August 26, 2020

EVALUATION OF TWO COATING SYSTEMS FOR REFRIGERATED SHIPPING CONTAINERS

1.0 INTRODUCTION

Two lots of paint coated coupons from one Chinese paint supplier, each with four individual samples, were submitted for evaluation. These lots had the following specifications: 4.0 mm SPA-H steel with HSG + Mid Coating + Top Coating and 4.0 mm SPA-H Steel with Zinc Primer + Mid Coating + Top Coating. A summary of the sample identifications and test matrix is shown in Table 1. The purpose of the evaluation was to analyze the coated samples after being subjected to mechanical and salt spray testing.

The samples were evaluated by the following laboratory procedures:

1) Impact Test
2) Bend Test
3) Salt Spray Test per ASTM B117[1]
4) Scribe Test per ASTM D1654[2]
5) Adhesion Test per ASTM D3359-09[3]

1.1 Summary

The results of this evaluation found that the 4.0mm SPA-H steel with HGS + Mid Coating +Top Coating performed the best in all four test evaluations (impact, bend, scribe and adhesion). The 4.0 mm SPA-H steel with Zinc Primer + Mid Coating + Top Coating samples performed well all the test evaluations except for the bend test.

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[1] ASTM B 117 – *Standard Practice for Operating Salt Spray (Fog) Apparatus*
[2] ASTM D D1654 – *Standard Test Method for Evaluation of Painted or Coated Specimens Subjected to Corrosive Environments*
[3] ASTM D 3359 – *Standard Test Method for Measuring Adhesion by Tape Test*

2.0 EVALUATION

2.1 Visual Examination

Photographs of the four lots of paint coated coupons are shown in the as-received condition in Figure 1. Representative Keyence digital images of the surface condition for both types of paint samples are shown in Figure 2.

2.2 Impact Test

Samples A and E were impact tested, then salt spray tested per ASTM B117 for 500 hours. The impact test consisted of placing the samples coating side up on a support base at the bottom of a vertical ten-foot guide tube and then a 17-pound weight was dropped through the guide tube. Digital images of the surface condition of Samples A and E after the impact test and before the salt spray test are shown in Figure 3 – Figure 4. A photograph of the samples after a salt spray test is shown in Figure 7 and digital images are shown in Figure 8 – Figure 9. The results are summarized in Table 2. Samples A and E did not exhibit de-bonding of the coating at the impact point or cracks in the coating at the indentation slope.

2.3 Bend Test

Samples B and F were three-point bend tested, then salt spray tested per ASTM B117 for 500 hours. Both coupons were placed coating-side down for the bend test. Digital images of the surface condition of Samples B and G after the bend test, before the salt spray test are shown in Figure 5 – Figure 6. A photograph of the samples after a salt spray test are shown in Figure 10 and digital images are shown in Figure 11 – Figure 12. The results are summarized in Table 3. Samples B and G had cracks in the coating at the bend radius.

2.4 ASTM B117: Salt Spray Test

All samples were exposed to salt spray testing per ASTM B117 for 500 hours. The degree of blistering was analyzed after 168 hours, 336 hours, and 500 hours of salt spray exposure per ASTM D714.[4] The results are summarized in Table 4. The number value refers to the blister size and ranges from 10 to 0, where a rating of 10 represents no blistering. The frequency of blistering is designated as: dense (D), medium dense (MD), medium (M), and few (F). The distribution of rusting is designated as: pinpoint rusting (P) and general rusting (G).

The degree of rusting was analyzed after 168 hours, 336 hours, and 500 hours of salt spray exposure per ASTM D610.[5] The results are summarized in Table 4. The number value refers to the percentage of the total surface area being rusted and ranges from 0 to 10, where a rating of 10 represents no rusting and a rating of 0 represents 50% and greater of the total surface area being rusted. All of the samples performed well in the salt spray test with the exception of Sample F.

[4] ASTM D 714 - *Standard Test Method for Evaluating Degree of Blistering of Paints*
[5] ASTM D 610 – *Standard Practice for Evaluating Degree of Rusting on Painted Steel Surfaces*

2.5 ASTM D1654: Scribe Test

Samples C and G were scribed per ASTM D1654, then salt spray tested per ASTM B117 for 500 hours. The results are summarized in Table 4. A photograph of the surface condition of Samples C and G after the scribe and salt spray is shown in Figure 13 and digital images are shown in Figure 14 – Figure 15.

2.6 ASTM D3359: Adhesion Test

Samples D and H were salt spray tested per ASTM B117 for 500 hours, then tested for adhesion performance per ASTM D3359 Method B. The samples were exposed to a salt fog environment for 500 hours, then three adhesion tests were performed on the coated surface. A photograph of the surface condition of Samples D and H after the salt spray and adhesion are shown in Figure 16 and digital images are shown in Figure 17 – Figure 18.

The results are summarized in Table 5. Three replicates were examined for each sample. The adhesion is rated on a scale from 5B to 0B, where 5B has completed smooth edges of the cuts and no coating detachment of the lattice while 0B has flaking and 65% or greater coating detachment of the lattice. Both samples performed well in the adhesion test, rating a 5B, indicating less than 5% flaking.

3.0 DISCUSSION

The HGS + Mid Coating + Top Coating performed very well in every evaluation. In the bend test, both samples, zinc primer (Sample F) and HGS (Sample B), exhibited cracks in the coating at the apex of the bend, shown in Figure 5 and Figure 6. After 500 hours of salt spray, the zinc primer samples exhibited extensive rust scoring 4 out of 10 (Figure 12), while the HGS sample exhibited only a small amount of rust and zinc salting (Figure 11) and scored 9 out of 10 in ASTM D 610 grading scale. The HGS samples performed better in the scribe test (Sample C) except for some very small blisters that were found adjacent to the scribe line after 500 hours of salt spray resulting in an ASTM D 714 blister rating of 8 and an ASTM D 1654 scribe rating of 9. The Zinc Primer sample (Sample G) was found to have bleeding corrosion and undercutting along the complete scribe line after the 500 hours of salt spray which resulted in an ASTM D 714 blister rating of 8 and an ASTM D 1654 scribe rating of 8.

CONCLUSIONS

The following conclusions are based upon the submitted samples and the evidence gathered:

1. The 4.0mm SPA-H steel with HGS + Mid Coating +Top Coating had the overall best performance in each impact, bend, scribe and adhesion testing.
2. The zinc primer specimen performed poorly in the bend test.
3. 4.0mm SPA-H steel with HGS + Mid Coating +Top Coating had superior corrosion performance in the impact and adhesion tests where the specimens exhibited no rust.

4. Even though cracking was observed on the apex of the bend specimen for the 4.0mm SPA-H steel with HGS + Mid Coating +Top Coating sample, it exhibited very little corrosion after 500 hours exposure to salt spray.

5. The overall lack of obvious rust present on the 4.0mm SPA-H steel with HGS + Mid Coating +Top Coating samples after 500 hours of salt spray exposure indicate that containers painted with this coating system would likely require less cosmetic maintenance over time than containers painted with the zinc primer coating system.

Table 1
Test Matrix

Coating System	Material	Sample Identification	Testing Performed				
			Impact	Bend	Scribe	Adhesion	None
HGS[6] + Mid Coating + Top Coating	SPA-H[7] 4.0mm	A	X				
		B		X			
		C			X		
		D				X	
Zinc Primer + Mid Coating + Top Coating	SPA-H[13] 4.0mm	E	X				
		F		X			
		G			X		
		H				X	

Table 2
Results of Impact Test

Sample Identification	Coating De-Bonded from Substrate Indentation Base	Coating Cracked on Indentation Slope
A	No	No
E	No	No

Table 3
Results of Bend Test

Sample Identification	Coating Cracked on Bend Radius
B	Yes
F	Yes

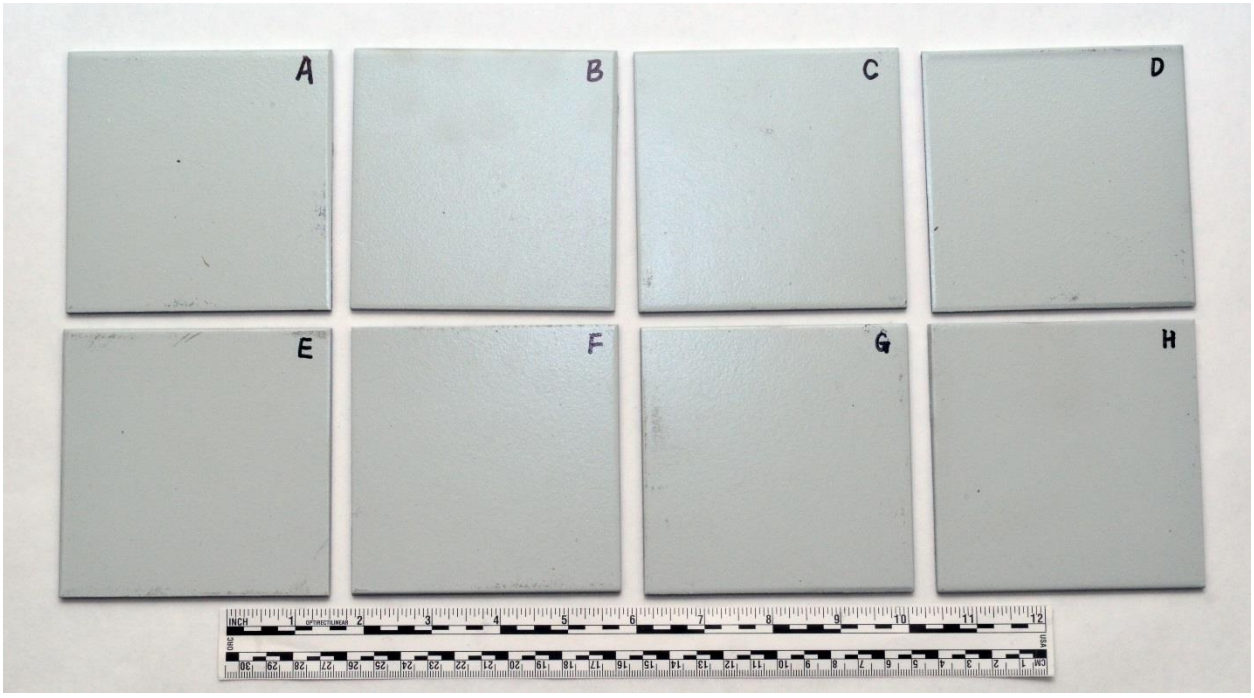
[6] HGS – hot galvanize spray (hot zinc spray)
[7] JIS G 3125 – Superior atmospheric corrosion resisting rolled steels

