramic
11	#8 2 ½ mechanically galvanized ASTM B695 Class 55 2006 IRC Compliant	Tile screw	IRC	MG
12	#8 2 ½ tile screw heavy zinc electroplated	Tile screw	unknown	EP
13	#8 2 ½ mechanically galvanized ASTM B695 Class 55 2006 IRC Compliant	Tile screw	IRC	MG
14	Hex 1/4 x 3 ¼ case hardened carbon steel blue Nylon cap applied post-install	Masonry	Unknown	Ceramic
15	Hex 5/16 12 x 1 SDS case hardened carbon steel red, Nylon head	Screen enclosure	Unknown	Ceramic

6.2. Specimen conditioning

The purpose of test-1 was to provide comparative corrosion performance of samples tested out-of-the-box against samples installed into appropriate substrate prior to testing.

Five samples from each of Groups 1 – 10, 14 and 15 were installed into aluminum screen enclosure stock prior to testing. The remaining five samples from each of Groups 1 – 10, 14 and 15 were tested out-of-the-box.

Five samples from each of Groups 11 – 13 were installed into roofing tiles and removed prior to testing. The remaining five samples from each of Groups 11 – 13 were tested out-of-the-box.

Figure 1 illustrates the installed in substrate and out-of-the-box samples for Group 10 in the chamber prior to testing.

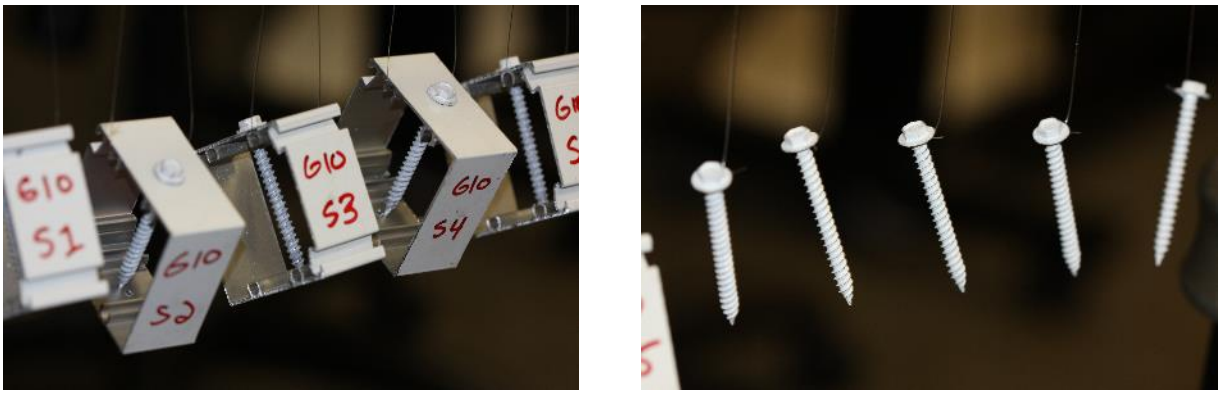


Figure 1: Group 10 specimens prior to testing. Left: installed in aluminum screen enclosure stock. Right: out-of-the-box

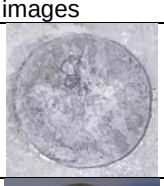
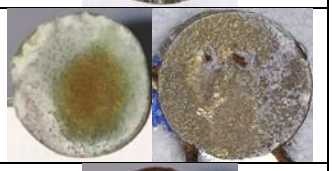
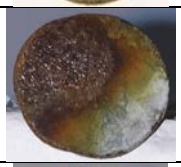
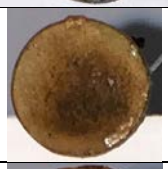
6.3. Test protocol

The test protocol followed TAS 114 Appendix E, which calls for compliance with ASTM G85 Annex A5. The corrosion testing apparatus was factory programmed to follow the ASTM G85 Annex A5 protocol. The acetic acid-salt spray (fog) test was conducted for 500 cycles, where one cycle consists of one hour of fog exposure and one hour of dry-off. The sequence was run without interruption over a 42 day period. The salt solution composition, chamber temperature, and water purity were monitored to conform to requirements. There is no conversion of this protocol to an equivalent time of in-field exposure to real conditions.

