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Adhesion Testing of Firebricks From Launch Pad 39A Flame Trench After STS-124

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July 2009

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ABSTRACT

During the launch of STS-124 from LC-39A, approximately 3500 bricks were liberated from the SRB flame trench east wall. This report presents results of adhesion testing that was performed on the firebricks in the flame trench of LC-39A. This testing was done to determine the strength of the epoxy bonded firebrick to the backing cement wall. The testing procedure consisted of drilling a 2-inch inside diameter (ID) core in the brick, attaching a pull stub, and performing the pull tests. In total, 18 cores were drilled. Of these, 10 of the cores were broken away from the cement backing wall during drilling. Adhesion testing of the remaining 8 was performed. Only one of the cores, core 8W, was pulled away from the concrete backing wall during testing. This core was removed with a pressure of 82 pounds per square inch (psi). For the 7 other cores tested, failure of the adhesion test system occurred in the front surface of the brick where the pull stub was attached. The average pull-off tensile strength for these 7 measurements was 86.3 psi. Since the failure did not occur at the firebrick/epoxy/concrete interface, it can be assumed that the interface of these 7 cores is stronger than 86.3 psi. Laboratory tests show that the outer face side of a firebrick exposed to launches has a weaker tensile strength than the interior side that was hidden. All the cores were photo-documented. In addition, pH testing was done on one brick core and one piece of the cement wall. The cement was found to have a pH of 13, while the brick surface had a pH near 5.

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ADHESION TESTING OF FIREBRICKS FROM LAUNCH PAD 39A FLAME TRENCH AFTER STS-124

1 BACKGROUND

During the launch of STS-124 from launch complex (LC) 39A, approximately 3500 bricks were liberated from the Solid Rocket Booster (SRB) flame trench east wall. The firebrick is used to provide thermal protection for the structural concrete wall. The bricks are dry stacked with a tongue-and-groove system and were attached to the backing cement wall with epoxy resin mortar and with dovetail anchors. The epoxy mortar consisted of a thermosetting resin epoxy, polysulfide polymer, and calcium aluminate cement mortar made in accordance with Fed. Spec. MMM-G-650; Grout, Adhesion Epoxy Resin, Flexible Filled. The anchors were placed with every other brick horizontally (approximately 2.5 feet) and with every sixth brick vertically.

Adhesion testing was performed to determine the strength of the epoxy bond holding the brick to the cement wall. In addition, the test locations were selected so that they could be correlated to hammer 'tap' tests. The tap tests consisted of hitting the bricks with a hammer. If the resulting sound is solid, it is thought that the brick is touching the wall; while if the sound is hollow, it is thought that the brick is not touching the wall and the epoxy/brick bond was compromised. Adhesion tests were performed on areas that sounded solid to determine if in fact this correlated to a good brick/cement bond.

2 METHODS AND RESULTS

Adhesion testing was performed on the firebricks in the flame trench of LC-39A to determine the strength of the epoxy/firebrick bond to the backing concrete wall. The testing used an Elcometer 110 pneumatic adhesion tensile testing instrument (PATTI). The PATTI tester consists of a 2-inch outside diameter (OD) dolly that is glued onto the brick and a piston that attaches to the dolly. The piston is inflated, and the force necessary to bring the system to failure is measured. The test method is performed as follows:

- a. Drill a 2-inch OD core through the firebrick to the concrete wall.
- b. Attach the dolly to the core using an epoxy adhesive. Allow the adhesive to cure.
- c. Perform pull testing.

The adhesion failure that occurs in the test can happen in different areas and is noted after testing. In this test, the adhesion/cohesion failures can occur between the pull stub/firebrick core and/or the firebrick core/cement wall interfaces as shown in figure 1.

Core locations were selected to survey different areas of the trench. The possible locations were limited, as the adhesion testing required a flat surface on the brick. Most bricks did not have a suitable surface to attach the pull stub. Each location was evaluated with hammer testing to determine if the area sounded solid or hollow. The approximate locations of the cores are shown in figure 2 through figure 5.

