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Study on the Durability of Traditional and Modified Limewash Recipes

Results Handmade and Modern Brick

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Executive Summary
Results from limewash study of handmade and modern brick samples
November 1, 2005

Introduction

This report is an executive summary of testing undertaken by NCPTT in partnership with the Cane River Creole National Historical Park (CARI) and Quality Finish.

In December 2003 meetings were held to discuss applying limewash to the brick cabins at Magnolia Plantation in hopes of prolonging the life of the structures. We developed a study to determine the durability of traditional and modified limewash recipes within certain criteria. CARI wanted to identify a durable low cost limewash that was applied in approximately three coats. As the project progressed we decided to also test limewash on wood, since CARI expressed interest in applying limewash to the wood structures at Oakland plantation. In collaboration with the project partners, NCPTT designed a program of testing for limewash on weathered wood, rough sawn wood, handmade brick, and modern brick.

Quality Finish researched possible limewash recipes that may have been used locally by interviewing community members. They were not able to identify recipes used in the community and thus turned to published limewash recipes, including a limewash identified through NPS contracting schedules. We worked together to prepare wood and brick test samples. Starting in November 2004, Quality Finish applied ten separate washes on handmade and modern brick samples. On all brick samples, an Edison acrylic emulsion was used as a primer. The same limewash recipes were applied to weather and rough-sawn wood, except for the wash K, the Virginia Limeworks putty and water which was only applied to the brick samples.

As of October 2005, NCPTT has completed scheduled testing on all samples. However the Center has decided to undertake additional testing, including traditional limewashes of lime and water on brick and wood samples without an Edison primer and the three best performing limewashes from the wood test on epoxy samples. The results from the additional testing are expected by the beginning of 2006. This report will focus on the results of durability testing of limewash recipes on the original handmade and modern brick samples.

Testing methods

NCPTT tested limewashed handmade and modern brick samples using artificial weathering, adhesion, and abrasion testing according to ASTM standard methods. We photographed samples before and after each test and monitored them for color change with a Minolta colorimeter. To perform artificial weathering, we placed the samples in a QUV weatherometer and subjected them to four hours of UV light exposure and four hours of condensation in the dark continuously alternating for 800 hours. This accelerated weathering gives us an idea of how the limewash may age over time. For the adhesion test, we cut an “X” through the limewash to the sample, and then placed

pressure sensitive tape over the cut. Upon removal of the tape, we assessed how much limewash was removed. This test evaluates how firmly the limewash bonds to the samples. In the abrasion test, we placed samples in a holder and poured measured amounts of falling sand on to the surface to determine how much sand is needed to remove a 4 mm (.1575 inch) diameter circular area of limewash. The abrasion test allows us to rank how a limewash will stand up to abrasion from wind- and rain-borne particles and from people touching the buildings. With the help of Quality Finish, we also performed a solids test to determine how much limewash is being applied to the samples.

Test results-Handmade Brick

We evaluated limewashed brick samples before and after artificial weathering using visual appearance, abrasion testing and adhesion testing. Test results are represented as an average of the results from the individual samples for each wash. Three replicates were prepared for each wash. Individual results for each sample are recorded in the appendix that is included with the report.

A ranking system was devised in order to evaluate the results of each test. Based on their performance, we ranked each limewash from best to worst for relative change in appearance, adhesion, and abrasion for samples both before and after weathering. Those with the best performance ranked a 10 and those with the worst performance ranked a 1. The rankings were then totaled for each wash, creating an overall ranking.

For unweathered samples, washes F, H, and D performed the best in adhesion testing. This means that washes F, H, and D bound most tightly to the brick prior to weathering. Upon abrasion testing, unweathered samples of washes A, B, and K performed the best. This means that they formed a harder coating that was more cohesive.

After artificial weathering, each wash was visually evaluated and we found that washes A, E, and K performed the best, although all of the washes performed very well. Washes C, E, and G performed the best in the adhesion test of the artificially weathered samples with no variability in any of the results. Wash K also averaged the same rating as the best performers, but there was a large standard deviation. Washes A, B, and D performed best in the abrasion test on the weathered samples although washes A and B performed almost twice as well as wash D.

For the handmade brick the three best performing limewashes were washes A, E, and K. Limewash A is Graymont's Ivory hydrated lime, table salt, alum, unsulphured molasses, laundry bluing, and water. Wash A performed the best in the abrasion test both for the unweathered and artificially weathered samples. For the abrasion test of the samples that were not weathered wash A averaged 93 liters, almost two times greater than the next best performing wash B and three times greater than the third best performing wash K. For the abrasion test on the samples that were weathered wash A also performed the best with an average of 8.25 liters that had a small standard deviation. For the adhesion test on samples that were not artificially weathered it performed in the middle of the group and towards the bottom of the group for samples that were artificially weathered.

The second best performers on the handmade brick were washes E and K. Wash E is Graymont's Niagara lime putty, unsulphered molasses, laundry bluing, clove oil, and water. It performed equally with A and K as the best that were artificially weathered and equally with C and G as the best in the adhesion test on the samples that were artificially weathered. In the abrasion test on the samples that were artificially weathered wash E performed in the middle group. For the samples that were not weathered wash E rated as the fourth best in the adhesion test and as the third worst in the abrasion test.

Wash K performed equally as well as wash E. Wash K is the Virginia Limeworks lime putty and water. For the artificial weathering wash K was grouped in the best rating with washes A and E. For the rest of the tests it ranked in the middle group when compared with the other washes. Wash

K is still considered a good performer despite it ranking in the middle of the group in several tests where a few washes far exceeded the others in performance such as the artificial weathering.

Test results-Modern Brick

For unweathered samples, washes K, F, and D performed the best in adhesion testing. This means that washes K, F, and D bound most tightly to the wood prior to weathering. Upon abrasion testing, unweathered samples of washes A, B, and C performed the best. This means that they formed a harder coating that was more cohesive.

After artificial weathering, each wash was visually evaluated and we found that washes D, H, and K performed the best, although all of the washes performed very well. Also, we found that washes I, H, and F were the best performers in the adhesion tests after weathering. Washes B, E, and A performed the best in abrasion tests on the weathered limewashed samples, although wash B performed twice as well as washes A and E.

For the modern brick samples we found that wash B performed the best overall of all the washes. Wash B is Graymont's Niagara lime putty, salt, alum, unsulphured molasses, laundry bluing, and water. It performed well on the adhesion, abrasion, artificial weathering, and abrasion test after artificial weathering. In the abrasion test on the samples that were not artificially weathered it performed better than all but wash A. On the adhesion test after weathering it performed poorly.

We found the second best performing limewash on modern brick to be Wash D. Wash D performed well on the adhesion test and the artificial weathering. It performed poorly on the abrasion test before and after weathering and the adhesion test after weathering.

The third best performing limewashes on the modern brick were washes A and K that performed equally well. Wash A performed the best on the abrasion test requiring three times as many liters of sand as the test's second best performer wash B. Wash A performed poorly on the adhesion test before weathering and the adhesion and abrasion tests after weathering. In the artificial weathering wash K ranked third from last, but all of the washes performed well and the differences were very slight. Wash K performed well in the adhesion and artificial weathering test, but poorly in the adhesion and abrasion test after weathering. On the abrasion test it performed in the middle of the group.

Recommendations based on results

Any recommendation for field application based on the results of this data must take into account the dynamic of moisture migration in masonry walls and processes such as efflorescence and subflorescence that may affect the choice of the ideal coating. Efflorescence is when salt appears on the surface of materials and subflorescence is when salt crystallizes beneath the surface of a material. Subflorescence is created when soluble salts in a liquid travel through a brick until temperature and atmospheric pressures cause the liquid to evaporate leaving behind the salt crystal deposits in the interior voids of a brick.[1] Soluble salts can be very detrimental to bricks contributing to physical problems such as spalling or flaking, increasing dry times, changing porosity, and micro fissures in the pore walls.[2] Soluble salts can transfer naturally through rising damp, pollution in the

[1] Weaver, Martin E. with F.G. Matero, *Conserving Buildings: guide to techniques and materials* (New York, John Wiley &Sons, 1993), 120.

[2] Franke, L. and I. Schumann, "Causes and Mechanisms of Decay of Historic Brick Buildings in Northern Germany," in *Conservation of Historic Brick Structures*, eds. N.S. Baer, S. Fitz, and R.A. Livingston (Shaftsbury: Donhead, 1998), *26-34*.

atmosphere,[3] mortar used to set the bricks, adjacent materials, or be present from the clay used in the brick construction.[4] We would recommend not introducing more salt to brick structures by using a limewash recipe that contains salt. During the artificial weathering process the modern brick samples with washes A, B, and C all experienced significant efflorescence on the side opposite of the limewash. We did not note any efflorescence on the historic brick, but that could have been affected by several factors such as porosity.

Although Wash A performed the best on the handmade brick and Wash B performed the best on the modern brick we feel that using a recipe with a salt additive could be detrimental to the bricks. Wash K performed well on both handmade brick and modern brick and is our recommendation for use on the brick structures at Cane River Creole National Historical Park. Wash K consists of Virginia Lime Putty and water and has no additives that could be detrimental to the brick.

Alternative limewashes include washes D and E. Wash E performed well on the handmade brick and is in the group of top performers, but on the modern brick it performed in the middle of the group. Wash D rated as the second best performer on the modern brick, but on the handmade brick it falls in the middle of the group.

It should be noted that all samples were subjected to color analysis before and after artificial aging. All limewashes display some color change over time and tend to darken and yellow. Since all washes changed approximately the same, we did not include these tests in our recommendations.

[3] Caner-Saltik, E.N., I. Schumann, and L. Franke, "Stages of Damage in the Structure of Brick Due to Salt Crystallization," in Conservation of Historic Brick Structures, eds. N.S. Baer, S. Fitz, and R.A. Livingston (Shaftsbury: Donhead, 1998), *49*.

[4] Ashurst, John and Nicola, *Practical building conservation: English Heritage technical handbook*, vol. 2 Brick, Terracotta, and Earth (Aldershot, Gower, 1995), 50.