6.4. Corrosion scale – performance metric

The TAS 114 Appendix E pass/fail criterion is greater than 5% surface corrosion indicates failure. However, the purpose of this study is to investigate the relative performance of fasteners. This requires a finer gradation of performance than pass/fail can provide. An integer scale of 1 – 8 was created to classify the degree of corrosion observed on the fasteners, where 1 indicates no corrosion and 8 indicates heavy corrosion with scaling. Table 2 provides a description of these classifications as well as a visual sample of each. The assignment of a corrosion score for each fastener is subjective to some degree, but the scale is designed such that this subjectivity does not span more than two adjacent scores. For example, 7 vs. 8 may be subjective, but 6 vs 8 provides a clear distinction. In this manner, the subjectivity does not dilute the significance of

results when viewed on an eight-point scale.

Table 2: Corrosion scale description and sample images	
1: No corrosion observed	
2: Edge corrosion only	
3: Light partial surface corrosion	
4: Light full surface corrosion	
5: Partial heavy surface corrosion	
6: Partial heavy and partial light full surface corrosion	
7: Heavy full surface corrosion without scaling	
8: Heavy full surface corrosion with scaling	

6.5. Graphical results of corrosion scoring

The 1-8 corrosion score was assigned to each tested specimen separately for the head and shaft of the fasteners. The scores were assigned based on visual inspection of the specimens as well as inspection of post-test photos taken of each specimen. Photos and scores for one or two samples of each group are provided in Appendix A.

The full scoring results (all ten samples from each of the 15 groups) are provided in Figures 1

through 4. In each of these figures, the commonly colored bars correspond to the 10 individual samples of that specimen type. Within any one color group of 10 bars, the left five are the installed samples, and the right five are the out-of-the-box samples. The bottom of the graph identifies the specimen type by group number as defined in Table 1. The vertical axis presents the 1-8 corrosion scale score. The light blue bar spanning each commonly colored bar group is the mean value of the 10 samples in that group. The results are stratified in figures 1 through 4 as follows:

- Figure 1: Stainless steel ceramic coated masonry screws
- Figure 2: Stainless steel ceramic coated self-driving and sheet metal screws
- Figure 3: Tile screws, mechanically galvanized and electroplated
- Figure 4: Case hardened carbon steel ceramic coated masonry and SDS screws