Table 4
Results of Evaluation Based on ASTM D714 and D1654 after 500 Hours of Salt Spray Exposure

		Salt Spray after 168 hours		Salt Spray after 336 hours		Salt Spray after 500 hours		
Sample Identification	Test	ASTM D610 Red Rust	ASTM D714 Blister	ASTM D610 Red Rust	ASTM D714 Blister	ASTM D610 Red Rust	ASTM D714 Blister	ASTM D1654 Scribe
A	Impact	10	10	10	10	10	10	
B	Bend	10	10	9	10	9	10	
C	Scribe	10	10	10	10	10	8 Few	9
D	Adhesion	10	10	10	10	10	10	
E	Impact	8	10	8	10	8	10	
F	Bend	5	10	4	10	4	10	
G	Scribe	10	10	10	10	10	8	8
H	Adhesion	10	10	9	10	9	10	

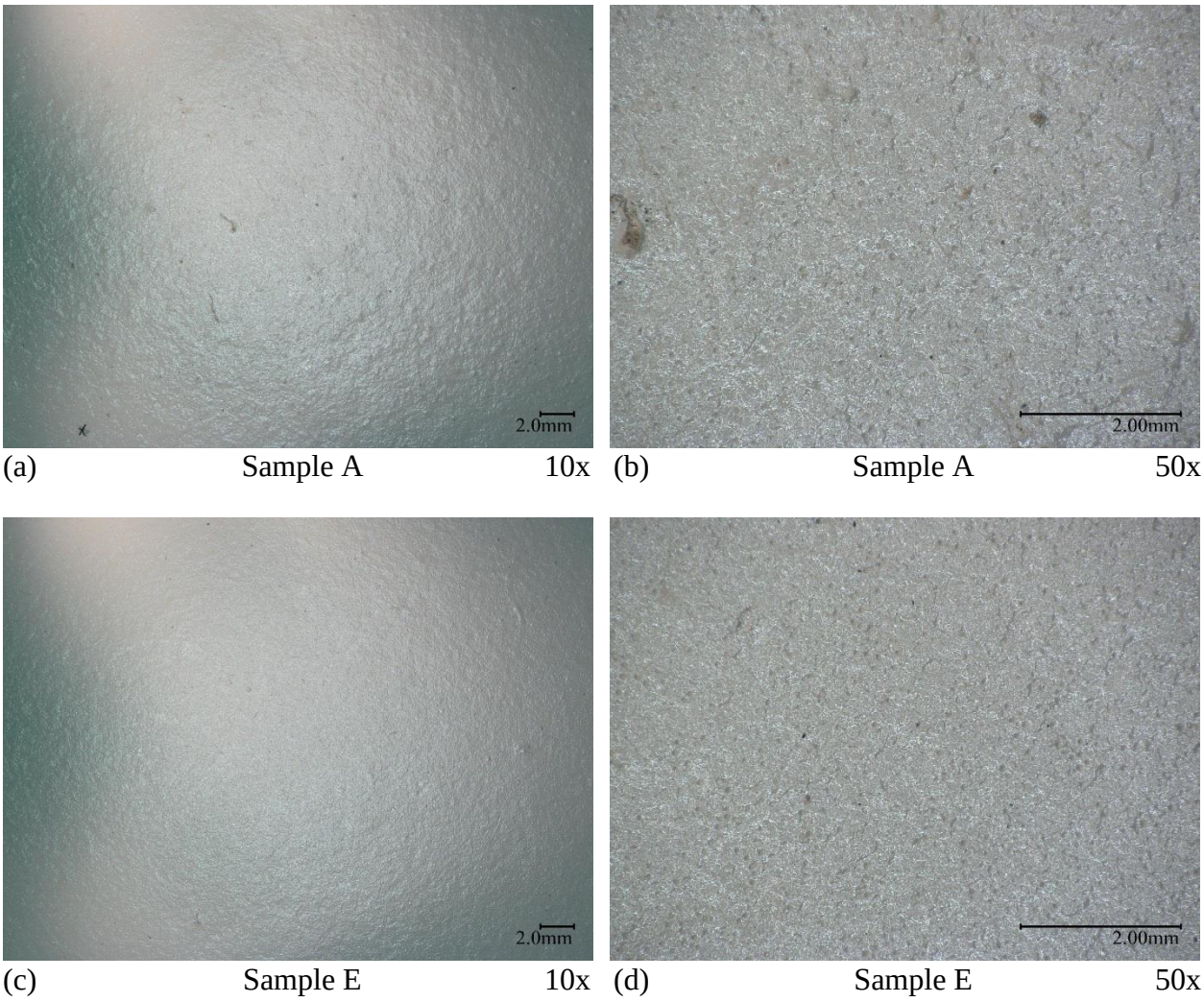
Table 5
Results of Adhesion Test After 500 Hours Salt Spray Exposure
Evaluation Based on ASTM D 3359-09, Method B

Sample Identification	Replicate	Adhesion per ASTM D 3359-09, Method B
D	T1 T2 T3	5B 5B 5B
H	T1 T2 T3	5B 5B 5B



(a) Samples A – H, Coating Side

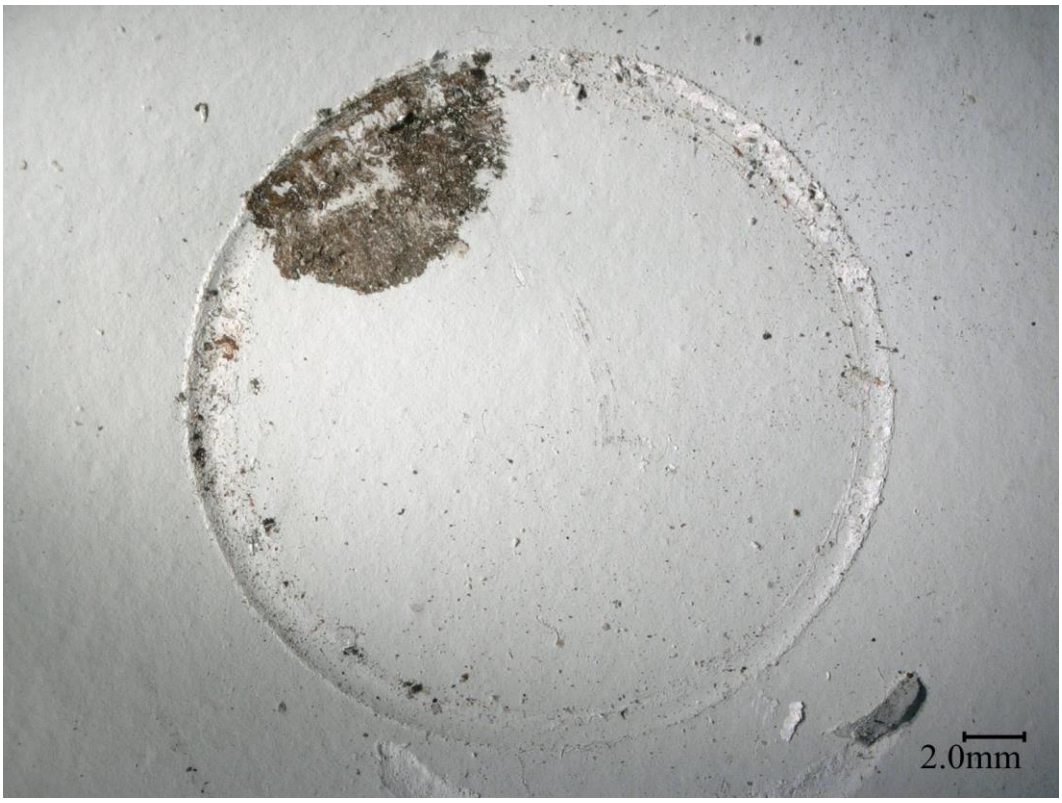
Figure 1 Photographs of the coating side of samples A – H in the as-received condition.



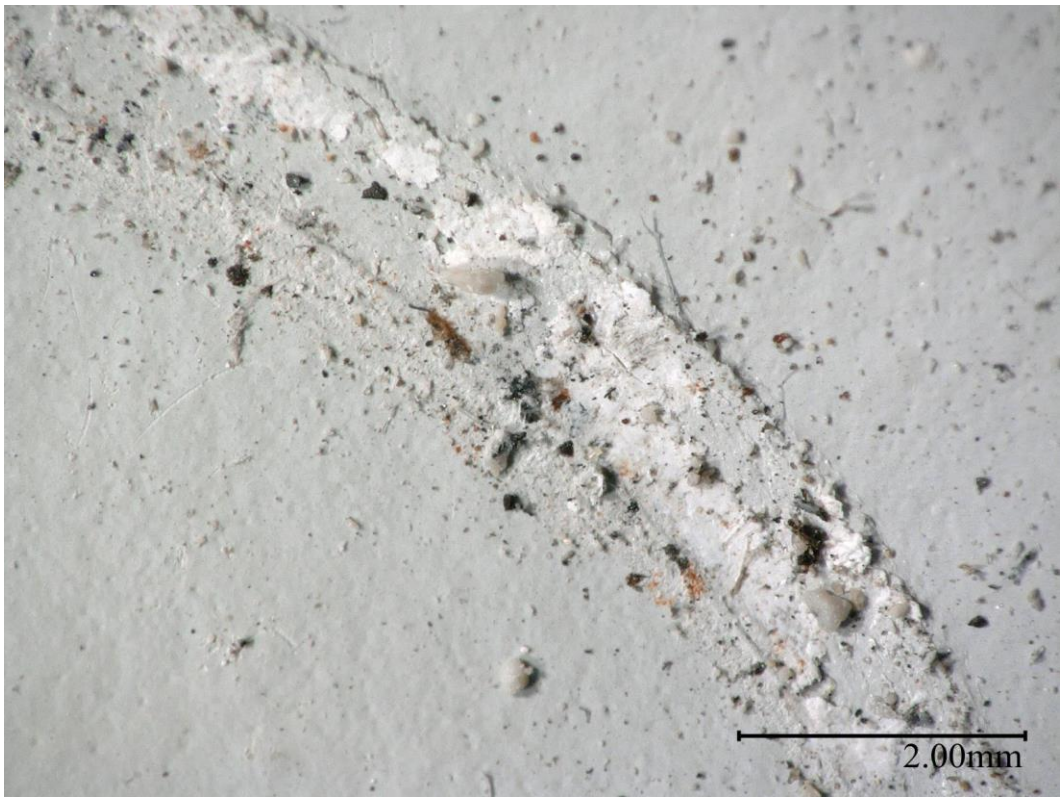
(a) Sample A 10x (b) Sample A 50x

(c) Sample E 10x (d) Sample E 50x

Figure 2 Digital microscope images of (a – b) Sample A and (c – d) Sample E.