Appendices A and B (figures 6 through 41) show photographs of the cores and the pull stubs for each core taken. Notes on the individual cores are also given with the photographs.

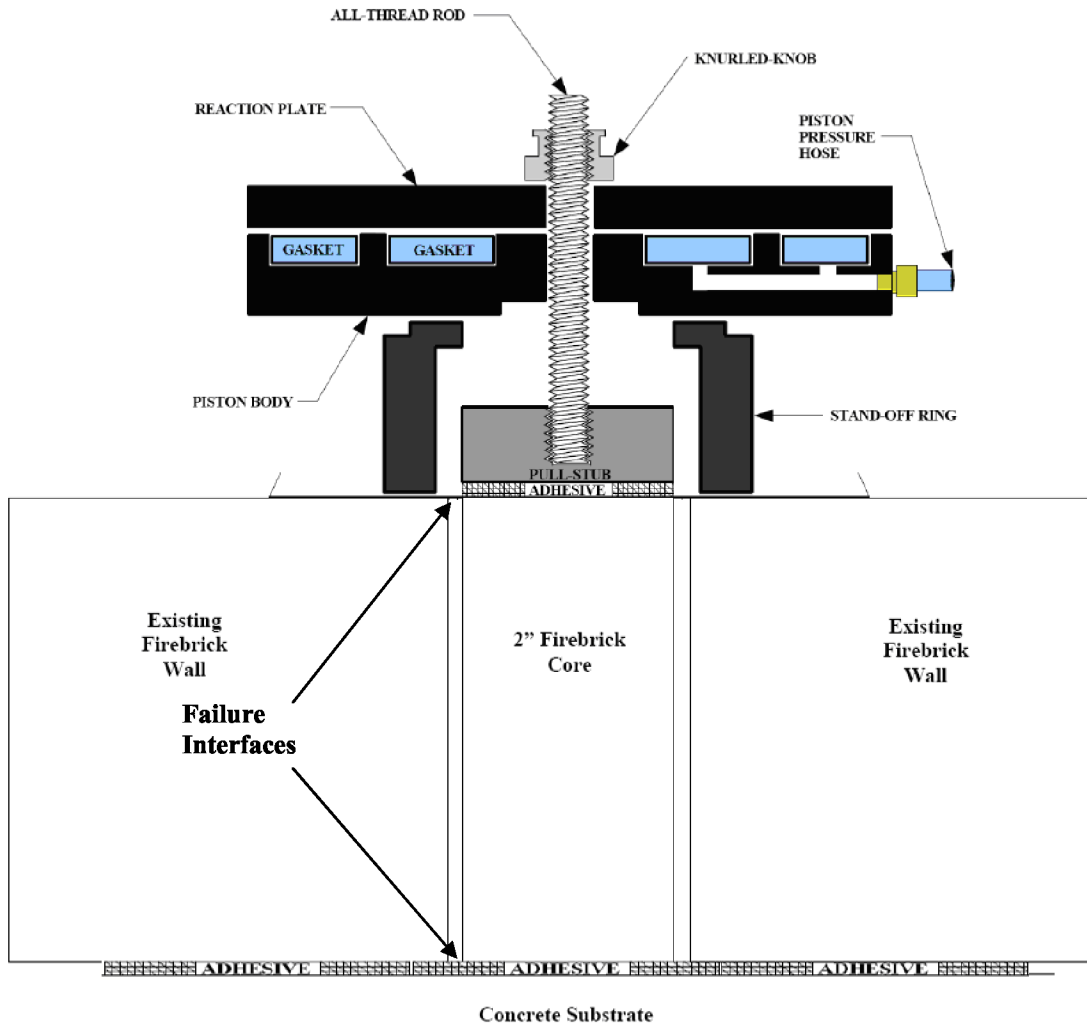
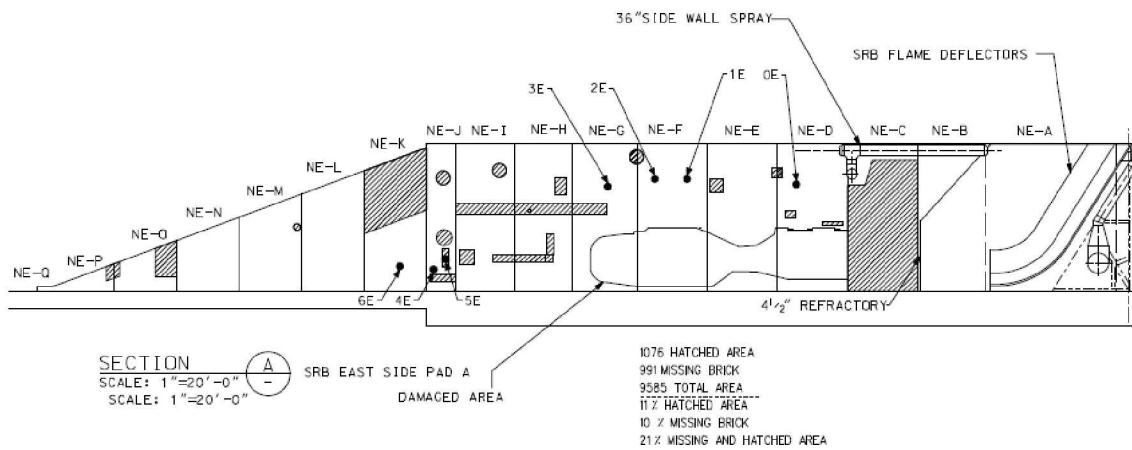