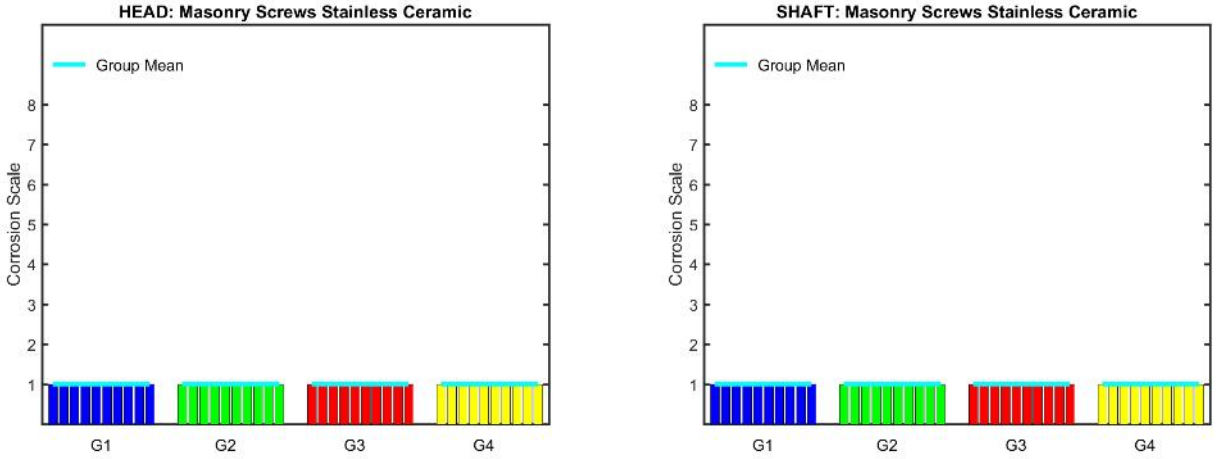


Figure 1: Test-1 Corrosion scale results for stainless steel ceramic coated masonry screws.
Ten samples of each. Five out-of-the-box, five installed in aluminum.
Per color grouping: left five are installed, right five are out-of-the-box.

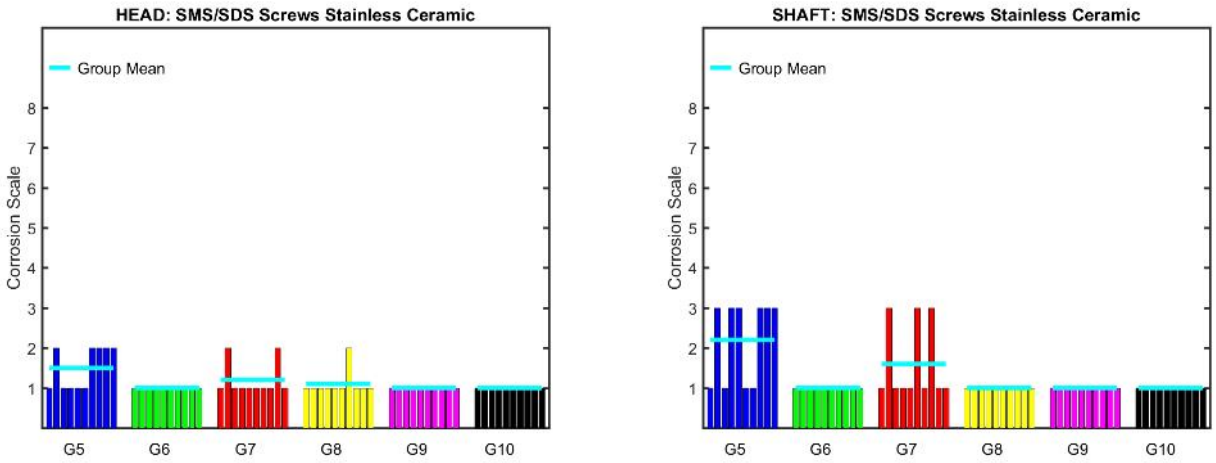


Figure 2: Test-1 Corrosion scale results for stainless steel ceramic coated self-driving and sheet metal screws. Ten samples of each. Five out-of-the-box, five installed in aluminum.
Per color grouping: left five are installed, right five are out-of-the-box.