	Lime	Part A	Part B	Mix
Wash A	Graymont Ivory hydrated lime.	1lb. Table salt, .5 oz alum, 1/3 cup unsulphured molasses, 1/12 tsp laundry bluing. Mix in 2 1/2 cups hot water.	4 1/4 cups hydrated lime mixed with 4 1/2 cups hot water let stand 12 hours	Mix parts A & B in equal parts. Viscosity 17 seconds at 70 degrees in #4 Ford cup.
Wash B	Graymont Niagara lime putty	1lb. Table salt, .5 oz alum, 1/3 cup unsulphured molasses, 1/12 tsp laundry bluing. Mix in 3 cups hot water.	Mix 8 1/2 cups Niagara putty with 4 cups hot water. Let stand 12 hours.	Mix parts A & B in equal parts. Viscosity 17 seconds at 70 degrees in #4 Ford cup.
Wash C	Virginia Limeworks lime putty	1lb. Table salt, .5 oz alum, 1/3 cup unsulphured molasses, 1/12 tsp laundry bluing. Mix in 2 1/2 cups hot water.	Mix 8 1/2 cups Virginia Limeworks with 4.75 cups hot water.	Mix parts A & B in equal parts. Viscosity 17 seconds at 70 degrees in #4 Ford cup.
Wash D	Graymont Ivory hydrated lime.	1/3 cup unsulphered molasses, 1/12 tsp laundry bluing, 1/4 tsp clove oil. Mix with 1.5 cups hot water.	4 1/4 cups hydrated lime mixed with 2 1/2 cups hot water. Let stand 12 hours.	Mix together A & B. Viscosity same as A. Add 4 tsp. Schmincke Casein Binding Medium per 1 cup limewash.
Wash E	Graymont Niagara lime putty	1/3 cup unsulphered molasses, 1/12 tsp laundry bluing, 1/4 tsp clove oil. Mix with 2 1/2 cups hot water.	8 1/2 cups putty with 2 1/4 cups hot water. Let stand 12 hours.	Mix together A & B. Viscosity same as A. Add 4 tsp. Schmincke Casein Binding Medium per 1 cup limewash.
Wash F	Virginia Limeworks lime putty	1/3 cup unsulphered molasses, 1/12 tsp laundry bluing, 1/4 tsp clove oil. Mix with 1 1/2 cups hot water.	8 1/2 cups Virginia Limeworks putty mixed with 2 1/4 cups hot water. Let stand 12 hours.	Mix together A & B. Viscosity same as A. Add 4 tsp. Schmincke Casein Binding Medium per 1 cup limewash.
Wash G	Graymont Ivory hydrated lime.	4 1/4 cups hydrated lime mixed with 7 1/2 cups hot water. Let stand 12 hours.		Check viscosity 17 seconds at 70 degrees. For each 1 cup of limewash, add 2 tablespoons of Edison.
Wash H	Graymont Niagara lime putty	8 1/2 cups Niagara lime putty mixed with 5 cups hot water. Let stand 12 hours.		Check viscosity 17 seconds at 70 degrees. For each 1 cup of limewash, add 2 tablespoons of Edison.
Wash I	Virginia Limeworks lime putty	8 1/2 cups Virginia lime putty with 5 cups hot water. Let stand 12 hours.		Check viscosity 17 seconds at 70 degrees. For each 1 cup of limewash, add 2 tablespoons of Edison.

Applied to handmade and modern brick, not wood

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Limewash Experimental Matrix

Graymont, "Ivory" hydrated lime

Wash A (Class C, Molasses, Alum, Salt, Lime, Water)

#	Wash	Photo	Color	Mass	Solids	Tape	Mass	Abrade	Mass	QUV	Mass	Photo	Color	Tape	Mass	Abrade	Mass	Color
-001-A	yes	yes	yes	yes	no	no	no	no	no	yes	yes	yes	yes	no	no	yes	yes	yes
-002-A	yes	yes	yes	yes	no	no	no	yes	yes	no	no	yes	no	no	no	no	no	no
-003-A	yes	yes	yes	yes	yes	no	yes	no	no	no	no	no	no	no	no	no	no	no
-004-A	yes	yes	yes	yes	no	yes	yes	no	no	no	no	yes	no	no	no	no	no	no
-005-A	yes	yes	yes	yes	no	no	no	no	yes	yes	yes	no	yes	yes	yes	no	no	no
-006-A	yes	yes	yes	yes	no	no	no	no	no	yes	yes	yes	yes	no	no	yes	yes	yes
-007-A	yes	yes	yes	yes	no	no	no	yes	yes	no	no	yes	no	no	no	no	no	no
-008-A	yes	yes	yes	yes	yes	no	yes	no	no	no	no	no	no	no	no	no	no	no
-009-A	yes	yes	yes	yes	no	yes	yes	no	no	no	no	yes	no	no	no	no	no	no
-010-A	yes	yes	yes	yes	no	no	no	no	yes	yes	yes	no	yes	yes	yes	no	no	no
-011-A	yes	yes	yes	yes	no	no	no	no	no	yes	yes	yes	yes	no	no	yes	yes	yes
-012-A	yes	yes	yes	yes	no	no	no	yes	yes	no	no	yes	no	no	no	no	no	no
-013-A	yes	yes	yes	yes	yes	no	yes	no	no	no	no	no	no	no	no	no	no	no
-014-A	yes	yes	yes	yes	no	yes	yes	no	no	no	no	yes	no	no	no	no	no	no
-015-A	yes	yes	yes	yes	no	no	no	no	yes	yes	yes	no	yes	yes	yes	no	no	no
-016-A	yes	yes	yes	yes	no	no	no	no	no	no	no	no	no	no	no	no	no	no

Graymont, Niagara lime putty

Wash B (Class C, Molasses, Alum, Salt, Lime, Water)

#	Wash	Photo	Color	Mass	Solids	Tape	Mass	Abrade	Mass	QUV	Mass	Photo	Color	Tape	Mass	Abrade	Mass	Color
-017-B	yes	yes	yes	yes	no	no	no	no	no	yes	yes	yes	yes	no	no	yes	yes	yes
-018-B	yes	yes	yes	yes	no	no	no	yes	yes	no	no	yes	no	no	no	no	no	no
-019-B	yes	yes	yes	yes	yes	no	yes	no	no	no	no	no	no	no	no	no	no	no
-020-B	yes	yes	yes	yes	no	yes	yes	no	no	no	no	yes	no	no	no	no	no	no
-021-B	yes	yes	yes	yes	no	no	no	no	yes	yes	yes	no	yes	yes	yes	no	no	no
-022-B	yes	yes	yes	yes	no	no	no	no	no	yes	yes	yes	yes	no	no	yes	yes	yes
-023-B	yes	yes	yes	yes	no	no	no	yes	yes	no	no	yes	no	no	no	no	no	no
-024-B	yes	yes	yes	yes	yes	no	yes	no	no	no	no	no	no	no	no	no	no	no
-025-B	yes	yes	yes	yes	no	yes	yes	no	no	no	no	yes	no	no	no	no	no	no
-026-B	yes	yes	yes	yes	no	no	no	no	yes	yes	yes	no	yes	yes	yes	no	no	no
-027-B	yes	yes	yes	yes	no	no	no	no	no	yes	yes	yes	yes	no	no	yes	yes	yes
-028-B	yes	yes	yes	yes	no	no	no	yes	yes	no	no	yes	no	no	no	no	no	no
-029-B	yes	yes	yes	yes	yes	no	yes	no	no	no	no	no	no	no	no	no	no	no
-030-B	yes	yes	yes	yes	no	yes	yes	no	no	no	no	yes	no	no	no	no	no	no
-031-B	yes	yes	yes	yes	no	no	no	no	yes	yes	yes	no	yes	yes	yes	no	no	no
-032-B	yes	yes	yes	yes	no	no	no	no	no	no	no	no	no	no	no	no	no	no

Virginia Limeworks lime putty

Wash C (Class C, Molasses, Alum, Salt, Lime, Water)

#	Wash	Photo	Color	Mass	Solids	Tape	Mass	Abrade	Mass	QUV	Mass	Photo	Color	Tape	Mass	Abrade	Mass	Color
-033-C	yes	yes	yes	yes	no	no	no	no	no	yes	yes	yes	yes	no	no	yes	yes	yes
-034-C	yes	yes	yes	yes	no	no	no	yes	yes	no	no	yes	no	no	no	no	no	no
-035-C	yes	yes	yes	yes	yes	no	yes	no	no	no	no	no	no	no	no	no	no	no
-036-C	yes	yes	yes	yes	no	yes	yes	no	no	no	no	yes	no	no	no	no	no	no
-037-C	yes	yes	yes	yes	no	no	no	no	yes	yes	yes	no	yes	yes	yes	no	no	no
-038-C	yes	yes	yes	yes	no	no	no	no	no	yes	yes	yes	yes	no	no	yes	yes	yes
-039-C	yes	yes	yes	yes	no	no	no	yes	yes	no	no	yes	no	no	no	no	no	no
-040-C	yes	yes	yes	yes	yes	no	yes	no	no	no	no	no	no	no	no	no	no	no
-041-C	yes	yes	yes	yes	no	yes	yes	no	no	no	no	yes	no	no	no	no	no	no
-042-C	yes	yes	yes	yes	no	no	no	no	yes	yes	yes	no	yes	yes	yes	no	no	no
-043-C	yes	yes	yes	yes	no	no	no	no	no	yes	yes	yes	yes	no	no	yes	yes	yes
-044-C	yes	yes	yes	yes	no	no	no	yes	yes	no	no	yes	no	no	no	no	no	no
-045-C	yes	yes	yes	yes	yes	no	yes	no	no	no	no	no	no	no	no	no	no	no
-046-C	yes	yes	yes	yes	no	yes	yes	no	no	no	no	yes	no	no	no	no	no	no
-047-C	yes	yes	yes	yes	no	no	no	no	yes	yes	yes	no	yes	yes	yes	no	no	no
-048-C	yes	yes	yes	yes	no	no	no	no	no	no	no	no	no	no	no	no	no	no

No. of samples this page = 48
No. of brick samples total = 158

Limewash Experimental Matrix

Graymont, "Ivory" hydrated lime

Wash D (Lime, Molasses, Casein, Clove Oil, Water)