Figure 1. Cross-sectional schematic of piston assembly with attached pull stub



Blue arrows show seam locations.

Figure 2. Core locations on the east wall of the trench



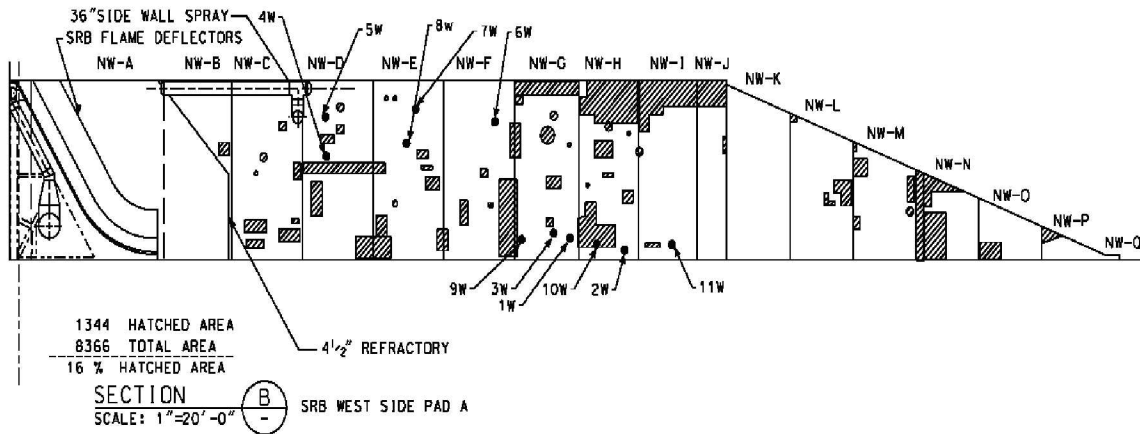
Cross-hatched areas sounded hollow according to the hammer test.

Figure 3. Core locations on the east wall of the trench



Blue arrows show seam locations.

Figure 4. Core locations on the west wall of the trench



Cross-hatched areas sounded hollow according to the hammer test.