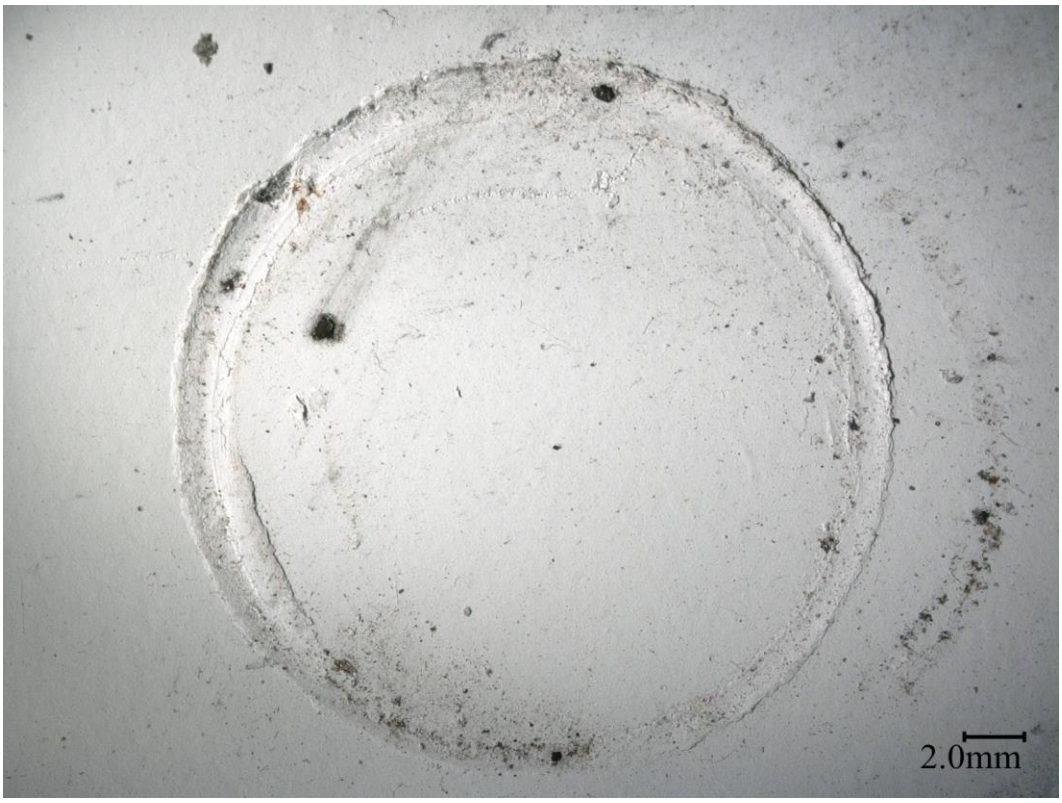


(a) Sample A 10X

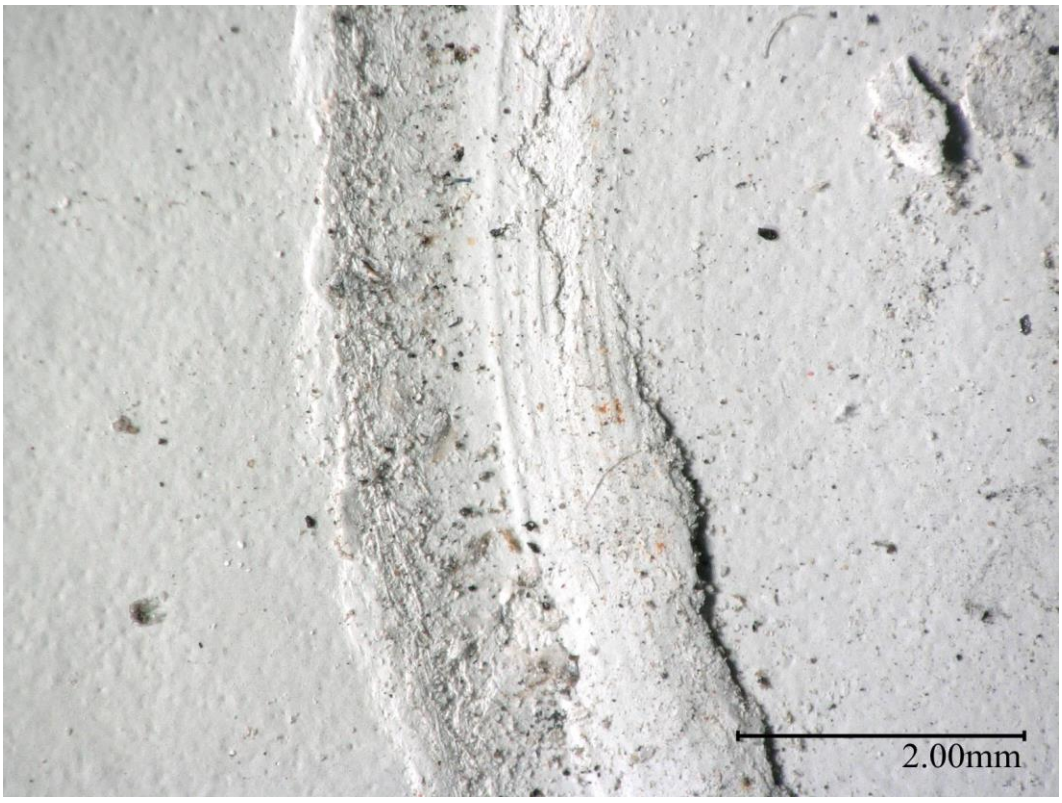


(b) Sample A, Box in (a) 50X

Figure 3 Digital microscope images of Sample A after an impact test.

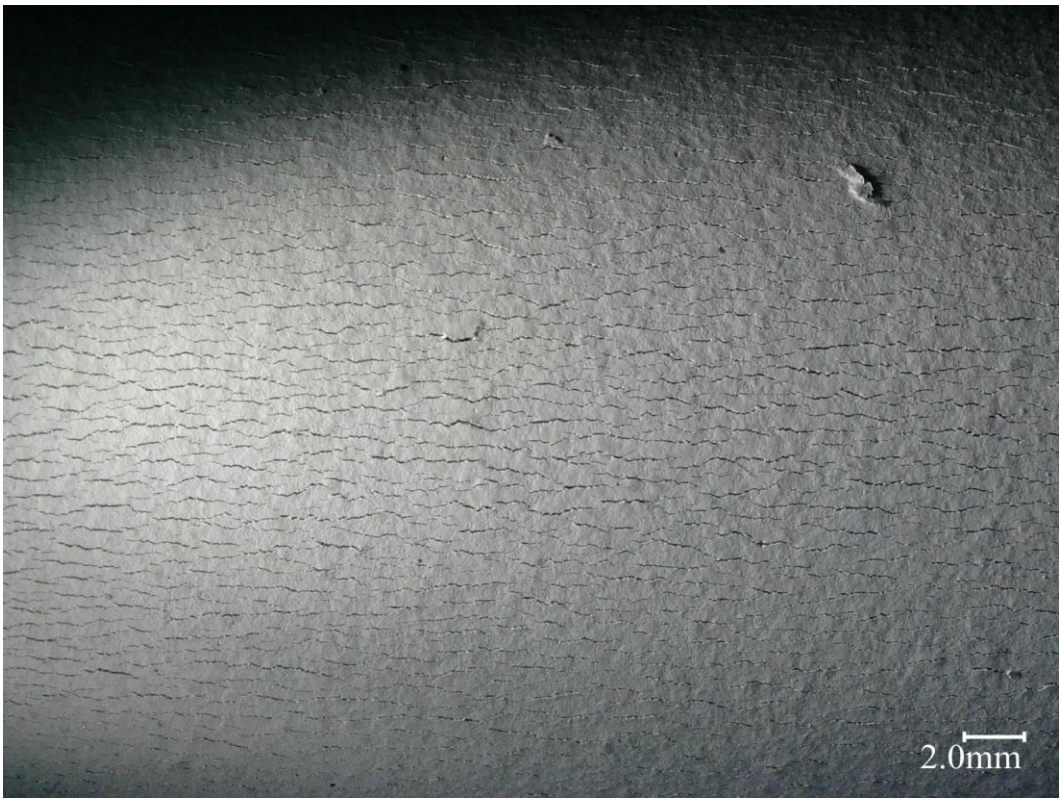


(a) Sample E 10X

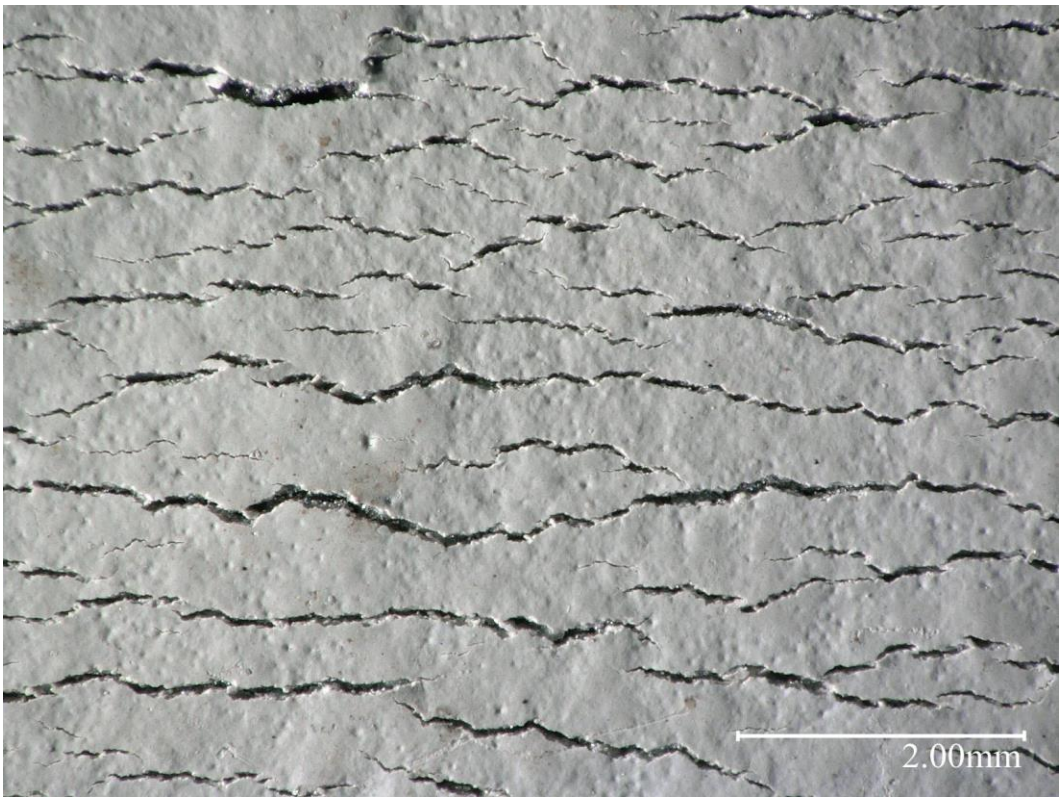


(b) Sample E, Box in (a) 50X

Figure 4 Digital microscope images of Sample E after an impact test.