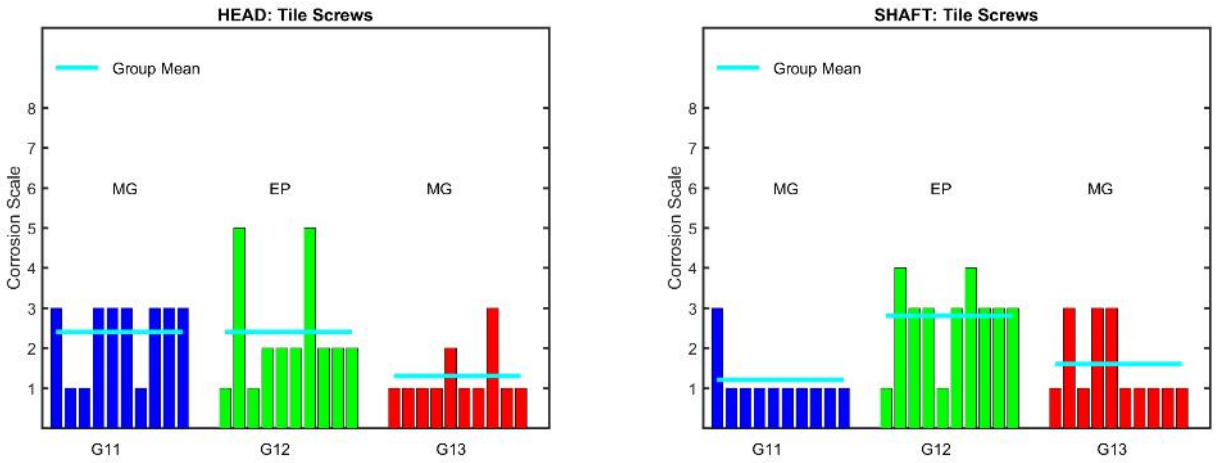


Figure 3: Test-1 Corrosion scale results for tile screws, mechanically galvanized and electroplated. Ten samples of each. Five out-of-the-box, five installed in tile and removed. Per color grouping: left five are installed, right five are out-of-the-box.

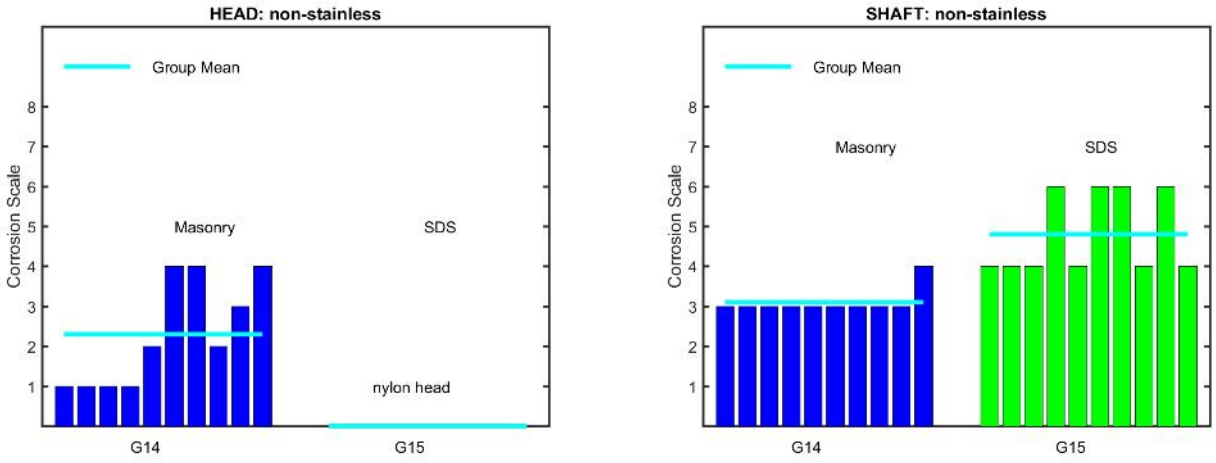


Figure 4: Test-1 Corrosion scale results for case hardened carbon steel masonry and SDS screws, ceramic coated. Ten samples of each. Five out-of-the-box, five installed in aluminum. Per color grouping: left five are installed, right five are out-of-the-box.

6.6. Discussion of scoring results

Findings to date are summarized as follows:

- Figures 1 & 2: Consistent with the findings from the 2015 – 2016 study, the performance of ceramic coated stainless steel masonry screws, SDS and SMS was excellent. There was no observed difference in corrosion resistance when comparing out-of-the-box samples with samples that were installed in aluminum. The loss of the ceramic coating was very common. Most samples had significant coating peeling after testing, and most samples that were installed in aluminum showed visible ceramic coating scratching prior to testing. However, this did not compromise the underlying stainless steel. The contact of unlike metals (stainless steel and aluminum) resulting from the loss of ceramic coating did not produce any observed corrosion.