Figure 5. Core locations on the west wall of the trench

The results of the adhesion measurements are given in tables 1 and 2. The tables list the core identification (ID), results of the hammer tap test (solid or hollow), if the core survived drilling or broke free from the wall during drilling (those that survived were subjected to testing), pull off tensile strength (POTS), and the failure mechanism. All cores are photo documented in appendix A and appendix B. The POTS value is reported in psi and represents the maximum pressure before the system, shown in figure 1, fails. For the cores subjected to this testing that failed at the adhesion pull stub/firebrick interface, it can be assumed that the firebrick/epoxy/concrete interface is stronger than the POTS value. In total, 18 cores were drilled. Of these, 10 of the cores broke away from the cement backing wall during drilling. Adhesion testing of the remaining eight was performed. Only core 8W failed at the firebrick/epoxy/concrete interface (table 1). The failure mechanism describes which interfaces failed and is given as a percentage for a particular interface (table 2). For example, core 6E failed approximately 50% at the interface between the brick and dolly adhesive and approximately 50% in the brick itself. In the image shown in figure 19, the outer areas of the pull stub, coated with the brick that was pulled out during the test, show that the failure occurred in the top layer of the brick. The inner white area of the pull stub is the adhesive and shows that the failure occurred between it and the outer brick face.

Testing on a brick that had been liberated during launch was performed. In this test, the pull stub was attached to the brick without drilling a core. The adhesive strength of the pull stub to the brick could be measured in this way. Two pull tests were performed on the outer face of the brick, and one test was done on the inner side, which was smooth and had not been exposed to launch conditions. The pull on the inner side had a POTS of 597 psi with complete failure in the firebrick. The pulls on the front exposed side of the brick, averaged 180 psi. It appears that the tensile strength of the exposed side of the brick has degraded as compared to the back side of the brick. It is unclear how thick or deep this layer of degradation is.

A universal pH indicator was sprayed on core 1 from the west wall and the small amount of concrete that was removed after drilling. The pH of the concrete was found to be about 13, which is appropriate and indicates the concrete is in good shape. The pH of the firebrick was checked at the face and near the back side. The pH of the back side appeared to be near 11, while the face was more acidic with a pH of 5. The proper pH for the bulk of the firebrick is unknown, but it was clear that the face was more acidic than the bulk.

3 CONCLUSIONS

Eighteen cores were drilled as part of this testing. Ten of these cores broke during drilling. Of these ten, seven cores sounded solid, according to hammer tap testing, before drilling. In addition, one core that sounded hollow withstood the drilling. Based on this, it is unlikely that hammer tap testing can identify whether the firebrick/epoxy/concrete bond is strong. Only one of the eight cores that survived drilling, core 8W, was pulled away from the concrete backing wall during the adhesion test. This core was removed with a pressure of 82 psi. For the seven other cores tested, failure of the adhesion test system occurred in the front surface of the brick where the pull stub was attached. The average pull off tensile strength for these seven measurements was 86.3 psi. Since the failure did not occur at the firebrick/epoxy/concrete interface, it can be assumed that that interface of these seven cores is stronger than the 86.3 psi. Laboratory tests have shown that the outer face side of a firebrick that has been exposed to launches has a weaker

tensile strength than the interior side that has been hidden. All the cores were photo-documented. In addition, pH testing was done on one brick core and one piece of the cement wall. The cement was found to have a pH of 13 while the brick surface had a pH near 5.

Table 1. Results of west wall adhesion testing.