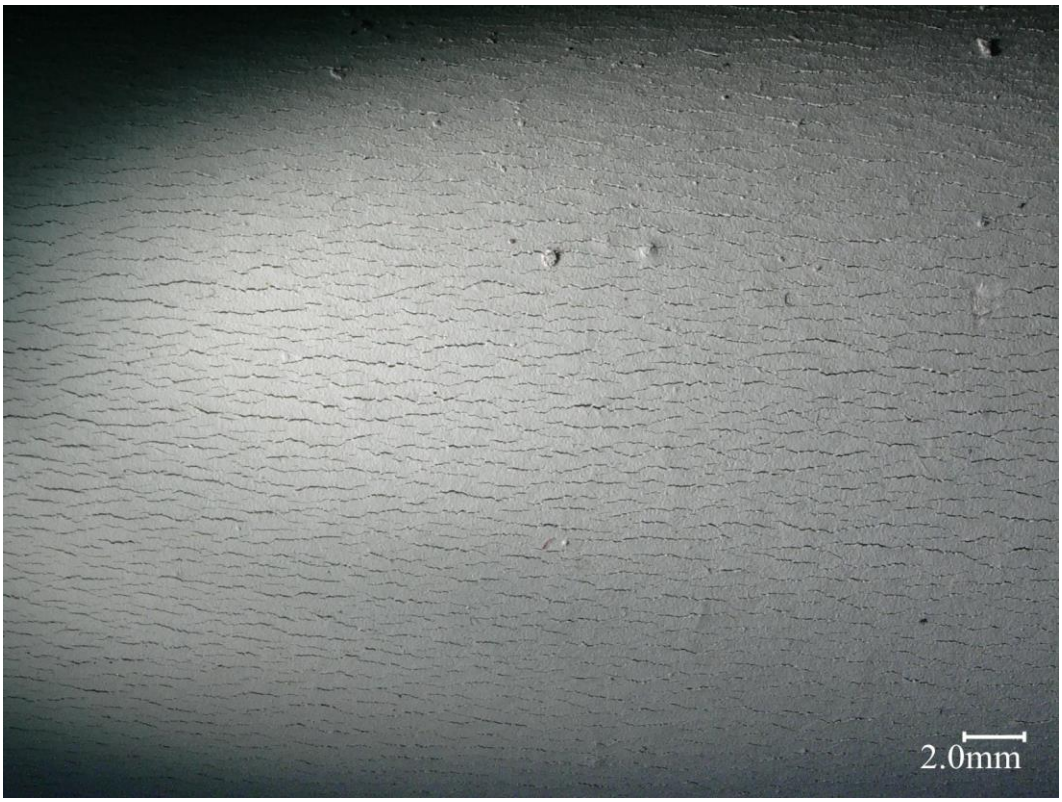


(a) Sample B 10X

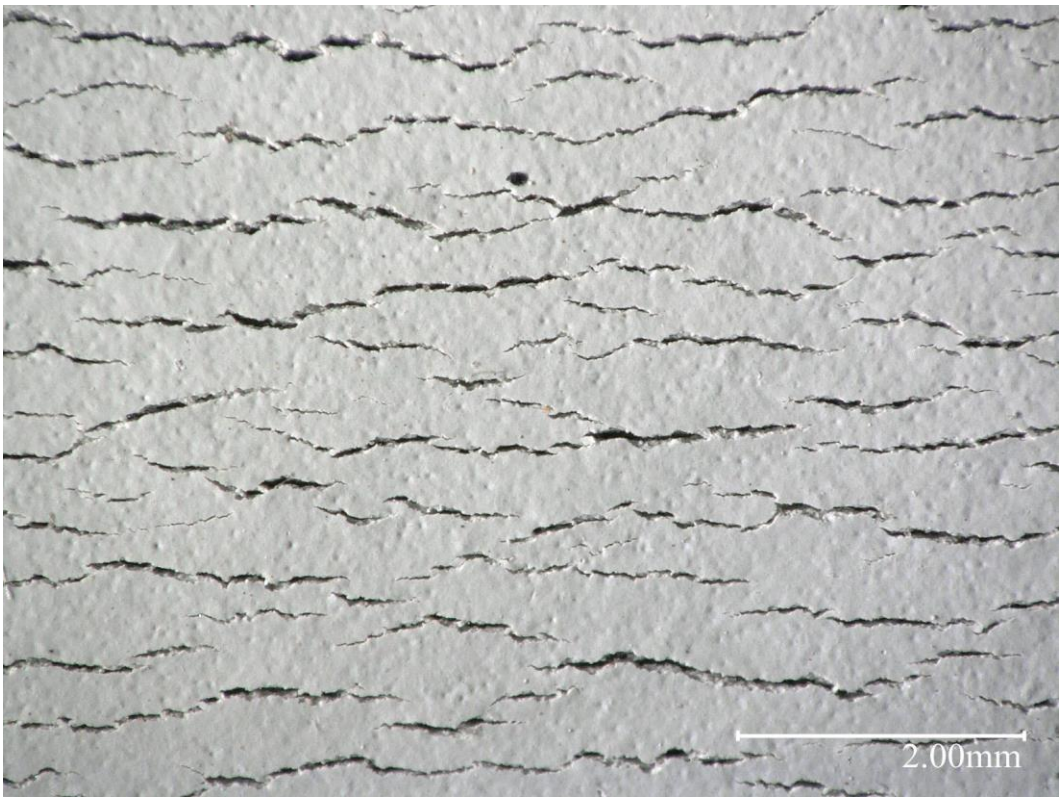


(b) Sample B, Box in (a) 50X

Figure 5 Digital microscope images of Sample B after a bend test.

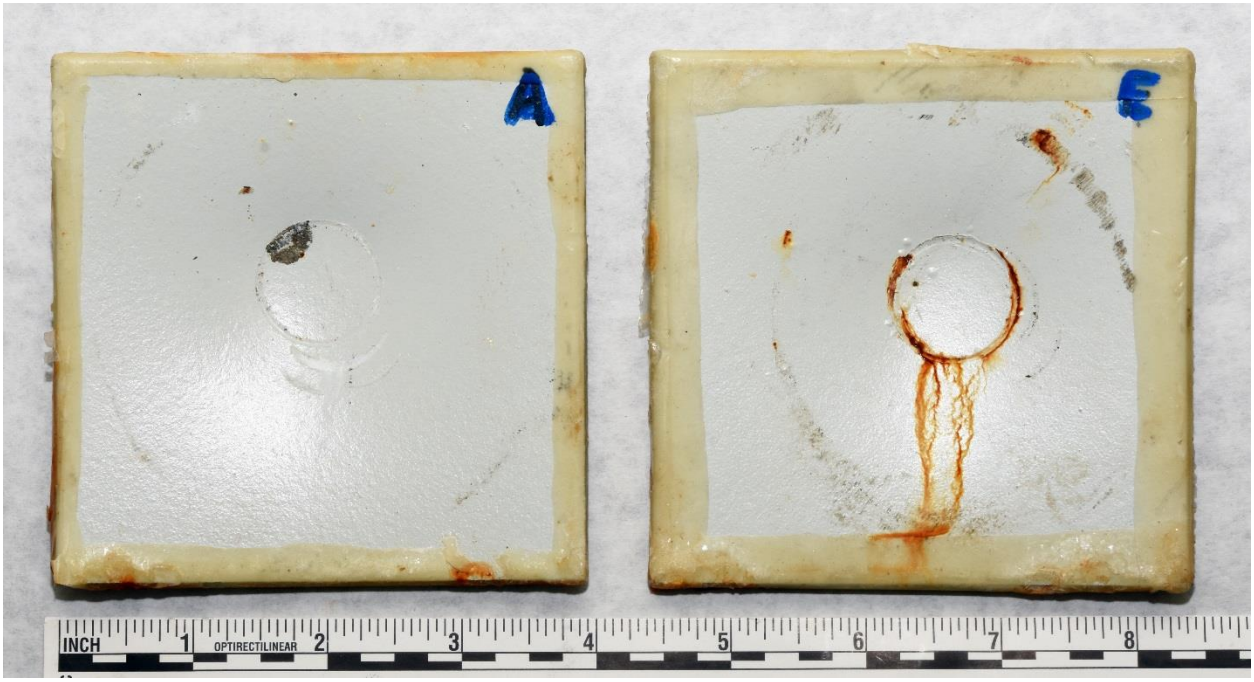


(a) Sample F 10X



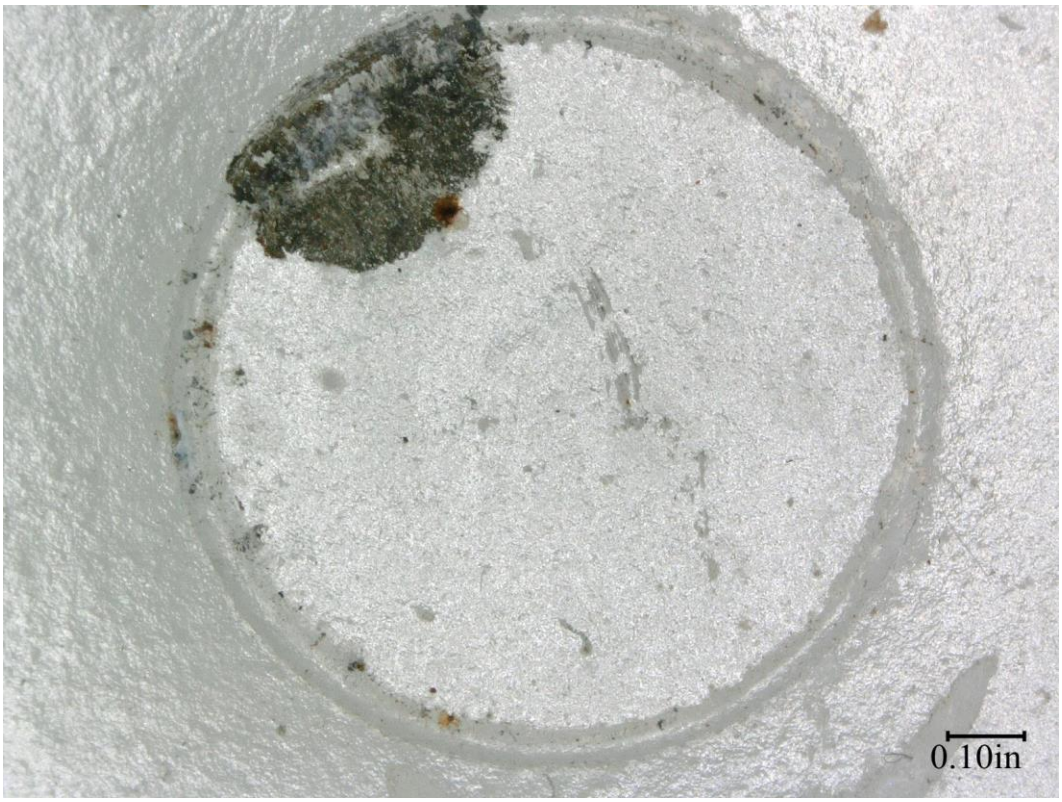
(b) Sample F, Box in (a) 50X

Figure 6 Digital microscope images of Sample F after a bend test.