#	Wash	Photo	Color	Mass	Solids	Tape	Mass	Abrade	Mass	QUV	Mass	Photo	Color	Tape	Mass	Abrade	Mass	Color
-049-D	yes	yes	yes	yes	no	no	no	no	no	yes	yes	yes	yes	no	no	yes	yes	yes
-050-D	yes	yes	yes	yes	no	no	no	yes	yes	no	no	yes	no	no	no	no	no	no
-051-D	yes	yes	yes	yes	yes	no	yes	no	no	no	no	no	no	no	no	no	no	no
-052-D	yes	yes	yes	yes	no	yes	yes	no	no	no	no	yes	no	no	no	no	no	no
-053-D	yes	yes	yes	yes	no	no	no	no	yes	yes	yes	no	yes	yes	yes	no	no	no
-054-D	yes	yes	yes	yes	no	no	no	no	no	yes	yes	yes	yes	no	no	yes	yes	yes
-055-D	yes	yes	yes	yes	no	no	no	yes	yes	no	no	yes	no	no	no	no	no	no
-056-D	yes	yes	yes	yes	yes	no	yes	no	no	no	no	no	no	no	no	no	no	no
-057-D	yes	yes	yes	yes	no	yes	yes	no	no	no	no	yes	no	no	no	no	no	no
-058-D	yes	yes	yes	yes	no	no	no	no	yes	yes	yes	no	yes	yes	yes	no	no	no
-059-D	yes	yes	yes	yes	no	no	no	no	no	yes	yes	yes	yes	no	no	yes	yes	yes
-060-D	yes	yes	yes	yes	no	no	no	yes	yes	no	no	yes	no	no	no	no	no	no
-061-D	yes	yes	yes	yes	yes	no	yes	no	no	no	no	no	no	no	no	no	no	no
-062-D	yes	yes	yes	yes	no	yes	yes	no	no	no	no	yes	no	no	no	no	no	no
-063-D	yes	yes	yes	yes	no	no	no	no	yes	yes	yes	no	yes	yes	yes	no	no	no
-064-D	yes	yes	yes	yes	no	no	no	no	no	no	no	no	no	no	no	no	no	no

Graymont, Niagara lime putty

Wash E (Lime, Molasses, Casein, Clove Oil, Water)

#	Wash	Photo	Color	Mass	Solids	Tape	Mass	Abrade	Mass	QUV	Mass	Photo	Color	Tape	Mass	Abrade	Mass	Color
-065-E	yes	yes	yes	yes	no	no	no	no	no	yes	yes	yes	yes	no	no	yes	yes	yes
-066-E	yes	yes	yes	yes	no	no	no	yes	yes	no	no	yes	no	no	no	no	no	no
-067-E	yes	yes	yes	yes	yes	no	yes	no	no	no	no	no	no	no	no	no	no	no
-068-E	yes	yes	yes	yes	no	yes	yes	no	no	no	no	yes	no	no	no	no	no	no
-069-E	yes	yes	yes	yes	no	no	no	no	yes	yes	yes	no	yes	yes	yes	no	no	no
-070-E	yes	yes	yes	yes	no	no	no	no	no	yes	yes	yes	yes	no	no	yes	yes	yes
-071-E	yes	yes	yes	yes	no	no	no	yes	yes	no	no	yes	no	no	no	no	no	no
-072-E	yes	yes	yes	yes	yes	no	yes	no	no	no	no	no	no	no	no	no	no	no
-073-E	yes	yes	yes	yes	no	yes	yes	no	no	no	no	yes	no	no	no	no	no	no
-074-E	yes	yes	yes	yes	no	no	no	no	yes	yes	yes	no	yes	yes	yes	no	no	no
-075-E	yes	yes	yes	yes	no	no	no	no	no	yes	yes	yes	yes	no	no	yes	yes	yes
-076-E	yes	yes	yes	yes	no	no	no	yes	yes	no	no	yes	no	no	no	no	no	no
-077-E	yes	yes	yes	yes	yes	no	yes	no	no	no	no	no	no	no	no	no	no	no
-078-E	yes	yes	yes	yes	no	yes	yes	no	no	no	no	yes	no	no	no	no	no	no
-079-E	yes	yes	yes	yes	no	no	no	no	yes	yes	yes	no	yes	yes	yes	no	no	no
-080-E	yes	yes	yes	yes	no	no	no	no	no	no	no	no	no	no	no	no	no	no

Virginia Limeworks lime putty

Wash F (Lime, Molasses, Casein, Clove Oil, Water)

#	Wash	Photo	Color	Mass	Solids	Tape	Mass	Abrade	Mass	QUV	Mass	Photo	Color	Tape	Mass	Abrade	Mass	Color
-081-F	yes	yes	yes	yes	no	no	no	no	no	yes	yes	yes	yes	no	no	yes	yes	yes
-082-F	yes	yes	yes	yes	no	no	no	yes	yes	no	no	yes	no	no	no	no	no	no
-083-F	yes	yes	yes	yes	yes	no	yes	no	no	no	no	no	no	no	no	no	no	no
-084-F	yes	yes	yes	yes	no	yes	yes	no	no	no	no	yes	no	no	no	no	no	no
-085-F	yes	yes	yes	yes	no	no	no	no	yes	yes	yes	no	yes	yes	yes	no	no	no
-086-F	yes	yes	yes	yes	no	no	no	no	no	yes	yes	yes	yes	no	no	yes	yes	yes
-087-F	yes	yes	yes	yes	no	no	no	yes	yes	no	no	yes	no	no	no	no	no	no
-088-F	yes	yes	yes	yes	yes	no	yes	no	no	no	no	no	no	no	no	no	no	no
-089-F	yes	yes	yes	yes	no	yes	yes	no	no	no	no	yes	no	no	no	no	no	no
-090-F	yes	yes	yes	yes	no	no	no	no	yes	yes	yes	no	yes	yes	yes	no	no	no
-091-F	yes	yes	yes	yes	no	no	no	no	no	yes	yes	yes	yes	no	no	yes	yes	yes
-092-F	yes	yes	yes	yes	no	no	no	yes	yes	no	no	yes	no	no	no	no	no	no
-093-F	yes	yes	yes	yes	yes	no	yes	no	no	no	no	no	no	no	no	no	no	no
-094-F	yes	yes	yes	yes	no	yes	yes	no	no	no	no	yes	no	no	no	no	no	no
-095-F	yes	yes	yes	yes	no	no	no	no	yes	yes	yes	no	yes	yes	yes	no	no	no
-096-F	yes	yes	yes	yes	no	no	no	no	no	no	no	no	no	no	no	no	no	no

No. of samples this page = 48
No. of brick samples total = 158

Limewash Experimental Matrix

Graymont, "Ivory" hydrated lime

Wash G (Lime, Water, acrylic binder)

#	Wash	Photo	Color	Mass	Solids	Tape	Mass	Abrade	Mass	QUV	Mass	Photo	Color	Tape	Mass	Abrade	Mass	Color
_-097-G	yes	yes	yes	yes	no	no	no	no	no	yes	yes	yes	yes	no	no	yes	yes	yes
_-098-G	yes	yes	yes	yes	no	no	no	yes	yes	no	no	yes	no	no	no	no	no	no
_-099-G	yes	yes	yes	yes	yes	no	yes	no	no	no	no	no	no	no	no	no	no	no
_-100-G	yes	yes	yes	yes	no	yes	yes	no	no	no	no	yes	no	no	no	no	no	no
_-101-G	yes	yes	yes	yes	no	no	no	no	yes	yes	yes	no	yes	yes	yes	no	no	no
_-102-G	yes	yes	yes	yes	no	no	no	no	no	yes	yes	yes	yes	no	no	yes	yes	yes
_-103-G	yes	yes	yes	yes	no	no	no	yes	yes	no	no	yes	no	no	no	no	no	no
_-104-G	yes	yes	yes	yes	yes	no	yes	no	no	no	no	no	no	no	no	no	no	no
_-105-G	yes	yes	yes	yes	no	yes	yes	no	no	no	no	yes	no	no	no	no	no	no
_-106-G	yes	yes	yes	yes	no	no	no	no	yes	yes	yes	no	yes	yes	yes	no	no	no
_-107-G	yes	yes	yes	yes	no	no	no	no	no	yes	yes	yes	yes	no	no	yes	yes	yes
_-108-G	yes	yes	yes	yes	no	no	no	yes	yes	no	no	yes	no	no	no	no	no	no
_-109-G	yes	yes	yes	yes	yes	no	yes	no	no	no	no	no	no	no	no	no	no	no
_-110-G	yes	yes	yes	yes	no	yes	yes	no	no	no	no	yes	no	no	no	no	no	no
_-111-G	yes	yes	yes	yes	no	no	no	no	yes	yes	yes	no	yes	yes	yes	no	no	no
_-112-G	yes	yes	yes	yes	no	no	no	no	no	no	no	no	no	no	no	no	no	no

Graymont, Niagara lime putty

Wash H (Lime, Water, acrylic binder)

#	Wash	Photo	Color	Mass	Solids	Tape	Mass	Abrade	Mass	QUV	Mass	Photo	Color	Tape	Mass	Abrade	Mass	Color
_-113-H	yes	yes	yes	yes	no	no	no	no	no	yes	yes	yes	yes	no	no	yes	yes	yes
_-114-H	yes	yes	yes	yes	no	no	no	yes	yes	no	no	yes	no	no	no	no	no	no
_-115-H	yes	yes	yes	yes	yes	no	yes	no	no	no	no	no	no	no	no	no	no	no
_-116-H	yes	yes	yes	yes	no	yes	yes	no	no	no	no	yes	no	no	no	no	no	no
_-117-H	yes	yes	yes	yes	no	no	no	no	yes	yes	yes	no	yes	yes	yes	no	no	no
_-118-H	yes	yes	yes	yes	no	no	no	no	no	yes	yes	yes	yes	no	no	yes	yes	yes
_-119-H	yes	yes	yes	yes	no	no	no	yes	yes	no	no	yes	no	no	no	no	no	no
_-120-H	yes	yes	yes	yes	yes	no	yes	no	no	no	no	no	no	no	no	no	no	no
_-121-H	yes	yes	yes	yes	no	yes	yes	no	no	no	no	yes	no	no	no	no	no	no
_-122-H	yes	yes	yes	yes	no	no	no	no	yes	yes	yes	no	yes	yes	yes	no	no	no
_-123-H	yes	yes	yes	yes	no	no	no	no	no	yes	yes	yes	yes	no	no	yes	yes	yes
_-124-H	yes	yes	yes	yes	no	no	no	yes	yes	no	no	yes	no	no	no	no	no	no
_-125-H	yes	yes	yes	yes	yes	no	yes	no	no	no	no	no	no	no	no	no	no	no
_-126-H	yes	yes	yes	yes	no	yes	yes	no	no	no	no	yes	no	no	no	no	no	no
_-127-H	yes	yes	yes	yes	no	no	no	no	yes	yes	yes	no	yes	yes	yes	no	no	no
_-128-H	yes	yes	yes	yes	no	no	no	no	no	no	no	no	no	no	no	no	no	no