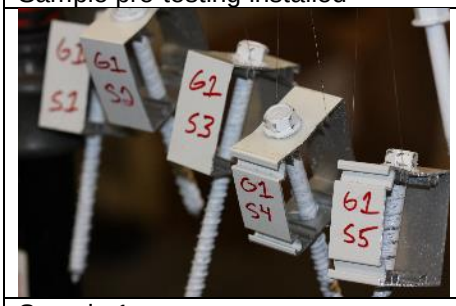
- Figure 3: The performance of mechanically galvanized and electroplated roof tile screws was consistent with the findings from the 2015 – 2016 study. In the previous study the tests were not run to the full duration of 500 cycles. The current test was run for the complete 500 cycles. Spots of light corrosion were observed on many samples, and others showed no signs of corrosion. The samples installed into tile and removed prior to testing showed no difference in performance compared to the samples tested out-of-the-box. Electroplated samples showed slightly more corrosion than mechanically galvanized samples

- Figure 4: Ceramic coated case hardened carbon steel masonry screws and SDS exhibit significant corrosion on the shaft on most samples, and corrosion on the head on the masonry screws (the SDS had a nylon head). Installation in aluminum did not influence the onset of corrosion on the shaft.

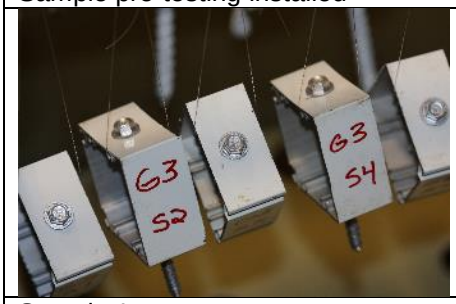
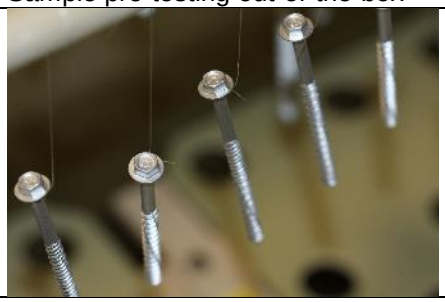
7. Upcoming testing

The next round of testing (test-2) is scheduled to begin at the end of February 2017. The corrosion testing equipment is scheduled for routine maintenance to be performed by the manufacturer on February 27th. Test-2 will address bullet three in the section 5 statement of work: hot dipped fasteners conforming to the ASTM A153 and ASTM A641 standards. Installed and out-of-the-box samples will be included.

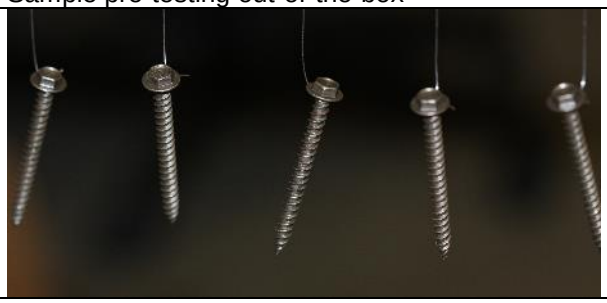
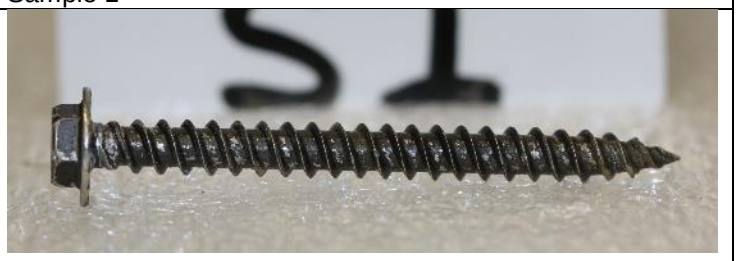
8. Appendix A: Corrosion results (photos for sample of each specimen type)