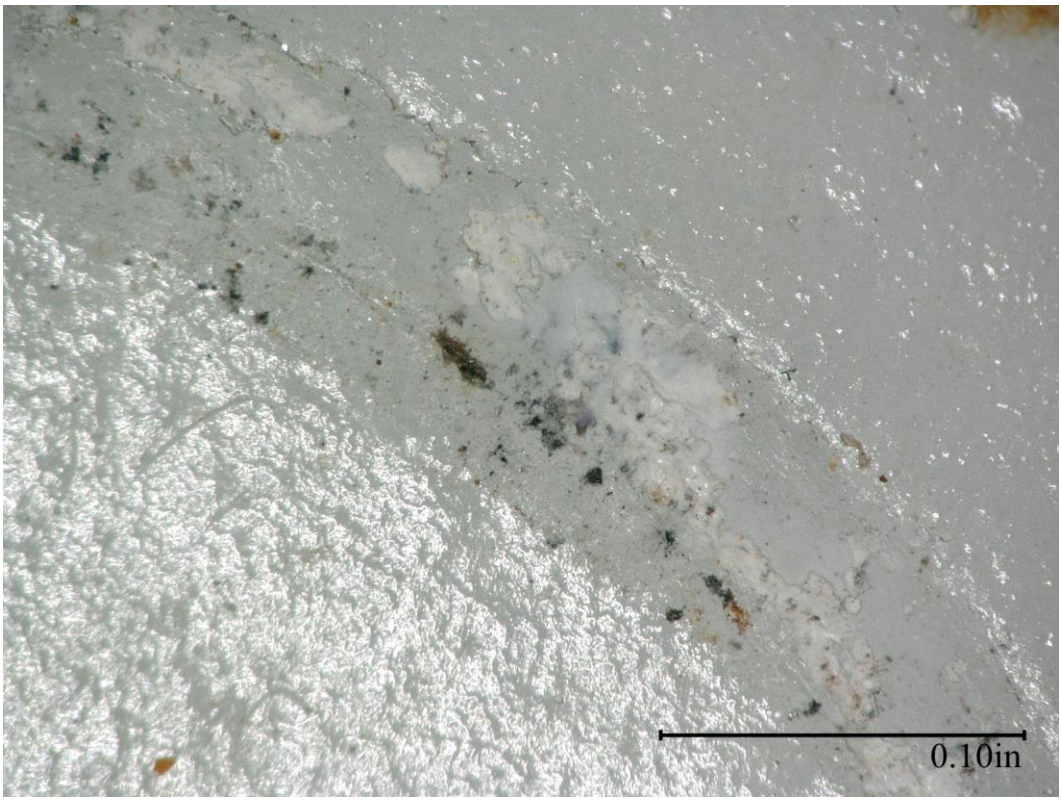


(a) Sample A and Sample E

Figure 7 Photograph of Sample A (left) and Sample E (right) after impact testing and salt spray.

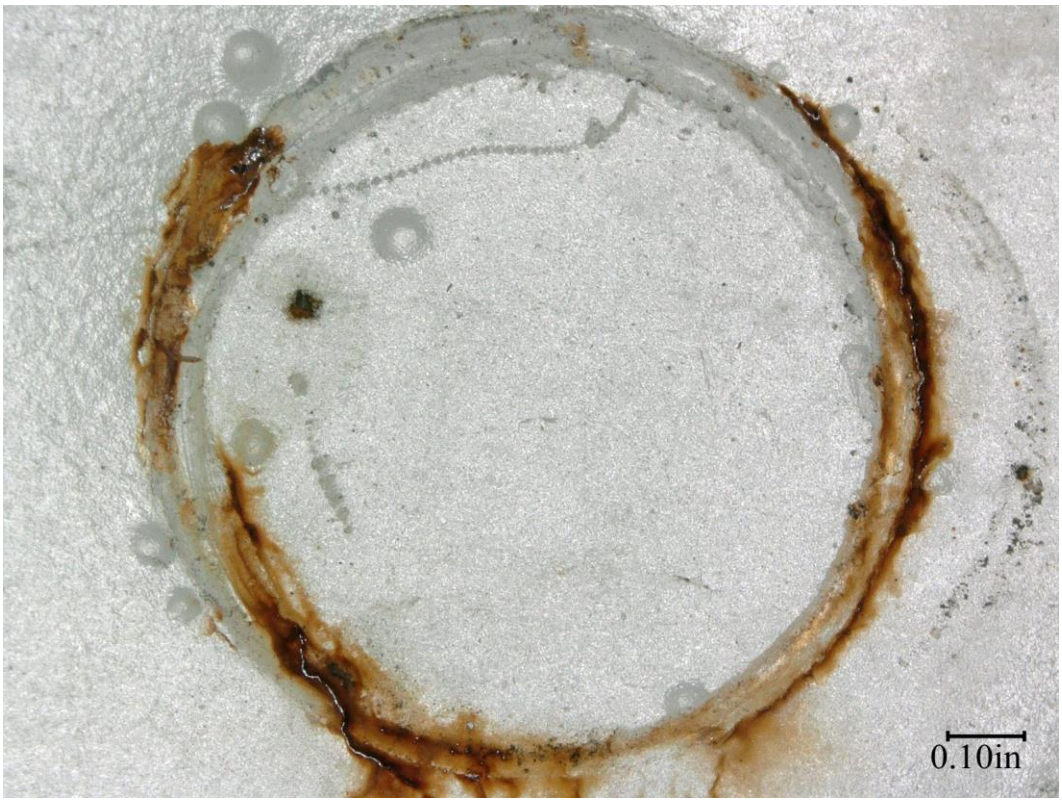


(a) Sample A 10X



(b) Sample A, Box in (a) 50X

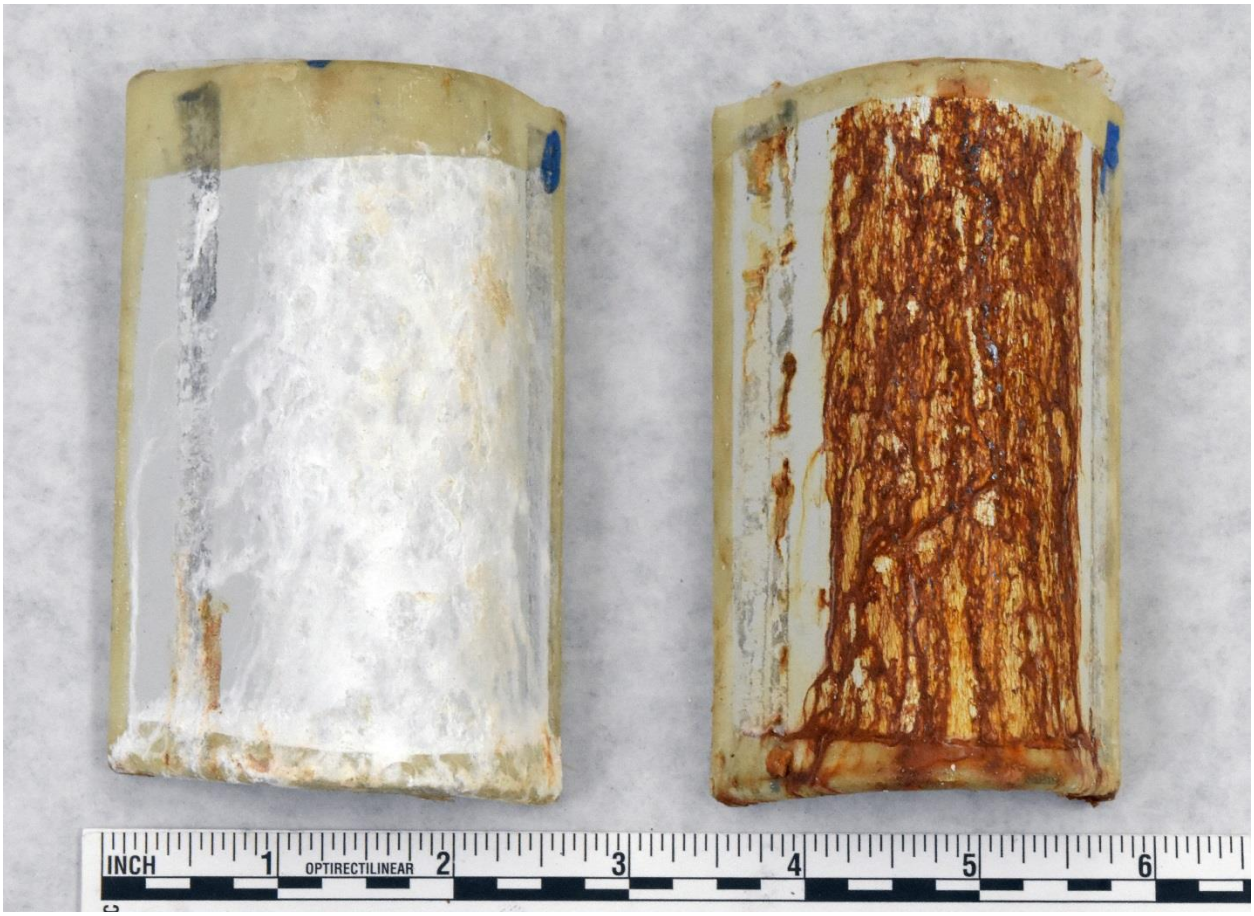
Figure 8 Digital microscope images of Sample A after an impact test and salt spray.