Virginia Limeworks lime putty

Wash I (Lime, Water, acrylic binder)

#	Wash	Photo	Color	Mass	Solids	Tape	Mass	Abrade	Mass	QUV	Mass	Photo	Color	Tape	Mass	Abrade	Mass	Color
_-129-I	yes	yes	yes	yes	no	no	no	no	no	yes	yes	yes	yes	no	no	yes	yes	yes
_-130-I	yes	yes	yes	yes	no	no	no	yes	yes	no	no	yes	no	no	no	no	no	no
_-131-I	yes	yes	yes	yes	yes	no	yes	no	no	no	no	no	no	no	no	no	no	no
_-132-I	yes	yes	yes	yes	no	yes	yes	no	no	no	no	yes	no	no	no	no	no	no
_-133-I	yes	yes	yes	yes	no	no	no	no	yes	yes	yes	no	yes	yes	yes	no	no	no
_-134-I	yes	yes	yes	yes	no	no	no	no	no	yes	yes	yes	yes	no	no	yes	yes	yes
_-135-I	yes	yes	yes	yes	no	no	no	yes	yes	no	no	yes	no	no	no	no	no	no
_-136-I	yes	yes	yes	yes	yes	no	yes	no	no	no	no	no	no	no	no	no	no	no
_-137-I	yes	yes	yes	yes	no	yes	yes	no	no	no	no	yes	no	no	no	no	no	no
_-138-I	yes	yes	yes	yes	no	no	no	no	yes	yes	yes	no	yes	yes	yes	no	no	no
_-139-I	yes	yes	yes	yes	no	no	no	no	no	yes	yes	yes	yes	no	no	yes	yes	yes
_-140-I	yes	yes	yes	yes	no	no	no	yes	yes	no	no	yes	no	no	no	no	no	no
_-141-I	yes	yes	yes	yes	yes	no	yes	no	no	no	no	no	no	no	no	no	no	no
_-142-I	yes	yes	yes	yes	no	yes	yes	no	no	no	no	yes	no	no	no	no	no	no
_-143-I	yes	yes	yes	yes	no	no	no	no	yes	yes	yes	no	yes	yes	yes	no	no	no
_-144-I	yes	yes	yes	yes	no	no	no	no	no	no	no	no	no	no	no	no	no	no

No. of samples this page = 48
No. of brick samples total = 158

Limewash Experimental Matrix

Controls

Wash J

#	Wash	Photo	Color	Mass	QUV	Mass	Photo	Color										
-145-J	no	yes	yes	yes	yes	yes	yes	yes										
-146-J	no	yes	yes	yes	yes	yes	yes	yes										
-147-J	no	yes	yes	yes	yes	yes	yes	yes										
-148-J	no	yes	yes	yes	no	no	no	no										
-149-J	no	yes	yes	yes	no	no	no	no										
-150-J	no	yes	yes	yes	no	no	no	no										

Virginia Limeworks lime putty

Wash K (Lime, Water, "no acrylic")

#	Wash	Photo	Color	Mass	Solids	Tape	Mass	Abrade	Mass	QUV	Mass	Photo	Color	Tape	Mass	Abrade	Mass	Color
-151-K	yes	yes	yes	yes	no	no	no	no	no	yes	yes	yes	yes	no	no	yes	yes	yes
-152-K	yes	yes	yes	yes	no	no	no	yes	yes	no	no	yes	no	no	no	no	no	no
-153-K	yes	yes	yes	yes	yes	yes	yes	no	no	no	no	yes	no	no	no	no	no	no
-154-K	yes	yes	yes	yes	no	yes	yes	no	no	no	no	yes	no	no	no	no	no	no
-155-K	yes	yes	yes	yes	no	no	no	no	yes	yes	yes	no	yes	yes	yes	no	no	no
-156-K	yes	yes	yes	yes	no	no	no	yes	yes	no	no	yes	no	no	no	no	no	no
-157-K	yes	yes	yes	yes	yes	no	yes	no	no	no	no	no	no	no	no	no	no	no
-158-K	yes	yes	yes	yes	no	no	no	no	no	yes	yes	yes	yes	no	no	yes	yes	yes

No. of samples this page = 14
No. of brick samples total = 158

Testing

QUV-Artificial Weathering

Adhesion by Tape Test

Abrasion by Falling Sand

Artificial Weathering: QUV

Artificial weathering was selected as one of the steps in the study to decrease the amount of time required to age the samples while imparting changes due to weathering.

Weathering Cycle

The weathering cycle selected for the study is 4 hours of UV light exposure at 60℃ (˜120℉), followed by 4 hours of condensation in the dark at 50℃ (˜140 ℉). This cycle will be repeated for a period of 800 hours. Calibrating the irradiance and temperature of the QUV prior to performing the experiment is important to ensure accurate and repeatable test results.

Prepared by
Sarah Jackson

Limewash Experiment: QUV Rating

5A	No peeling or removal		
4A	Trace peeling or removal		
3A	Jagged removal up to 1/16 inch		
2A	Jagged removal up to 1/8 inch		
1A	Removal from most of the area		
0A	Removal from most of the sample		

Prepared by
Sarah Jackson

Designation: D 3359 – 95

Standard Test Methods for Measuring Adhesion by Tape Test[1]

This standard is issued under the fixed designation D 3359; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

These methods have been approved for use by agencies of the Department of Defense. Consult the DoD Index of Specifications and Standards for the specific year of issue which has been adopted by the Department of Defense.

1. Scope

1.1 These test methods cover procedures for assessing the adhesion of coating films to metallic substrates by applying and removing pressure-sensitive tape over cuts made in the film.

1.2 Test Method A is primarily intended for use at job sites while Test Method B is more suitable for use in the laboratory. Also, Test Method B is not considered suitable for films thicker than 5 mils (125 μm).

NOTE 1—Subject to agreement between the purchaser and the seller, Test Method B can be used for thicker films if wider spaced cuts are employed.

1.3 These test methods are used to establish whether the adhesion of a coating to a substrate is at a generally adequate level. They do not distinguish between higher levels of adhesion for which more sophisticated methods of measurement are required.

NOTE 2—It should be recognized that differences in adherability of the coating surface can affect the results obtained with coatings having the same inherent adhesion.

1.4 In multicoat systems adhesion failure may occur between coats so that the adhesion of the coating system to the substrate is not determined.

1.5 The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are for information only.

1.6 *This standard does not purport to address the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*

D 609 Practice for Preparation of Cold-Rolled Steel Panels for Testing Paint, Varnish, Conversion Coatings, and Related Coating Products[2]

D 823 Practice for Producing Films of Uniform Thickness of Paint, Varnish, and Related Products on Test Panels[2]

D 1000 Test Methods For Pressure-Sensitive Adhesive-Coated Tapes Used for Electrical and Electronic Applications[3]

D 1730 Practices for Preparation of Aluminum and Aluminum-Alloy Surfaces for Painting[4]

D 2092 Practices for Preparation of Zinc-Coated (Galvanized) Steel Surfaces for Painting[5]

D 2197 Test Methods for Adhesion of Organic Coatings by Scrape Adhesion[2]

D 2370 Test Method for Tensile Properties of Organic Coatings[2]

D 3330 Test Method for Peel Adhesion of Pressure-Sensitive Tape of 180° Angle[6]

D 3924 Specification for Standard Environment for Conditioning and Tesing Paint, Varnish, Lacquers, and Related Materials[2]

D 4060 Test Method for Abrasion Resistance of Organic Coatings by the Taber Abraser[2]

3. Summary of Test Methods

3.1 *Test Method A*—An X-cut is made in the film to the substrate, pressure-sensitive tape is applied over the cut and then removed, and adhesion is assessed qualitatively on the 0 to 5 scale.

3.2 *Test Method B*—A lattice pattern with either six or eleven cuts in each direction is made in the film to the substrate, pressure-sensitive tape is applied over the lattice and then removed, and adhesion is evaluated by comparison with descriptions and illustrations.

4. Significance and Use

4.1 If a coating is to fulfill its function of protecting or decorating a substrate, it must adhere to it for the expected service life. Because the substrate and its surface preparation (or lack of it) has a drastic effect on the adhesion of coatings, a method of evaluation adhesion of a coating to different substrates or surface treatments, or of different coatings to the same substrate and treatment, is of considerable usefulness in the industry.

4.2 The limitations of all adhesion methods and the specific limitation of this test method to lower levels of adhesion (see 1.3) should be recognized before using it. The intra- and inter-laboratory precision of this test method is similar to other widely-accepted tests for coated substrates

[1] These test methods are under the jurisdiction of ASTM Committee D-1 on Paint and Related Coatings, Materials, and Applications and are the direct responsibility of Subcommittee D01.23 on Physical Properties of Applied Paint Films.

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[2] *Annual Book of ASTM Standards*, Vol 06.01.

[3] *Annual Book of ASTM Standards*, Vol 10.01.

[4] *Annual Book of ASTM Standards*, Vol 02.05.

[5] *Annual Book of ASTM Standards*, Vol 06.02.

[6] *Annual Book of ASTM Standards*, Vol 15.09.

(for example, Test Method D 2370 and Test Method D 4060), but this is partly the result of it being insensitive to all but large differences in adhesion. The limited scale of 0 to 5 was selected deliberately to avoid a false impression of being sensitive.

TEST METHOD A—X-CUT TAPE TEST

5. Apparatus and Materials

5.1 *Cutting Tool*—Sharp razor blade, scalpel, knife or other cutting devices. It is of particular importance that the cutting edges be in good condition.

5.2 *Cutting Guide*—Steel or other hard metal straightedge to ensure straight cuts.

5.3 *Tape*-One-inch (25-mm) wide semitransparent pressure-sensitive tape with an adhesion strength agreed upon by the supplier and the user is needed[7]. Because of the variability in adhesion strength from batch-to-batch and with time, it is essential that tape from the same batch be used when tests are to be run in different laboratories. If this is not possible the test method should be used only for ranking a series of test coatings.