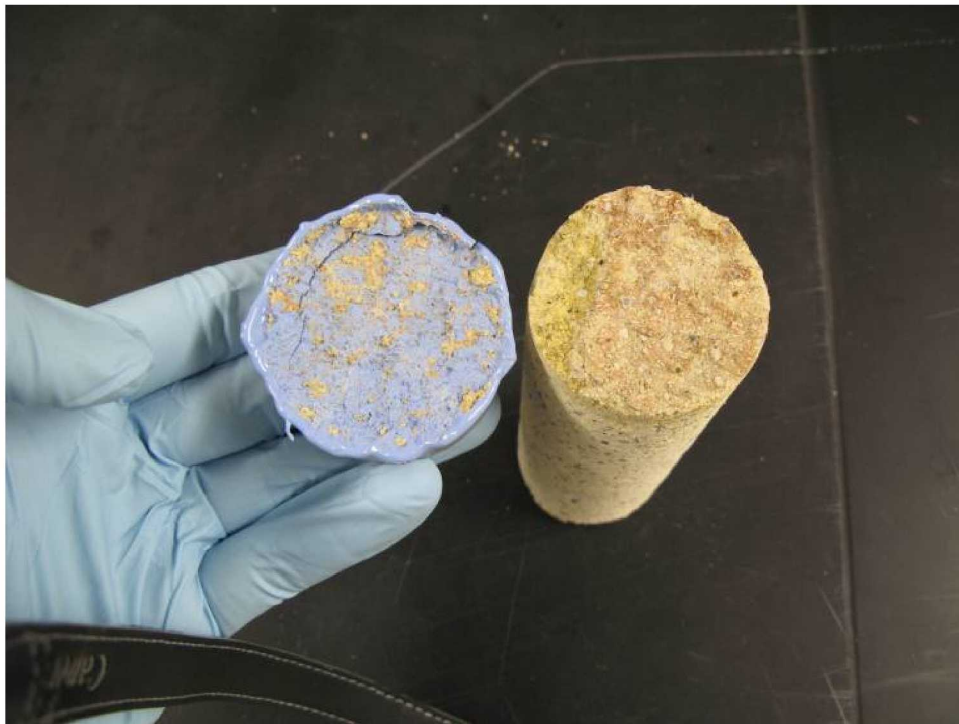
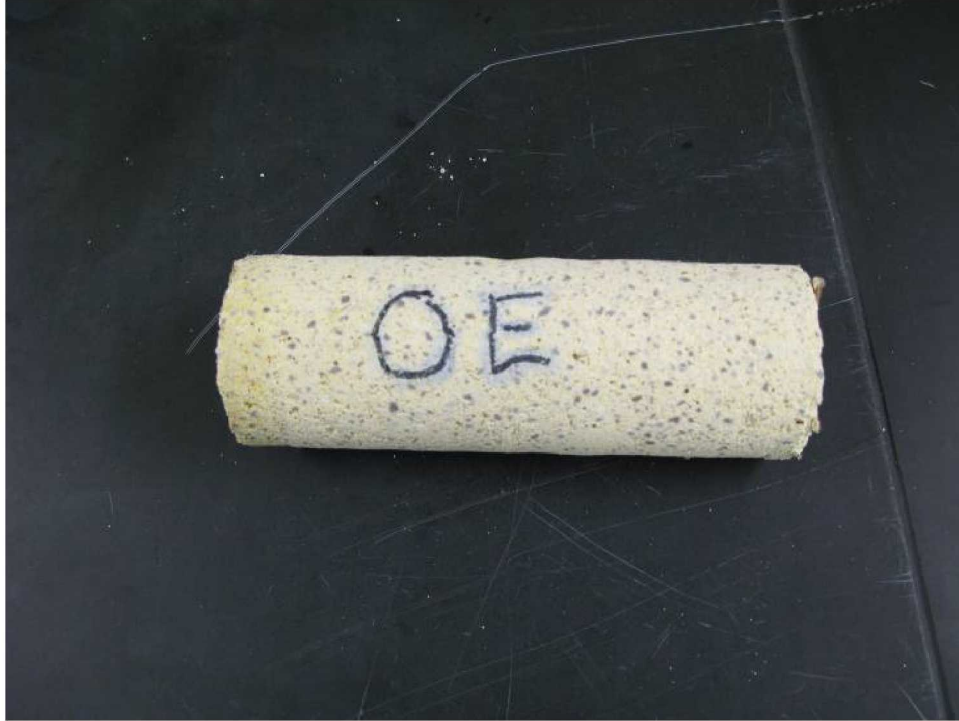
Core	Hammer test (S/H)	Core survived drilling?	Pull Off Tensile Strength (psi)	Failure mechanism
1W	Hollow	Loose after drilling but did not come out completely	NA	Epoxy/epoxy (see figure 1)
2W	Solid	Survived initial drilling. Did not survive further drilling to get concrete plug.	NA	Firebrick/epoxy
3W	Hollow	No	NA	Firebrick/epoxy
4W	Solid	No	NA	Firebrick/epoxy
5W	Solid	No	NA	Firebrick/epoxy
6W	Solid	No	NA	Firebrick/epoxy
7W	Solid	No	NA	Firebrick/epoxy
8W*	Solid	Yes	82	Concrete/epoxy/firebrick
9W	Solid	Yes	54	50% Brick failure 50% Brick/adhesive
10W	Solid	Yes	101	60% Brick failure 40% Brick/adhesive
11W	Solid	Came out as adhesion testing began	NA	Core had some epoxy still attached
*Core 8W was the only core that underwent pull testing and failed at the firebrick/epoxy/concrete interface. All others failed at the brick/dolly adhesive interface or in the top layer of the brick itself.				