(a) Sample E 10X

(b) Sample E, Box in (a) 50X

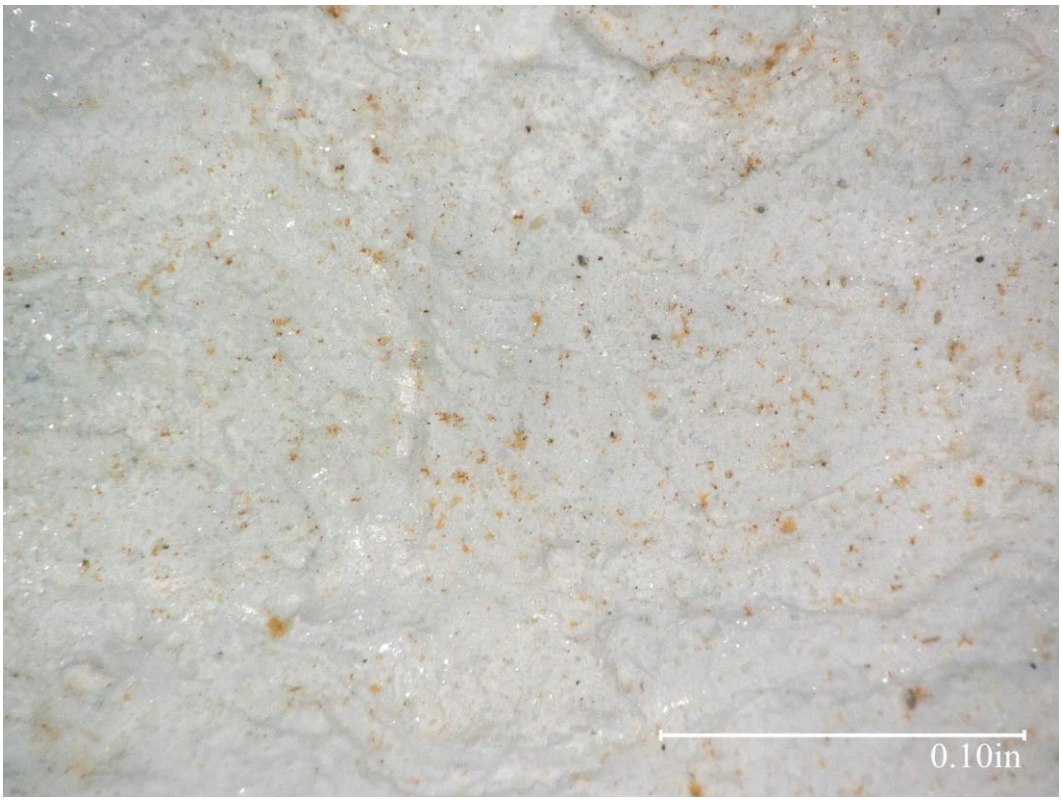
Figure 9 Digital microscope images of Sample E after an impact test and salt spray.



(a) Sample B and Sample F

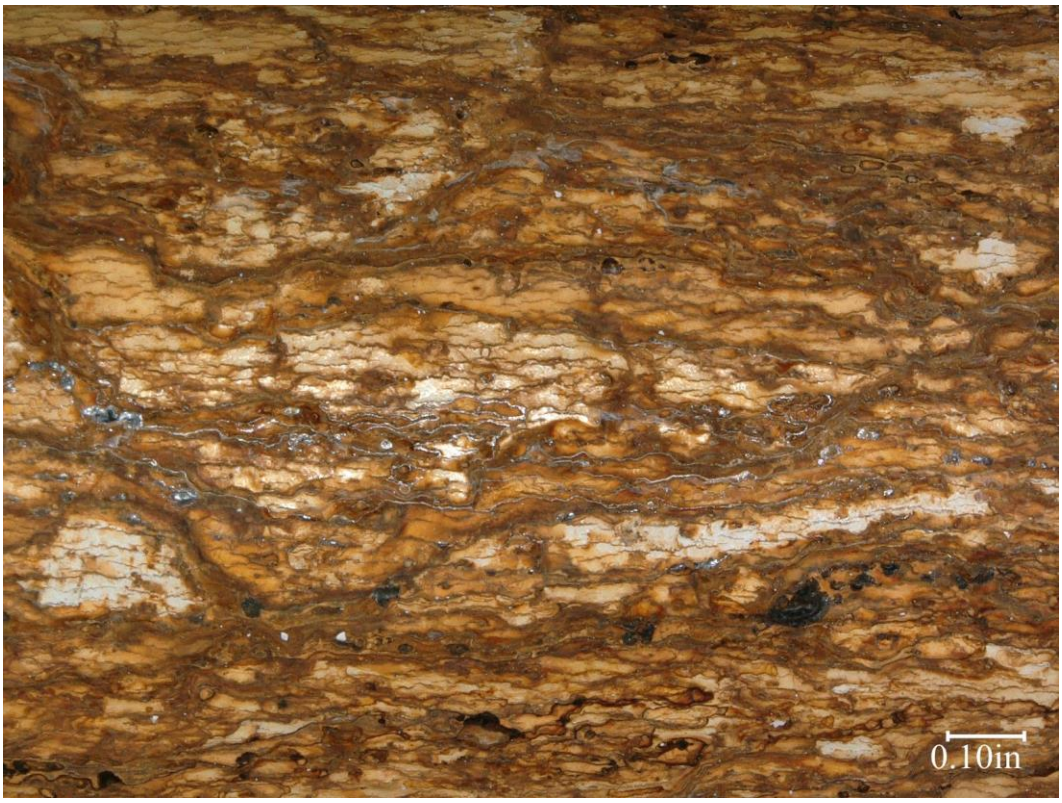
Figure 10 Photograph of Sample B (left) and Sample F (right) after bend testing and salt spray.

(a) Sample B 10X



(b) Sample B, Box in (a) 50X

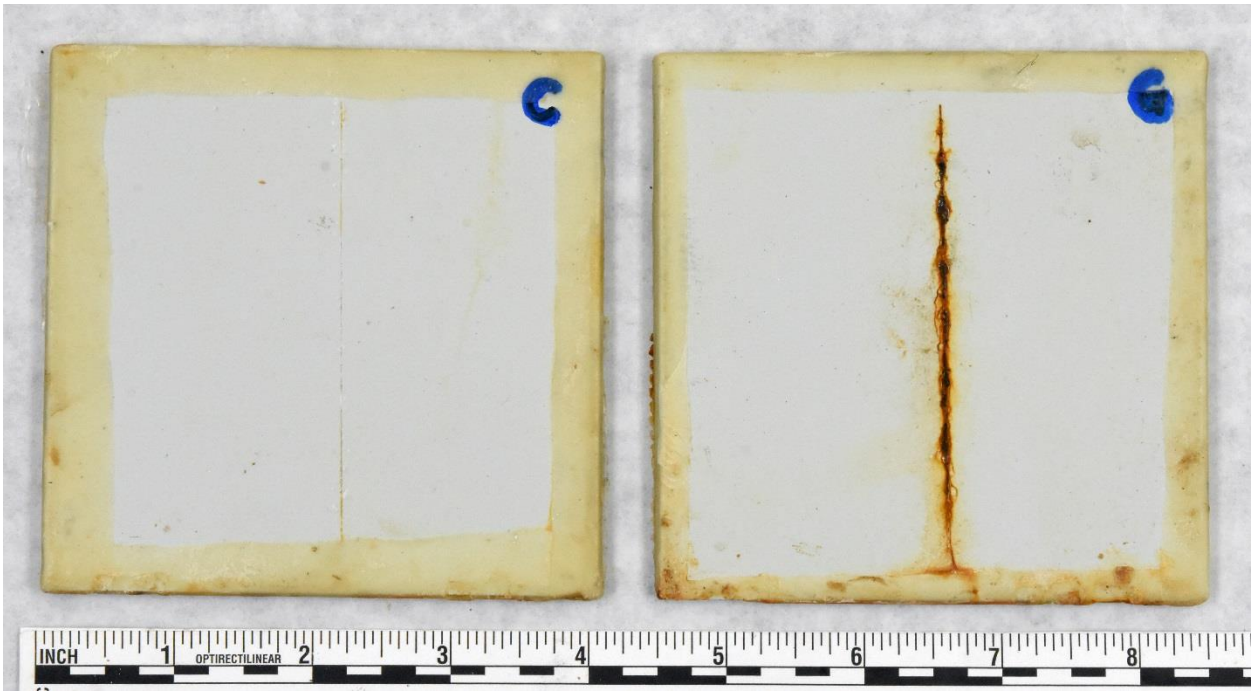
Figure 11 Digital microscope images of Sample B after a bend test and salt spray.



(a) Sample F 10X

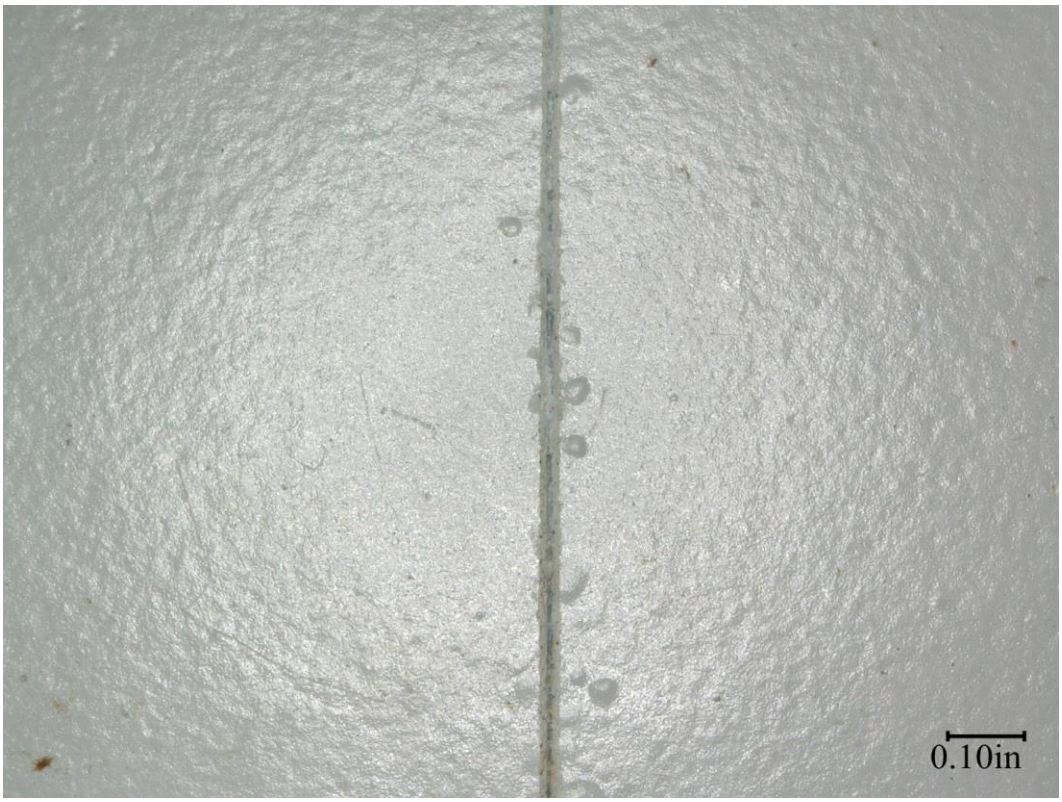
(b) Sample F, Box in (a) 50X

Figure 12 Digital microscope images of Sample F after a bend test and salt spray.