5.4 *Rubber Eraser*, on the end of a pencil.

5.5 *Illumination*—A light source is helpful in determining whether the cuts have been made through the film to the substrate.

6. Test Specimens

6.1 When this test method is used in the field, the specimen is the coated structure or article on which the adhesion is to be evaluated.

6.2 For laboratory use apply the materials to be tested to panels of the composition and surface conditions on which it is desired to determine the adhesion.

NOTE 3—Applicable test panel description and surface preparation methods are given in Practice D 609 and Practices D 1730 and D 2092.

NOTE 4—Coatings should be applied in accordance with Practice D 823, or as agreed upon between the purchaser and the seller.

NOTE 5—If desired or specified, the coated test panels may be subjected to a preliminary exposure such as water immersion, salt spray, or high humidity before conducting the tape test. The conditions and time of exposure will be governed by ultimate coating use or shall be agreed upon between the purchaser and seller.

7. Procedure

7.1 Select an area free of blemishes and minor surface imperfections. For tests in the field, ensure that the surface is clean and dry. Extremes in temperature or relative humidity may affect the adhesion of the tape or the coating.

7.2 Make two cuts in the film each about 1.5 in. (40 mm) long that intersect near their middle with a smaller angle of between 30 and 45°. When making the incisions, use the straightedge and cut through the coating to the substrate in one steady motion.

7.3 Inspect the incisions for reflection of light from the metal substrate to establish that the coating film has been penetrated. If the substrate has not been reached make another X in a different location. Do not attempt to deepen a previous cut as this may affect adhesion along the incision.

7.4 Remove two complete laps of the pressure-sensitive tape from the roll and discard. Remove an additional length at a steady (that is, not jerked) rate and cut a piece about 3 in. (75 mm) long.

7.5 Place the center of the tape at the intersection of the cuts with the tape running in the same direction as the smaller angles. Smooth the tape into place by finger in the area of the incisions and then rub firmly with the eraser on the end of a pencil. The color under the transparent tape is a useful indication of when good contact has been made.

7.6 Within 90 ± 30 s of application, remove the tape by seizing the free end and pulling it off rapidly (not jerked) back upon itself at as close to an angle of 180° as possible.

7.7 Inspect the X-cut area for removal of coating from the substrate or previous coating and rate the adhesion in accordance with the following scale:

5A No peeling or removal,
4A Trace peeling or removal along incisions or at their intersection,
3A Jagged removal along incisions up to 1/16 in. (1.6 mm) on either side,
2A Jagged removal along most of incisions up to 1/8 in. (3.2 mm) on either side,
1A Removal from most of the area of the X under the tape, and
0A Removal beyond the area of the X.

7.8 Repeat the test in two other locations on each test panel. For large structures make sufficient tests to ensure that the adhesion evaluation is representative of the whole surface.

7.9 After making several cuts examine the cutting edge and, if necessary, remove any flat spots or wire-edge by abrading lightly on a fine oil stone before using again. Discard cutting tools that develop nicks or other defects that tear the film.

8. Report

8.1 Report the number of tests, their mean and range, and for coating systems, where the failure occurred that is, between first coat and substrate, between first and second coat, etc.

8.2 For field tests report the structure or article tested, the location and the environmental conditions at the time of testing.

8.3 For test panels report the substrate employed, the type of coating, the method of cure, and the environmental conditions at the time of testing.

8.4 If the adhesion strength of the tape has been determined in accordance with Test Methods D 1000 or D 3330, report the results with the adhesion rating(s). If the adhesion strength of the tape has not been determined, report the specific tape used and its manufacturer.

9. Precision and Bias[8]

9.1 In an interlaboratory study of this test method in which operators in six laboratories made one adhesion measurement on three panels each of three coatings covering

[7] Permacel 99 manufactured by Permacel, New Brunswick, NJ 08903, and available from various Permacel tape distributors, is reported to be suitable for this purpose. The manufacturer of this tape and the manufacturer of the tape used in the interlaboratory study (see RR: D01-1008), have advised this subcommittee that the properties of these tapes were changed. Users of it should, therefore, check whether current material gives comparable results to previous supplied material.

[8] Supporting data are available from ASTM Headquarters. Request RR: D01-1008.

a wide range of adhesion, the within-laboratories standard deviation was found to be 0.33 and the between-laboratories 0.44. Based on these standard deviations, the following criteria should be used for judging the acceptability of results at the 95 % confidence level:

9.1.1 *Repeatability*—Provided adhesion is uniform over a large surface, results obtained by the same operator should be considered suspect if they differ by more than 1 rating unit for two measurements.

9.1.2 *Reproducibility*—Two results, each the mean of triplicates, obtained by different operators should be considered suspect if they differ by more than 1.5 rating units.

9.2 Bias cannot be established for these test methods.

TEST METHOD B—CROSS-CUT TAPE TEST

10. Apparatus and Materials

10.1 *Cutting Tool*—Sharp razor blade, scalpel, knife or other cutting device having a cutting edge angle between 15 and 30° that will make either a single cut or several cuts at once[9]. It is of particular importance that the cutting edge or edges be in good condition.

10.2 *Cutting Guide*—If cuts are made manually (as opposed to a mechanical apparatus) a steel or other hard metal straightedge or template to ensure straight cuts.

10.3 *Rule*—Tempered steel rule graduated in 0.5 mm for measuring individual cuts.

10.4 *Tape*, as described in 5.3.

10.5 *Rubber Eraser*, on the end of a pencil.

10.6 *Illumination*, as described in 5.5.

10.7 *Magnifying Glass*—An illuminated magnifier to be used while making individual cuts and examining the test area.

11. Test Specimens

11.1 Test specimens shall be as described in Section 6. It should be noted, however, that multitip cutters provide good results only on test areas sufficiently plane[10] that all cutting edges contact the substrate to the same degree. Check for flatness with a straight edge such as that of the tempered steel rule (10.3).

12. Procedure

12.1 Where required or when agreed upon, subject the specimens to a preliminary test before conducting the tape test (see Note 3). After drying or testing the coating, conduct the tape test at room temperature as defined in Specification D 3924, unless D 3924 standard temperature is required or agreed.

12.2 Select an area free of blemishes and minor surface imperfections, place on a firm base, and under the illuminated magnifier, make parallel cuts as follows:

12.2.1 For coatings having a dry film thickness up to and including 2.0 mils (50 μm) space the cuts 1 mm apart and make eleven cuts unless otherwise agreed upon.

12.2.2 For coatings having a dry film thickness between 2.0 mils (50 μm) and 5 mils (125 μm), space the cuts 2 mm apart and make six cuts. For films thicker than 5 mils use Test Method A.

12.2.3 Make all cuts about ¾ in. (20 mm) long. Cut through the film to the substrate in one steady motion using just sufficient pressure on the cutting tool to have the cutting edge reach the substrate. When making successive single cuts with the aid of a guide, place the guide on the uncut area.

12.3 After making the required cuts brush the film lightly with a soft brush or tissue to remove any detached flakes or ribbons of coatings.

12.4 Examine the cutting edge and, if necessary, remove any flat spots or wire-edge by abrading lightly on a fine oil stone. Make the additional number of cuts at 90° to and centered on the original cuts.

12.5 Brush the area as before and inspect the incisions for reflection of light from the substrate. If the metal has not been reached make another grid in a different location.

12.6 Remove two complete laps of tape and discard. Remove an additional length at a steady (that is, not jerked) rate and cut a piece about 3 in. (75 mm) long.

12.7 Place the center of the tape over the grid and in the area of the grid smooth into place by a finger. To ensure good contact with the film rub the tape firmly with the eraser on the end of a pencil. The color under the tape is a useful indication of when good contact has been made.

12.8 Within 90 ± 30 s of application, remove the tape by seizing the free end and rapidly (not jerked) back upon itself at as close to an angle of 180° as possible.

12.9 Inspect the grid area for removal of coating from the substrate or from a previous coating using the illuminated magnifier. Rate the adhesion in accordance with the following scale illustrated in Fig. 1:

5B The edges of the cuts are completely smooth; none of the squares of the lattice is detached.

4B Small flakes of the coating are detached at intersections; less than 5 % of the area is affected.

3B Small flakes of the coating are detached along edges and at intersections of cuts. The area affected is 5 to 15 % of the lattice.

2B The coating has flaked along the edges and on parts of the squares. The area affected is 15 to 35 % of the lattice.

1B The coating has flaked along the edges of cuts in large ribbons and whole squares have detached. The area affected is 35 to 65 % of the lattice.

0B Flaking and detachment worse than Grade 1.

12.10 Repeat the test in two other locations on each test panel.

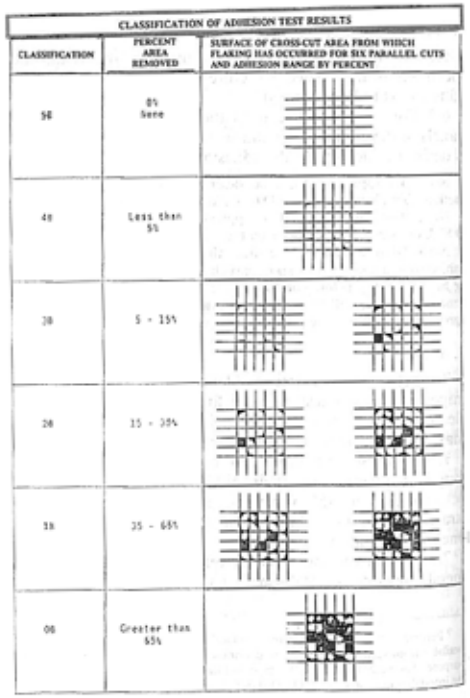

FIG. 1 Classification of Adhesion Test Results

13. Report

13.1 Report the number of tests, their mean and range, and for coating systems, where the failure occurred, that is, between first coat and substrate, between first and second coat, etc.

13.2 Report the substrate employed, the type of coating and the method of cure.

13.3 If the adhesion strength has been determined in accordance with Test Methods D 1000 or D 3330, report the results with the adhesion rating(s). If the adhesion strength of the tape has not been determined, report the specific tape used and its manufacturer.