Table 2. Results of east wall adhesion testing

Core	Hammer test (S/H)	Core survived drilling?	Pull Off Tensile Strength (psi)	Failure mechanism
0E	Solid	Yes	60	Brick/adhesive
1E	Solid	No	NA	Firebrick/epoxy
2E	Solid	No	NA	Firebrick/epoxy
3E	Solid	No	NA	Firebrick/epoxy
4E	Solid	Yes	114	80% Brick failure 20% Brick/adhesive
5E	Hollow	Yes	82	80% Brick failure 20% Brick/adhesive
6E	Solid	Yes	107	50% Brick failure 50% Brick/adhesive

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APPENDIX A. EAST WALL CORES



The pull test failed at the adhesive/firebrick interface.

Figure 6. Core 0E – successful test: failed at 60 psi (side image of core and outer surface of core and pull stub).



Figure 7. Core 0E – inner surface of core



Figure 8. Core 1E – side image of core and outer surface of core



Figure 9. Core 1E – inner surface of core removed during core drilling



Figure 10. Core 2E – side image of core and outer surface of core removed during core drilling



Figure 11. Core 2E – inner surface of core removed during core drilling



Figure 12. Core 3E – side image of core and outer surface of core removed during core drilling

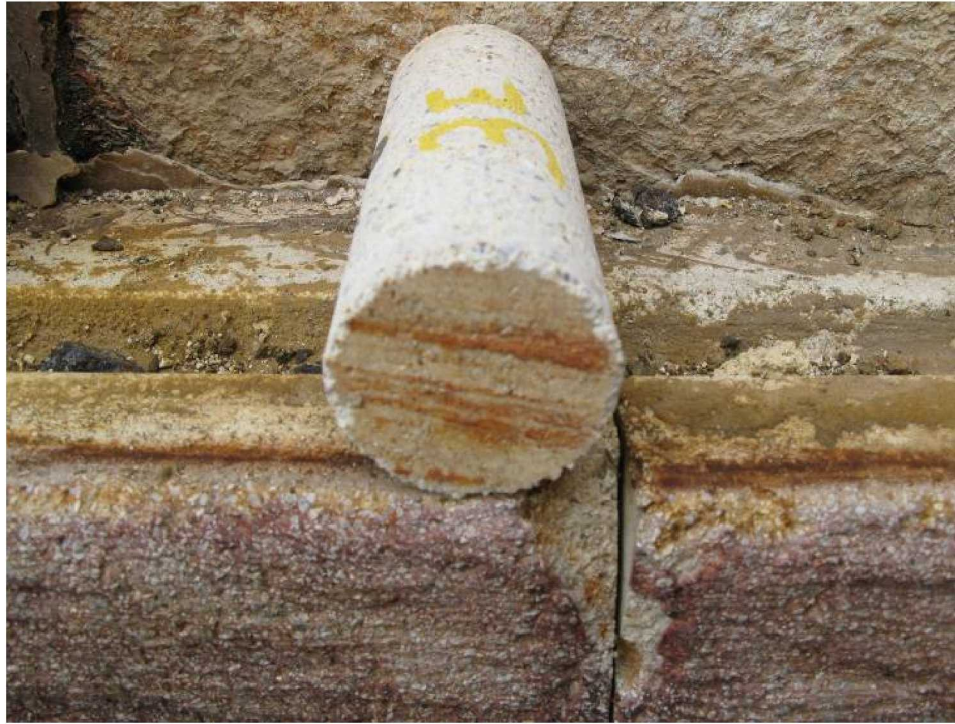


Figure 13. Core 3E – inner surface of core removed during core drilling



No epoxy was found on the core

Figure 14. Core 4E – side image of core and back end of core, closest to the concrete wall