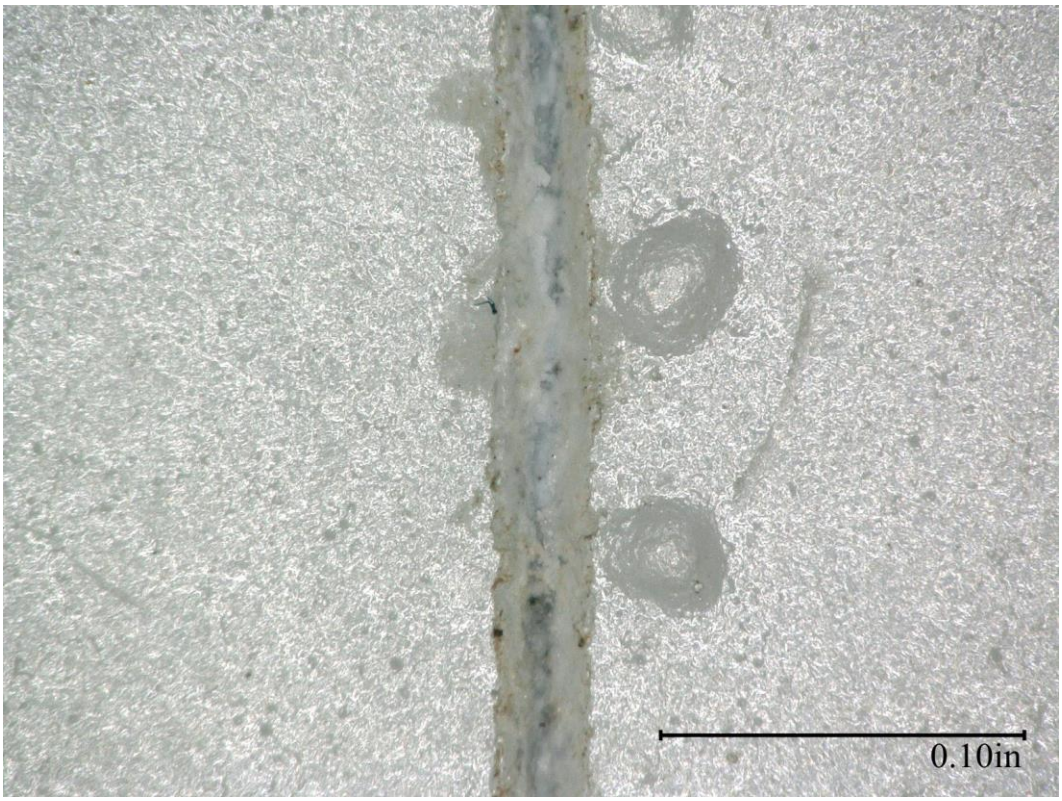


(a) Sample C and Sample G

Figure 13 Photograph of Sample C (left) and Sample G (right) after scribe and salt spray.



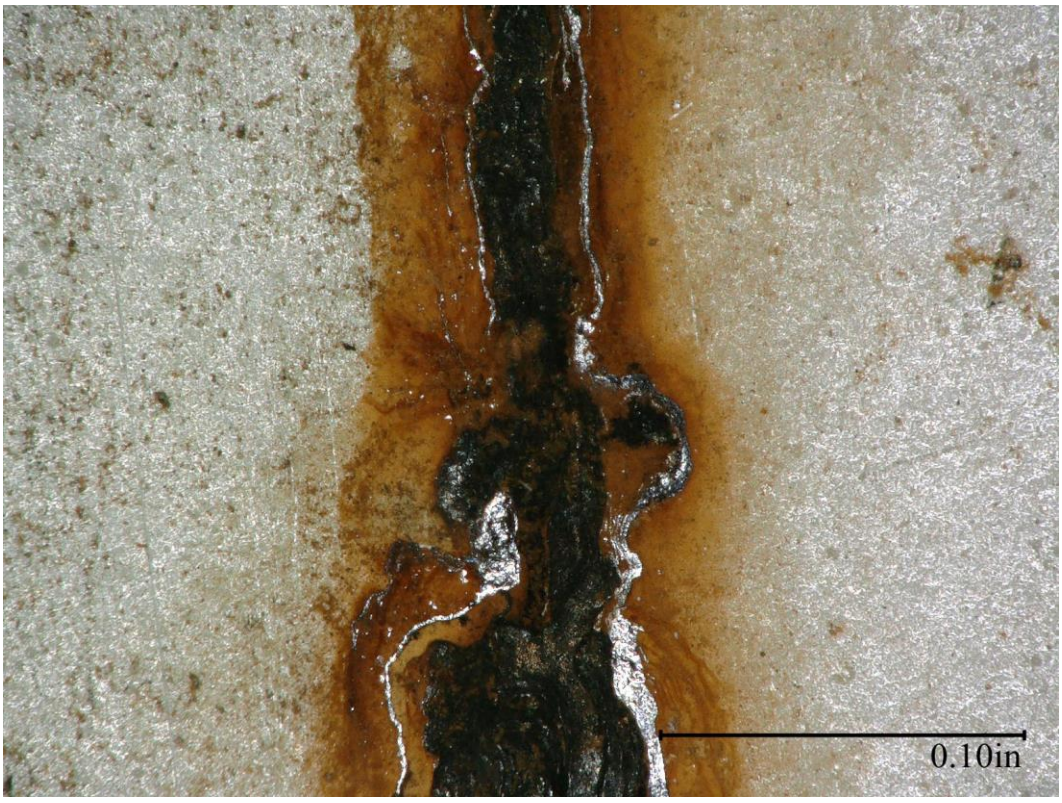
(a) Sample C 10X



(b) Sample C, Box in (a) 50X

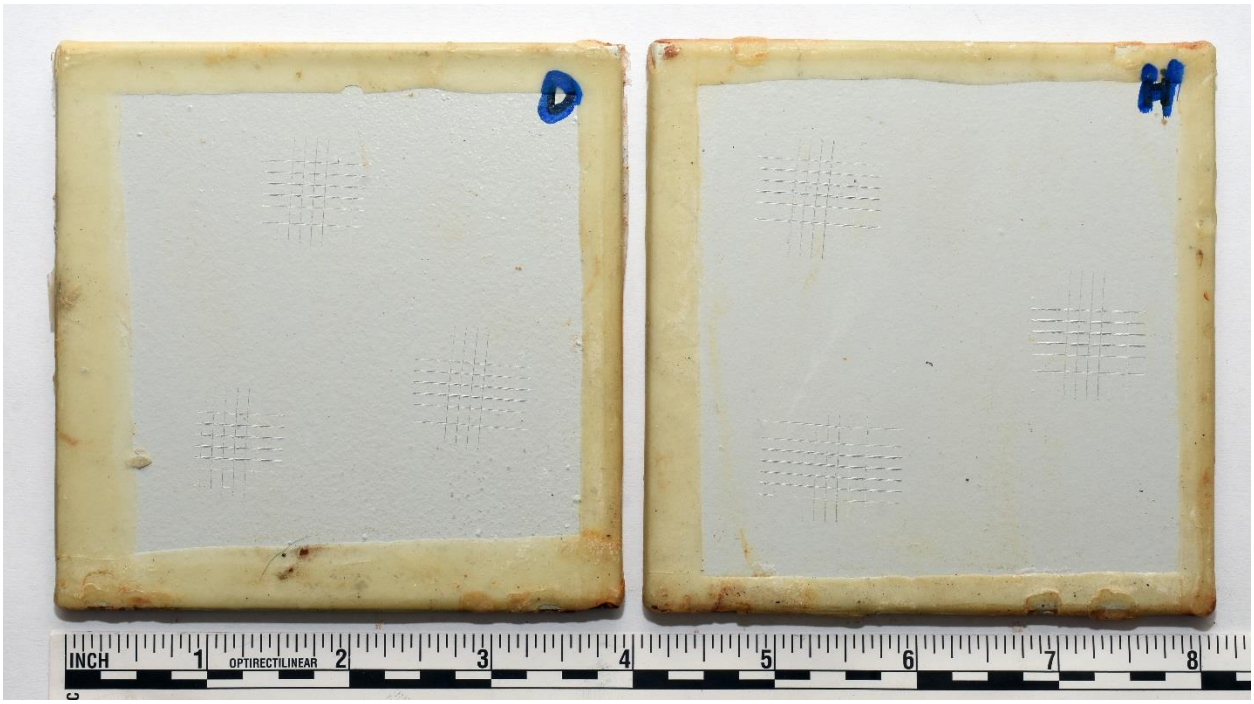
Figure 14 Digital microscope images of Sample C after a scribe and salt spray.