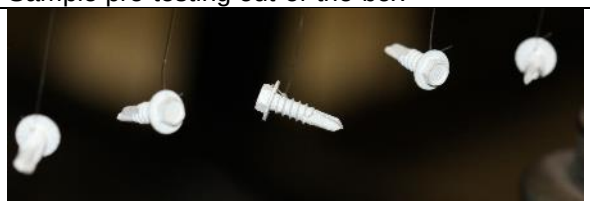
Group 1: Ceramic coated Hex 3/8 x 5 304 Stainless white	
Sample pre-testing installed	Sample pre-testing out-of-the-box
	
Sample 1	Sample 1
	

Group 2: Ceramic coated Hex 3/8 x 7 304 Stainless white	
Sample pre-testing installed	Sample pre-testing out-of-the-box
	
Sample 1	Sample 1
	

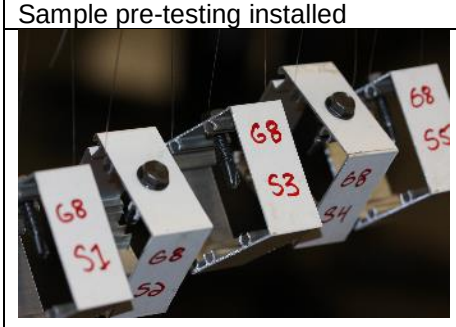
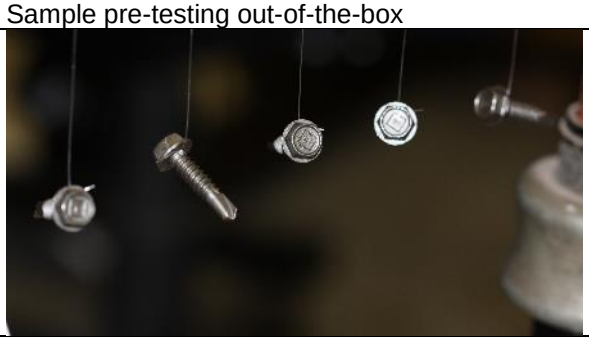
Group 3: Ceramic coated Hex 1/4 x 3 ¼ 304 Stainless silver	
Sample pre-testing installed	Sample pre-testing out-of-the-box
	
Sample 1	Sample 1
	

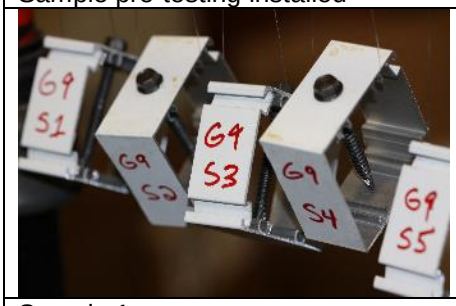
Group 4: Ceramic coated Hex 1/4 x 2 ¼ 304 Stainless silver	
Sample pre-testing installed	Sample pre-testing out-of-the-box
	
Sample 1	Sample 1
	

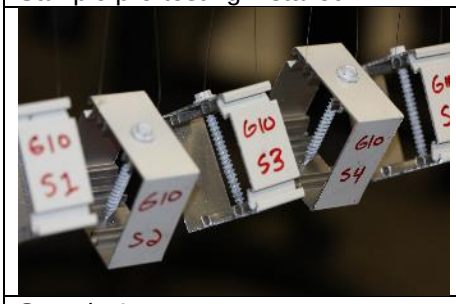
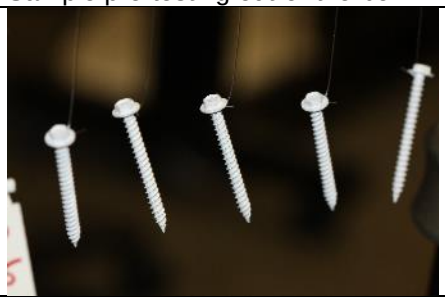
Group 5: Ceramic coated Hex 1/4 10 x 2 SMS 316 Stainless bronze	
Sample pre-testing installed	Sample pre-testing out-of-the-box
	