Figure 15. Core 4E – successful test: failed at 114 psi (pull stub and core face and the image inside the brick after the core was removed)



No epoxy was found on the core.

Figure 16. Core 5E – side image of core and back end of core, closest to the concrete wall



Figure 17. Core 5E – successful test: failed at 82 psi (pull stub and core face and the image inside the brick after the core was removed)



Some epoxy was found on the core.

Figure 18. Core 6E – side image of core and back end of core, closest to the concrete wall



Figure 19. Core 6E – successful test: failed at 107 psi (image of pull stub and core face and the image inside the brick after the core was removed)

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APPENDIX B. WEST WALL CORES



Core became loose during drilling. Then an additional section of the concrete was cored out. Epoxy covered the entire inner surface when pulled, but it flaked off easily

Figure 20. Core 1 – side view of core and inner surface of core



Core became loose during drilling. Then an additional section of the concrete was cored out. Both sections had epoxy, but the sections did not appear to be bonded together. It appears as if the epoxy was applied to the brick and to the concrete, but they never made contact.

Figure 21. Core 1 – inner surface of the core and a small core of concrete that was removed



Core became loose during drilling. After coring the firebrick, an additional section of the concrete was cored out. The pH testing was done on the concrete and firebrick.

Figure 22. Core 1 – pH of the concrete was about 13, which is appropriate for concrete, and pH of the brick was more acidic



The core remained attached to the concrete wall after drilling to a depth of 6 inches from the face of the brick. Drilling continued after the initial 6 inches to try to get a complete core. There was adhesion failure between the firebrick and the epoxy when the deeper drilling occurred. Hammer testing showed this to be a solid brick.

Figure 23. Core 2 – adhesion failure



Figure 24. Core 3 – side image of core and outer surface of core removed during core drilling



Figure 25. Core 3 – inner surface of core removed during core drilling



Figure 26. Core 4W – side image of core and outer surface of core removed during core drilling



Figure 27. Core 4W – inner surface of core removed during core drilling



Figure 28. Core 5W – side image of core and bottom outer surface of core removed during core drilling



Figure 29. Core 5W – inner surface of core removed during core drilling



Figure 30. Core 6W – side image of core and outer surface of core removed during core drilling