(a) Sample G 10X



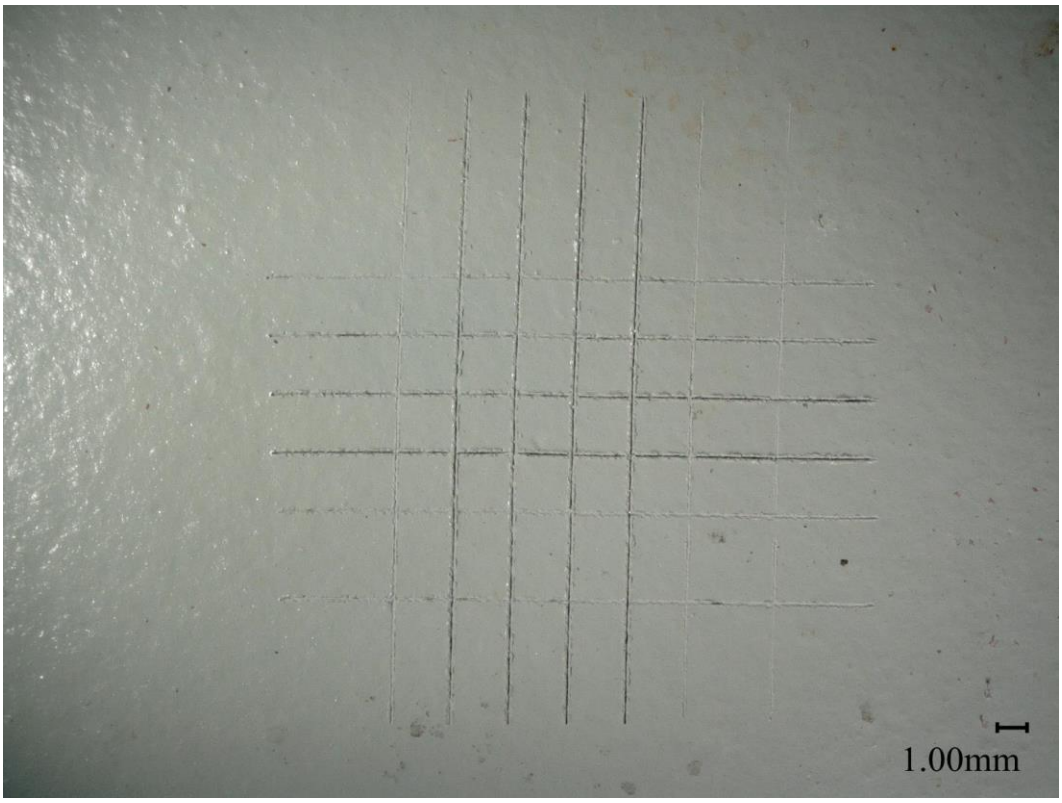
(b) Sample G, Box in (a) 50X

Figure 15 Digital microscope images of Sample G after a scribe and salt spray.

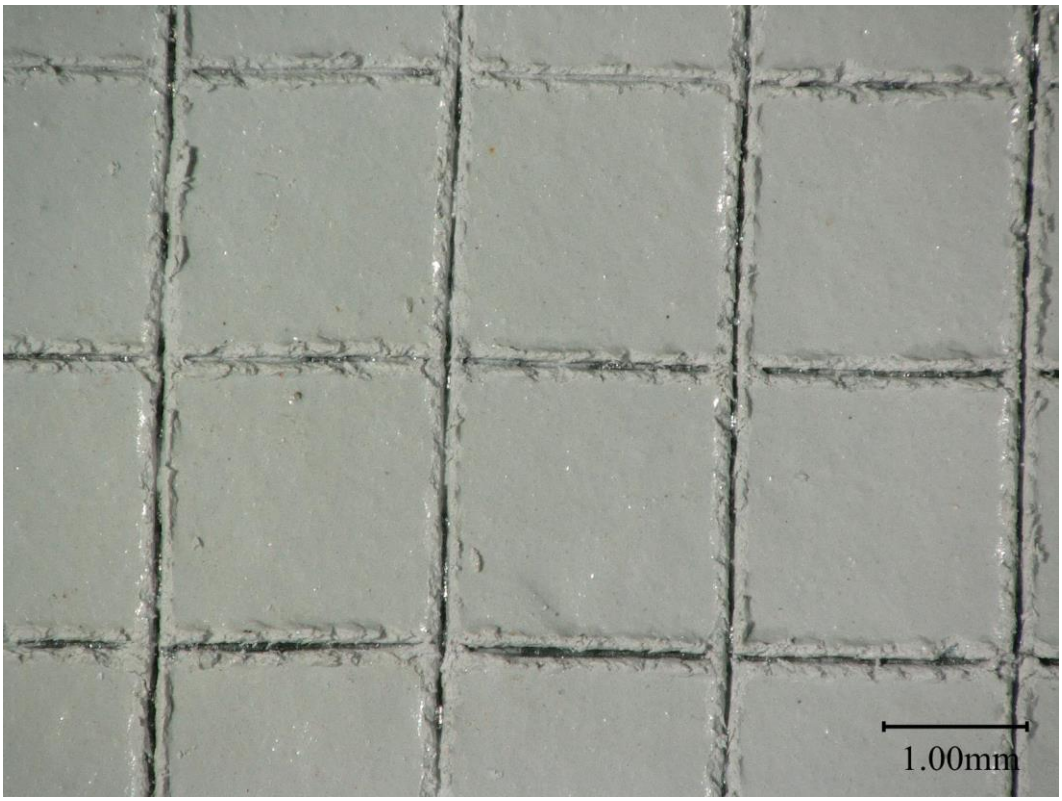


(a) Sample D and Sample H

Figure 16 Photograph of Sample D (left) and Sample H (right) after salt spray and adhesion.

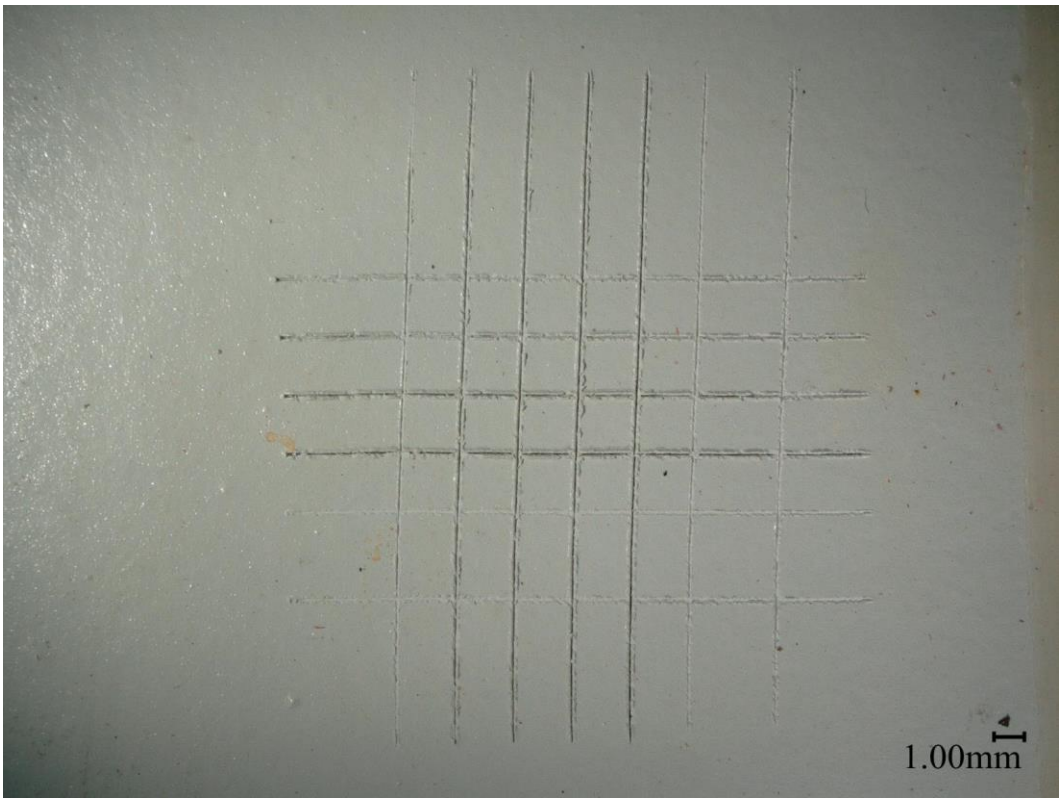


(a) Sample D 10X

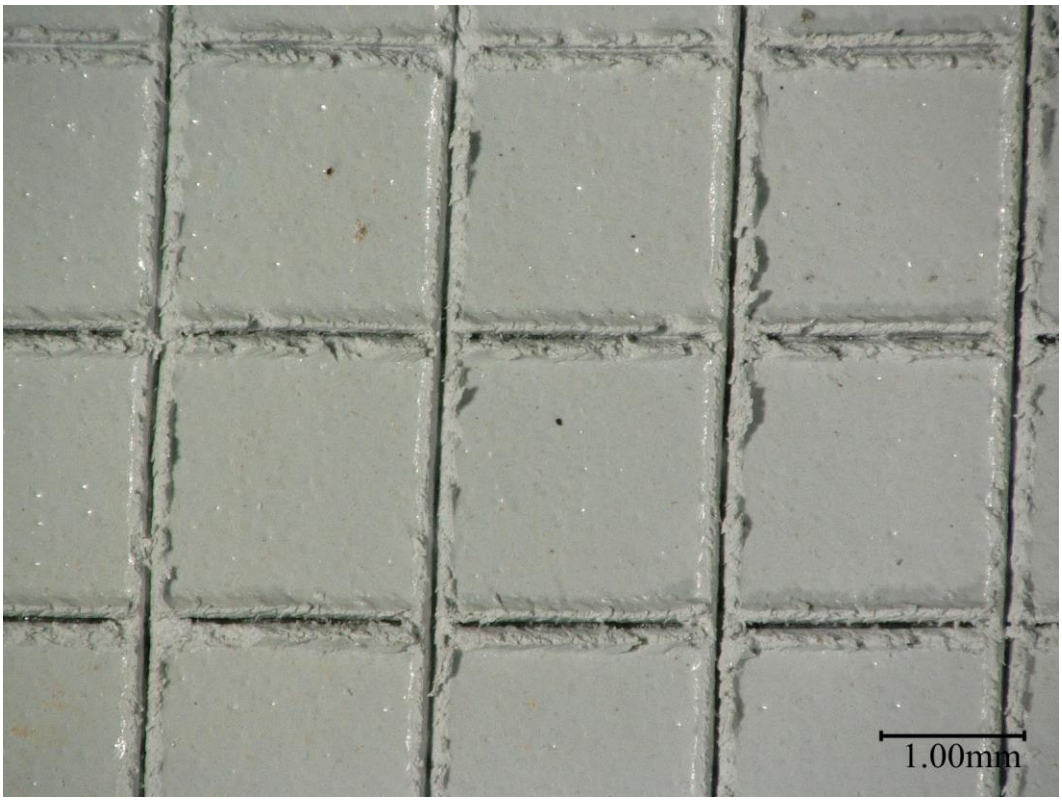


(b) Sample D, Box in (a) 50X

Figure 17 Digital microscope images of Sample D after a salt spray and adhesion.



(a) Sample H 10X



(b) Sample H, Box in (a) 50X

Figure 18 Digital microscope images of Sample H after a salt spray and before adhesion.