Sample 1	Sample 1
	

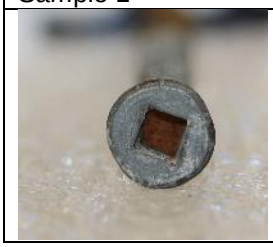
Group 6: Ceramic coated Hex 1/4 12 x ¾ SDS 316 Stainless white	
Sample pre-testing installed	Sample pre-testing out-of-the-box
	
Sample 1	Sample 1
	

Group 7: Ceramic coated Hex 5/16 14 x 1 SDS 316 Stainless bronze	
Sample pre-testing installed	Sample pre-testing out-of-the-box
	
Sample 1	Sample 1
	

Group 8: Ceramic coated Hex 3/8 14 x 1 SDS 316 Stainless bronze	
Sample pre-testing installed	Sample pre-testing out-of-the-box
	
Sample 1	Sample 1
	

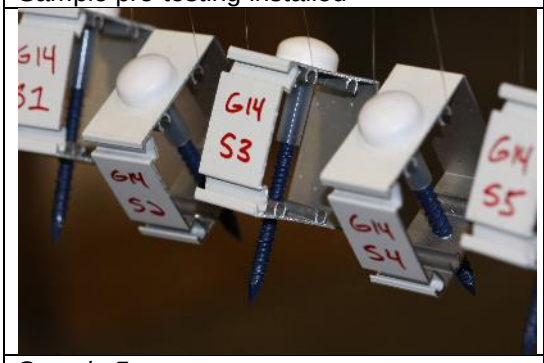
Group 9: Ceramic coated Hex 5/16 12 x 2 SDS 316 Stainless bronze	
Sample pre-testing installed	Sample pre-testing out-of-the-box
	
Sample 1	Sample 1
	

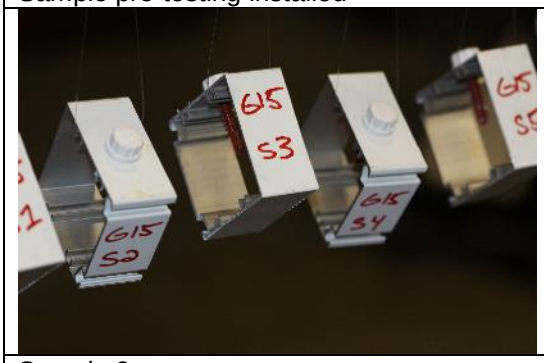
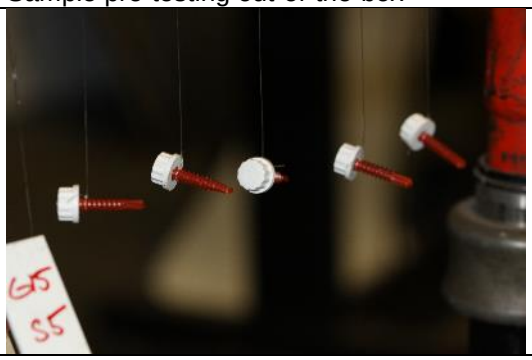
Group 10: Ceramic coated Hex 1/4 10 x 2 SDS Stainless white	
Sample pre-testing installed	Sample pre-testing out-of-the-box
	
Sample 1	Sample 1
	

Group 11: Tile screw mechanically galvanized	
Sample pre-testing installed	Sample pre-testing out-of-the-box
	
Sample 1	Sample 1
	

Group 12: Tile screw electroplated	
Sample pre-testing installed	Sample pre-testing out-of-the-box
	
Sample 2	Sample 2
	

Group 13: Tile screw mechanically galvanized	
Sample pre-testing installed	Sample pre-testing out-of-the-box
	
Sample 5	Sample 5
	

Group 14: Ceramic coated case hardened carbon steel masonry screw	
Sample pre-testing installed	Sample pre-testing out-of-the-box
	
Sample 5	Sample 5
	

Group 15: Ceramic coated case hardened carbon steel SDS	
Sample pre-testing installed	Sample pre-testing out-of-the-box
	
Sample 2	Sample 7