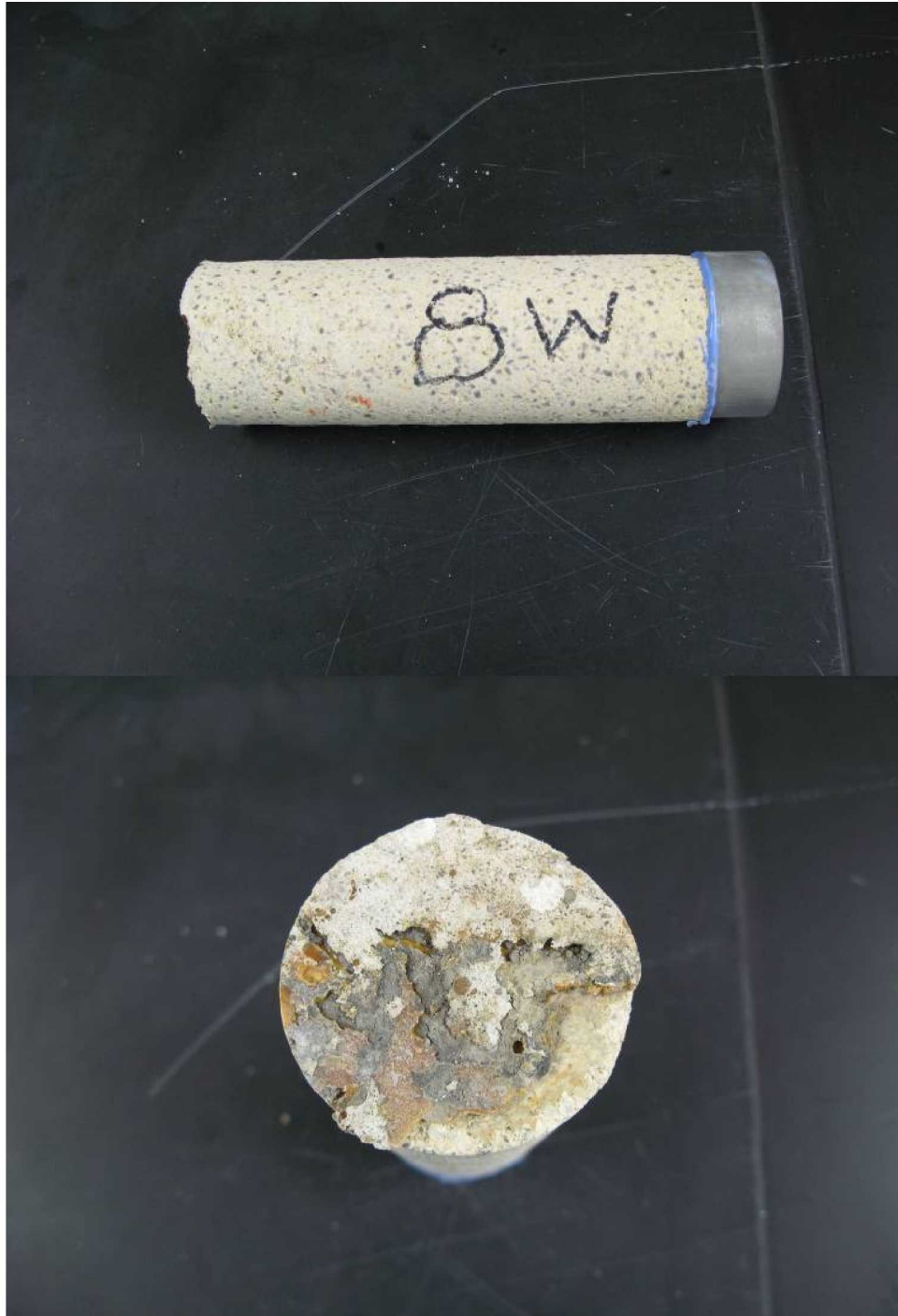
Figure 31. Core 6W – inner surface of core removed during core drilling



Figure 32. Core 7W – side image of core and outer surface of core removed during core drilling



Figure 33. Core 7W – inner surface of core removed during core drilling



This was the only pull test that resulted in the entire core being removed.

Figure 34. Core 8W – successful test: failed at 82 psi (side view of core with pull stub still attached and interior surface of core, with epoxy and/or concrete still attached)



This was the only pull test that resulted in the entire core was removed.

Figure 35. Core 8W – inside the brick after the core was removed



No epoxy was found on the core.

Figure 36. Core 9W – side image of core and back end of core, closest to the concrete wall



There is evidence of corrosion shown at the concrete/firebrick interface.

Figure 37. Core 9W – successful test: failed at 54 psi (pull stub and core face and inside the brick after the core was removed)



No epoxy was found on the core.

Figure 38. Core 10W – side image of core and back end of core, closest to the concrete wall



Figure 39. Core 10W – successful test: failed at 101 psi (pull stub and core face and inside the brick after the core was removed)



This core came out as adhesion testing began, so the pull stub was still attached. Some epoxy was found on the core.

Figure 40. Core 11W – side image of core and back end of core, closest to the concrete wall



Figure 41. Core 11W –inside the brick after the core was removed

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