14. Precision and Bias[9]

14.1 On the basis of two interlaboratory tests of this test method in one of which operators in six laboratories made one adhesion measurement on three panels each of three coatings covering a wide range of adhesion and in the other operators in six laboratories made three measurements on two panels each of four different coatings applied over two other coatings, the pooled standard deviations for within- and between-laboratories were found to be 0.37 and 0.7. Based on these standard deviations, the following criteria should be used for judging the acceptability of results at the 95 % confidence level:

14.1.1 *Repeatability*—Provided adhesion is uniform over a large surface, results obtained by the same operator should be considered suspect if they differ by more than one rating unit for two measurements.

14.1.2 *Reproducibility*—Two results, each the mean of duplicates or triplicates, obtained by different operators should be considered suspect if they differ by more than two rating units.

14.2 Bias cannot be established for these test methods.

15. Keywords

15.1 adhesion, tape; crosscut adhesion test method; tape adhesion test method; X-cut adhesion test method

APPENDIX

(Nonmandatory Information)

X1. COMMENTARY

X1.1 Introduction

X1.1.1 Given the complexities of the adhesion process, can adhesion be measured? As Mittal (**1**)[11] has pointed out, the answer is both yes and no. It is reasonable to state that at the present time no test exists that can precisely assess the actual physical strength of an adhesive bond. But it can also be said that it is possible to obtain an indication of relative adhesion performance.

X1.1.2 Practical adhesion test methods are generally of two types: "*implied*" and "*direct*". "Implied" tests include indentation or scribe techniques, rub testing, and wear testing. Criticism of these tests arises when they are used to quantify the strength of adhesive bonding. But this, in fact, is not their purpose. An "implied" test should be used to assess coating performance under actual service conditions. "Direct" measurements, on the other hand, are intended expressly to measure adhesion. Meaningful tests of this type are highly sought after, primarily because the results are expressed by a single discrete quantity, the force required to rupture the coating/substrate bond under prescribed conditions. Direct tests include the Hesiometer and the Adherometer (**2**). Common methods which approach the direct tests are peel, lap-shear, and tensile tests.

X1.2 Test Methods

X1.2.1 In practice, numerous types of tests have been used to attempt to evaluate adhesion by inducing bond rupture by different modes. Criteria deemed essential for a test to warrant large-scale acceptance are: use of a straightforward and unambiguous procedure; relevance to its intended application; repeatability and reproducibility; and quantifiability, including a meaningful rating scale for assessing performance.

X1.2.2 Test methods used for coatings on metals are: peel adhesion or "tape testing"; Gardner impact flexibility testing; and adhesive joint testing including shear (lap joint) and direct tensile (butt joint) testing. These tests do not strictly meet all the criteria listed, but an appealing aspect of these tests is that in most cases the equipment/instrumentation is readily available or can be obtained at reasonable cost.

[9] Multiblade cutters are available from a few sources that specialize in testing equipment for the paint industry. One supplier that has assisted in the refinement of these methods and of Test Methods D 2197 is given in footnote 10.

[10] A multitip cutter for coated pipe surfaces is now available from Paul N. Gardner Co., 316 NE First St., Pompano Beach, FL 33060.

[11] The boldface numbers in parentheses refer to the list of references at the end of this test method.

X1.2.3 A wide diversity of tests methods have been developed over the years that measure aspects of adhesion (1–5). There generally is difficulty, however, in relating these tests to basic adhesion phenomena.

X1.3 The Tape Test

X1.3.1 By far, the most used test for evaluating coating "adhesion" is the peel test. In use since the 1930's, in its simplest version a piece of adhesive tape is pressed against the paint film. The test consists of observing if the film is peeled off when the tape is removed. The method can be refined to measure the force required for film removal. However, if the coating is removed simply by pulling off the tape, the strength of the adhesive bond is at such a low level as to be practically useless. Consequently, in most cases to assess coatings of appreciable adhesion, crosses or a cross-hatched pattern are cut into the coating, a tape applied and removed. The coating removed is assessed against an established rating scale. If a coating debonds from merely cutting an "X" and not applying tape, the adhesion is also very poor.

X1.3.2 The current widely-used version was first published in 1974; two test methods are covered in this standard. Both test methods are used to establish whether the adhesion of a coating to a substrate is at an adequate level; however they do not distinguish between higher levels of adhesion for which more sophisticated methods of measurement are required. Major limitations of the tape test are its low sensitivity, applicability only to coatings of relatively low bond strengths, and non-determination of adhesion to the substrate where failure occurs within a single coat, as when testing primers alone, or within or between coats in multicoat systems. For multicoat systems where adhesion failure may occur between or within coats, the adhesion of the coating system to the substrate is not determined.

X1.3.3 Repeatability within one rating unit is generally observed for coatings on metals for both methods, with reproducibility of one to two units. The tape test enjoys widespread popularity and is viewed as "simple" as well as low in cost. Applied to metals, it is economical to perform, lends itself to job site application, and most importantly, after decades of use, people feel comfortable with it.

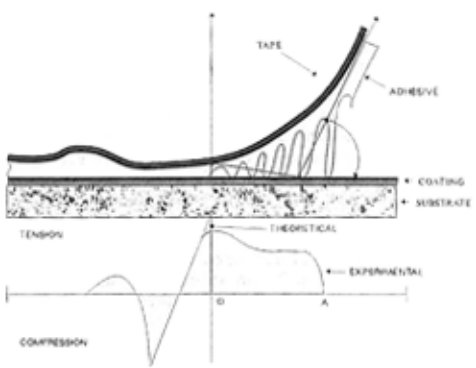

FIG. X1.1 Peel Profile (5)

X1.3.4 When a flexible adhesive tape is applied to a coated rigid substrate surface and then removed, the removal process has been described in terms of the "peel phenomenon," as illustrated in Fig. X1.1.

X1.3.5 Peeling begins at the "toothed" leading edge (at the right) and proceeds along the coating adhesive/interface or the coating/substrate interface, depending on the relative bond strengths. It is assumed that coating removal occurs when the tensile force generated along the latter interface, which is a function of the rheological properties of the backing and adhesive layer materials, is greater than the bond strength at the coating-substrate interface (or cohesive strength of the coating). In actuality, however, this force is distributed over a discrete distance (O-A) in Fig. X1.1, which relates directly to the properties described, not concentrated at a point (O) in Fig. X1.1 as in the theoretical case—though the tensile force is greatest at the origin for both. A significant compressive force arises from the response of the tape backing material to being stretched. Thus both tensile and compressive forces are involved in adhesion tape testing.

X1.3.6 Close scrutiny of the tape test with respect to the nature of the tape employed and certain aspects of the procedure itself reveal several factors, each or any combination of which can dramatically affect the results of the test as discussed (6).

X1.4 Peel Adhesion Testing on Plastic Substrates

X1.4.1 Tape tests have been criticized when used for substrates other than metal, such as plastics. The central issues are that the test on plastics lacks reproducibility and does not relate to the intended application. Both concerns are well founded: poor precision is a direct result of several factors intrinsic to the materials employed and the procedure itself. More importantly, in this instance the test is being applied beyond its intended scope. These test methods were designed for relatively ductile coatings applied to metal substrates, not for coatings (often brittle) applied to plastic parts (7). The unique functional requirements of coatings on plastic substrates cause the usual tape tests to be unsatisfactory for measuring adhesion performance in practice.

X1.5 The Tape Controversy

X1.5.1 With the withdrawal from commerce of the tape specified originally, 3M No. 710, current test methods no longer identify a specific tape. Differences in tapes used can lead to different results as small changes in backing stiffness and adhesive rheology cause large changes in the tension area. Some commercial tapes are manufactured to meet minimum standards. A given lot may surpass these standards and thus be suitable for general market distribution; however, such a lot may be a source of serious and unexpected error in assessing adhesion. One commercially available tape test kit had included a tape with adhesion strength variances of up to 50 % claimed by the manufacturer. Also, because tapes change on storage, bond strengths of the tape may change over time (7, 8).

X1.5.2 While there are tapes available that appear to deliver consistent performance, a given tape does not adhere equally well to all coatings. For example, when the peel removal force of the tape (from the coating) used earlier by Task Group D01.23.10 to establish precision of the method

by 3M No. 710 was examined with seven different electromagnetic interference/radio frequency interference (EMI/RFI) coatings, it was found that, while peel was indeed consistent for a given coating, the value varied by 25 % between the highest and lowest ratings among coatings. Several factors that contribute to these differences include coating composition and topology; as a result, no single tape is likely to be suitable for testing all coatings. Further, the tape test does not give an absolute value for the force required for bond rupture, but serves only as an indicator that some minimum value for bond strength was met or exceeded (7, 8).

X1.6 Procedural Problems

X1.6.1 The tape test is operator intensive. By design it was made as simple as possible to perform, and requires a minimum of specialized equipment and materials that must meet certain specifications. The accuracy and precision depend largely upon the skill of the operator and the operator's ability to perform the test in a consistent manner. Key steps that directly reflect the importance of operator skill include the angle and rate of tape removal and the visual assessment of the tested sample. It is not unexpected that different operators might obtain different results (7, 8).

X1.6.2 *Peel Angle and Rate:* The standard requires that the free end of the tape be removed rapidly at as close to a 180° angle as possible. If the peel angle and rate vary, the force required to remove the tape can change dramatically. Nearly linear increases were observed in peel force approaching 100 % as peel angle was changed from 135 to 180, and similar large differences can be expected in peel force as peel rate varies. These effects are related as they reflect certain rheological properties of the backing and adhesive that are molecular in origin. Variation in pull rate and peel angle can effect large differences in test values and must be minimized to assure reproducibility (9).

X1.6.3 *Visual Assessment:* The final step in the test is visual assessment of the coating removed from the specimen, which is subjective in nature, so that the coatings can vary among individuals evaluating the same specimen (9).

X1.6.3.1 Performance in the tape test is based on the amount of coating removed compared to a descriptive scale. The exposure of the substrate can be due to factors other than coating adhesion, including that arising from the requirement that the coating be cut (hence the synonym "cross-hatch adhesion test"). Justification for the cutting step is reasonable as cutting provides a free edge from which peeling can begin without having to overcome the cohesive strength of the coating layer.

X1.6.3.2 Cutting might be suitable for coatings applied to metal substrates, but for coatings applied to plastics or wood, the process can lead to a misleading indication of poor adhesion due to the unique interfacial zone. For coatings on soft substrates, issues include how deep should this cut penetrate, and is it possible to cut only to the interface?

X1.6.3.3 In general, if adhesion test panels are examined microscopically, it is often clearly evident that the coating removal results from substrate failure at or below the interface, and not from the adhesive failure between the coating and the substrate. Cohesive failure within the coating film is also frequently observed. However, with the tape test, failures within the substrate or coating layers are rare because the tape adhesive is not usually strong enough to exceed the cohesive strengths of normal substrates and organic coatings. Although some rather brittle coatings may exhibit cohesive failure, the tape test adhesion method does not make provision for giving failure locality (7, 8).

X1.6.4 Use of the test method in the field can lead to variation in test results due to temperature and humidity changes and their effect upon tape, coating and substrate.

X1.7 Conclusion

X1.7.1 All the issues aside, if these test methods are used within the Scope Section and are performed carefully, some insight into the approximate, relative level of adhesion can be gained.

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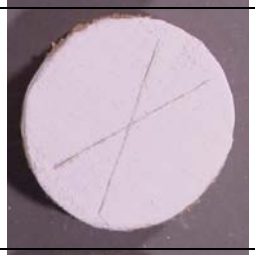
Limewash Experiment: Adhesion Rating

5A	No peeling or removal		
4A	Trace peeling or removal along incisions or at their intersection		
3A	Jagged removal along most of incisions up to 1/16 inch on either side		
2A	Jagged removal along most incisions up to 1/8 inch on either side		
1A	Removal from most of the area of the X under the tape		
0A	Removal beyond the area of the X		

Prepared by
Sarah Jackson

Abrasion Testing Procedure

1. Assemble the apparatus so that the sample holder is directly in-line with the sand tube and funnel, and so that the large collection bin is able to trap all used sand.

2. Choose sample to abrade and mount it in holder directly under the outlet tube, so that the center of the flow will hit the center of the sample.

3. Position the sample so that the nearest portion of it to the end of the outlet tube is exactly one (1) inch from the outlet tube.

4. Fill the one liter beaker with sand to exactly the 1000 mL mark.

5. Load the upper funnel with the sand, thus allowing sand to abrade the sample.

6. Record each 1 L of sand used.

7. Repeat steps 4 through 6 until the sample begins to show substrate, but empty the collection bin of its sand before the sand "backs up" onto the sample.

8. Once substrate begins to show, switch to using 250 mL at a time by using the plastic beaker.

9. Make sure to <u>record exactly the total volume of sand</u> used.

10. The run is complete once a patch of substrate is exposed that measures 4 mm in diameter (no more, no less). Use the longest diameter if the patch is not circular.

11. The final piece of data for each sample is then the volume of sand required to expose a 4 mm diameter patch of substrate.

Revised: 5/2/2005 TWB

Results

Handmade Brick

Limewash Experimental Matrix: Handmade Brick

Graymont, "Ivory" hydrated lime

Wash A (Class C, Molasses, Alum, Salt, Lime, Water)

#	Wash	Photo	Color	Mass	Solids	Tape	Mass	Abrade	Mass	QUV	Mass	Photo	Color	Tape	Mass	Abrade	Mass	Color
HB-001-A	yes	yes	yes	16.2367	no	no	no	no	no	5A	16.2814	yes	yes	no	no	8 L	16.1985	yes
HB-002-A	yes	yes	yes	17.7219	no	no	no	27 L	17.7220	no	no	yes	no	no	no	no	no	no
HB-003-A	yes	yes	yes	16.8341	0.7669	no	16.9156	no	no	no	no	no	no	no	no	no	no	no
HB-004-A	yes	yes	yes	21.0527	no	5A	21.0228	no	no	no	no	yes	no	no	no	no	no	no
HB-005-A	yes	yes	yes	13.8931	no	no	no	no	yes	5A	13.9049	no	yes	2A	13.8418	no	no	no
HB-006-A	yes	yes	yes	16.5957	no	no	no	no	no	5A	16.5080	yes	yes	no	no	8.5 L	16.3918	yes
HB-007-A	yes	yes	yes	16.8292	no	no	no	104 L	16.8336	no	no	yes	no	no	no	no	no	no
HB-008-A	yes	yes	yes	20.9735	0.6148	no	20.7548	no	no	no	no	no	no	no	no	no	no	no
HB-009-A	yes	yes	yes	17.4729	no	4A	17.4497	no	no	no	no	yes	no	no	no	no	no	no
HB-010-A	yes	yes	yes	21.3540	no	no	no	no	yes	5A	21.3867	no	yes	3A	21.3685	no	no	no
HB-011-A	yes	yes	yes	17.1885	no	no	no	no	no	yes	yes	yes	yes	no	no	yes	yes	yes
HB-012-A	yes	yes	yes	21.6583	no	no	no	148 L	21.6161	no	no	yes	no	no	no	no	no	no
HB-013-A	yes	yes	yes	16.5249	0.5074	no	16.1504	no	no	no	no	no	no	no	no	no	no	no
HB-014-A	yes	yes	yes	18.0225	no	2A	17.9899	no	no	no	no	yes	no	no	no	no	no	no
HB-015-A	yes	yes	yes	17.3333	no	no	no	no	yes	yes	yes	no	yes	yes	yes	no	no	no
HB-016-A	yes	yes	yes		no	no	no	no	no	no	no	no	no	no	no	no	no	no

Graymont, Niagara lime putty

Wash B (Class C, Molasses, Alum, Salt, Lime, Water)

#	Wash	Photo	Color	Mass	Solids	Tape	Mass	Abrade	Mass	QUV	Mass	Photo	Color	Tape	Mass	Abrade	Mass	Color
HB-017-B	yes	yes	yes	20.0485	no	no	no	no	no	4A	19.9704	yes	yes	no	no	9.5 L	19.9144	yes
HB-018-B	yes	yes	yes	23.5783	no	no	no	72 L	23.4992	no	no	yes	no	no	no	no	no	no
HB-019-B	yes	yes	yes	19.0066	0.7417	no	18.8288	no	no	no	no	no	no	no	no	no	no	no
HB-020-B	yes	yes	yes	18.9839	no	1A	18.9355	no	no	no	no	yes	no	no	no	no	no	no
HB-021-B	yes	yes	yes	17.9863	no	no	no	no	yes	4A	18.0191	no	yes	1A	17.9242	no	no	no
HB-022-B	yes	yes	yes	16.1423	no	no	no	no	no	4A	16.1525	yes	yes	no	no	4 L	16.1189	yes
HB-023-B	yes	yes	yes	21.0037	no	no	no	51 L	20.9196	no	no	yes	no	no	no	no	no	no
HB-024-B	yes	yes	yes	16.5319	0.5860	no	16.2841	no	no	no	no	no	no	no	no	no	no	no
HB-025-B	yes	yes	yes	23.7587	no	4A	23.7393	no	no	no	no	yes	no	no	no	no	no	no
HB-026-B	yes	yes	yes	17.0188	no	no	no	no	yes	5A	17.0226	no	yes	2A	16.9463	no	no	no
HB-027-B	yes	yes	yes	17.2435	no	no	no	no	no	yes	yes	yes	yes	no	no	yes	yes	yes
HB-028-B	yes	yes	yes	16.6144	no	no	no	16 L	16.5836	no	no	yes	no	no	no	no	no	no
HB-029-B	yes	yes	yes	22.1304	0.7570	no	22.1792	no	no	no	no	no	no	no	no	no	no	no
HB-030-B	yes	yes	yes	20.2461	no	3A	20.2086	no	no	no	no	yes	no	no	no	no	no	no
HB-031-B	yes	yes	yes	17.0455	no	no	no	no	yes	yes	yes	no	yes	yes	yes	no	no	no
HB-032-B	yes	yes	yes	19.2325	no	no	no	no	no	no	no	no	no	no	no	no	no	no

Virginia Limeworks lime putty

Wash C (Class C, Molasses, Alum, Salt, Lime, Water)

#	Wash	Photo	Color	Mass	Solids	Tape	Mass	Abrade	Mass	QUV	Mass	Photo	Color	Tape	Mass	Abrade	Mass	Color
HB-033-C	yes	yes	yes	19.0625	no	no	no	no	no	4A	19.0843	yes	yes	no	no	2 L	19.0277	yes
HB-034-C	yes	yes	yes	17.0894	no	no	no	21 L	17.0320	no	no	yes	no	no	no	no	no	no
HB-035-C	yes	yes	yes	24.7851	0.8644	no	25.0994	no	no	no	no	no	no	no	no	no	no	no
HB-036-C	yes	yes	yes	20.3022	no	3A	20.2671	no	no	no	no	yes	no	no	no	no	no	no
HB-037-C	yes	yes	yes	19.7419	no	no	no	no	yes	4A	19.7512	no	yes	4A	19.6891	no	no	no
HB-038-C	yes	yes	yes	16.8328	no	no	no	no	no	4A	16.1525	yes	yes	no	no	1.5 L	16.7497	yes
HB-039-C	yes	yes	yes	18.5945	no	no	no	17.5 L	18.5480	no	no	yes	no	no	no	no	no	no
HB-040-C	yes	yes	yes	17.7632	0.5852	no	17.7497	no	no	no	no	no	no	no	no	no	no	no
HB-041-C	yes	yes	yes	21.4861	no	2A	21.4345	no	no	no	no	yes	no	no	no	no	no	no
HB-042-C	yes	yes	yes	23.0965	no	no	no	no	yes	4A	17.0226	no	yes	4A	22.9655	no	no	no
HB-043-C	yes	yes	yes	21.7949	no	no	no	no	no	yes	yes	yes	yes	no	no	yes	yes	yes
HB-044-C	yes	yes	yes	25.0601	no	no	no	31.5 L	25.0049	no	no	yes	no	no	no	no	no	no
HB-045-C	yes	yes	yes	23.4628	0.8014	no	23.2266	no	no	no	no	no	no	no	no	no	no	no
HB-046-C	yes	yes	yes	22.4945	no	4A	22.4664	no	no	no	no	yes	no	no	no	no	no	no
HB-047-C	yes	yes	yes	17.4273	no	no	no	no	yes	yes	yes	no	yes	yes	yes	no	no	no
HB-048-C	yes	yes	yes	22.0972	no	no	no	no	no	no	no	no	no	no	no	no	no	no

No. of samples this page = 48
No. of brick samples total = 158

Limewash Experimental Matrix: Handmade Brick

Graymont, "Ivory" hydrated lime

Wash D (Lime, Molasses, Casein, Clove Oil, Water)

#	Wash	Photo	Color	Mass	Solids	Tape	Mass	Abrade	Mass	QUV	Mass	Photo	Color	Tape	Mass	Abrade	Mass	Color
HB-049-D	yes	yes	yes	18.9165	no	no	no	no	no	4A	18.9244	yes	yes	no	no	1.5 L	18.9049	yes
HB-050-D	yes	yes	yes	17.0744	no	no	no	16.5 L	17.0289	no	no	yes	no	no	no	no	no	no
HB-051-D	yes	yes	yes	16.6301	0.4065	no	16.3524	no	no	no	no	no	no	no	no	no	no	no
HB-052-D	yes	yes	yes	15.6192	no	5A	15.5935	no	no	no	no	yes	no	no	no	no	no	no
HB-053-D	yes	yes	yes	17.3028	no	no	no	no	yes	5A	17.2850	no	yes	1A	17.2338	no	no	no
HB-054-D	yes	yes	yes	17.0217	no	no	no	no	no	5A	16.4849	yes	yes	no	no	6.5 L	16.4225	yes
HB-055-D	yes	yes	yes	21.3384	no	no	no	5 L	21.3193	no	no	yes	no	no	no	no	no	no
HB-056-D	yes	yes	yes	20.7094	0.5544	no	20.7672	no	no	no	no	no	no	no	no	no	no	no
HB-057-D	yes	yes	yes	13.2909	no	3A	13.2776	no	no	no	no	yes	no	no	no	no	no	no
HB-058-D	yes	yes	yes	14.6773	no	no	no	no	yes	4A	14.7172	no	yes	4A	14.6910	no	no	no
HB-059-D	yes	yes	yes	16.6344	no	no	no	no	no	yes	yes	yes	yes	no	no	yes	yes	yes
HB-060-D	yes	yes	yes	21.2354	no	no	no	32.5 L	21.2058	no	no	yes	no	no	no	no	no	no
HB-061-D	yes	yes	yes	15.6980	0.5202	no	15.7651	no	no	no	no	no	no	no	no	no	no	no
HB-062-D	yes	yes	yes	16.1964	no	4A	16.1838	no	no	no	no	yes	no	no	no	no	no	no
HB-063-D	yes	yes	yes	19.3499	no	no	no	no	yes	yes	yes	no	yes	yes	yes	no	no	no
HB-064-D	yes	yes	yes	14.5796	no	no	no	no	no	no	no	no	no	no	no	no	no	no

Graymont, Niagara lime putty

Wash E (Lime, Molasses, Casein, Clove Oil, Water)

#	Wash	Photo	Color	Mass	Solids	Tape	Mass	Abrade	Mass	QUV	Mass	Photo	Color	Tape	Mass	Abrade	Mass	Color
HB-065-E	yes	yes	yes	16.6772	no	no	no	no	no	5A	16.6815	yes	yes	no	no	2.75 L	16.6599	yes
HB-066-E	yes	yes	yes	16.1082	no	no	no	13.5 L	16.0542	no	no	yes	no	no	no	no	no	no
HB-067-E	yes	yes	yes	20.6706	0.3810	no	22.3285	no	no	no	no	no	no	no	no	no	no	no
HB-068-E	yes	yes	yes	17.3531	no	4A	17.3370	no	no	no	no	yes	no	no	no	no	no	no
HB-069-E	yes	yes	yes	14.7227	no	no	no	no	yes	5A	14.7499	no	yes	4A	14.7311	no	no	no
HB-070-E	yes	yes	yes	21.3866	no	no	no	no	no	5A	21.3900	yes	yes	no	no	3.5 L	21.3443	yes
HB-071-E	yes	yes	yes	18.3993	no	no	no	4 L	18.3927	no	no	yes	no	no	no	no	no	no
HB-072-E	yes	yes	yes	21.6241	0.3125	no	21.5916	no	no	no	no	no	no	no	no	no	no	no
HB-073-E	yes	yes	yes	15.2448	no	3A	15.2239	no	no	no	no	yes	no	no	no	no	no	no
HB-074-E	yes	yes	yes	17.2435	no	no	no	no	yes	5A	17.2809	no	yes	4A	17.2582	no	no	no
HB-075-E	yes	yes	yes	17.5429	no	no	no	no	no	yes	yes	yes	yes	no	no	yes	yes	yes
HB-076-E	yes	yes	yes	17.6926	no	no	no	2 L	17.6946	no	no	yes	no	no	no	no	no	no
HB-077-E	yes	yes	yes	17.0476	0.2730	no	16.9225	no	no	no	no	no	no	no	no	no	no	no
HB-078-E	yes	yes	yes	17.3254	no	4A	17.3189	no	no	no	no	yes	no	no	no	no	no	no
HB-079-E	yes	yes	yes	16.5220	no	no	no	no	yes	yes	yes	no	yes	yes	yes	no	no	no
HB-080-E	yes	yes	yes	19.7014	no	no	no	no	no	no	no	no	no	no	no	no	no	no

Virginia Limeworks lime putty

Wash F (Lime, Molasses, Casein, Clove Oil, Water)

#	Wash	Photo	Color	Mass	Solids	Tape	Mass	Abrade	Mass	QUV	Mass	Photo	Color	Tape	Mass	Abrade	Mass	Color
HB-081-F	yes	yes	yes	20.9785	no	no	no	no	no	4A	20.9551	yes	yes	no	no	2 L	20.8961	yes
HB-082-F	yes	yes	yes	16.9124	no	no	no	1.5 L	16.8992	no	no	yes	no	no	no	no	no	no
HB-083-F	yes	yes	yes	20.2932	0.4331	no	19.7203	no	no	no	no	no	no	no	no	no	no	no
HB-084-F	yes	yes	yes	18.9285	no	5A	18.9095	no	no	no	no	yes	no	no	no	no	no	no
HB-085-F	yes	yes	yes	21.0118	no	no	no	no	yes	5A	21.0717	no	yes	4A	21.0370	no	no	no
HB-086-F	yes	yes	yes	22.1965	no	no	no	no	no	5A	22.2754	yes	yes	no	no	2 L	22.2041	yes
HB-087-F	yes	yes	yes	21.1766	no	no	no	2.5 L	21.1557	no	no	yes	no	no	no	no	no	no
HB-088-F	yes	yes	yes	21.4396	0.3982	no	21.2071	no	no	no	no	no	no	no	no	no	no	no
HB-089-F	yes	yes	yes	16.9567	no	5A	16.9158	no	no	no	no	yes	no	no	no	no	no	no
HB-090-F	yes	yes	yes	19.0147	no	no	no	no	yes	5A	19.0584	no	yes	3A	19.0104	no	no	no
HB-091-F	yes	yes	yes	17.6096	no	no	no	no	no	yes	yes	yes	yes	no	no	yes	yes	yes
HB-092-F	yes	yes	yes	19.7335	no	no	no	1.5 L	19.7423	no	no	yes	no	no	no	no	no	no
HB-093-F	yes	yes	yes	17.6478	0.3432	no	17.6508	no	no	no	no	no	no	no	no	no	no	no
HB-094-F	yes	yes	yes	22.5562	no	5A	22.5436	no	no	no	no	yes	no	no	no	no	no	no
HB-095-F	yes	yes	yes	17.0653	no	no	no	no	yes	yes	yes	no	yes	yes	yes	no	no	no
HB-096-F	yes	yes	yes	16.6370	no	no	no	no	no	no	no	no	no	no	no	no	no	no

No. of samples this page = 48
No. of brick samples total = 158

Limewash Experimental Matrix: Handmade Brick

Graymont, "Ivory" hydrated lime

Wash G (Lime, Water, acrylic binder)

#	Wash	Photo	Color	Mass	Solids	Tape	Mass	Abrade	Mass	QUV	Mass	Photo	Color	Tape	Mass	Abrade	Mass	Color
HB-097-G	yes	yes	yes	16.9048	no	no	no	no	no	5A	16.9813	yes	yes	no	no	1.5 L	16.9785	yes
HB-098-G	yes	yes	yes	17.1932	no	no	no	8 L	17.1795	no	no	yes	no	no	no	no	no	no
HB-099-G	yes	yes	yes	16.0381	0.3841	no	15.9422	no	no	no	no	no	no	no	no	no	no	no
HB-100-G	yes	yes	yes	16.9013	no	2A	16.8970	no	no	no	no	yes	no	no	no	no	no	no
HB-101-G	yes	yes	yes	19.4285	no	no	no	no	yes	4A	19.5260	no	yes	4A	19.4873	no	no	no
HB-102-G	yes	yes	yes	15.9990	no	no	no	no	no	4A	15.4925	yes	yes	no	no	1 L	15.4537	yes
HB-103-G	yes	yes	yes	16.2512	no	no	no	7 L	16.2422	no	no	yes	no	no	no	no	no	no
HB-104-G	yes	yes	yes	18.2849	0.4241	no	18.2895	no	no	no	no	no	no	no	no	no	no	no
HB-105-G	yes	yes	yes	17.6191	no	3A	17.6135	no	no	no	no	yes	no	no	no	no	no	no
HB-106-G	yes	yes	yes	23.0592	no	no	no	no	yes	5A	23.0556	no	yes	4A	23.0395	no	no	no
HB-107-G	yes	yes	yes	17.1978	no	no	no	no	no	yes	yes	yes	yes	no	no	yes	yes	yes
HB-108-G	yes	yes	yes	20.8360	no	no	no	4.5 L	20.8228	no	no	yes	no	no	no	no	no	no
HB-109-G	yes	yes	yes	17.5719	0.3626	no	17.2819	no	no	no	no	no	no	no	no	no	no	no
HB-110-G	yes	yes	yes	18.9512	no	4A	18.9430	no	no	no	no	yes	no	no	no	no	no	no
HB-111-G	yes	yes	yes	16.6784	no	no	no	no	yes	yes	yes	no	yes	yes	yes	no	no	no
HB-112-G	yes	yes	yes	16.5530	no	no	no	no	no	no	no	no	no	no	no	no	no	no

Graymont, Niagara lime putty

Wash H (Lime, Water, acrylic binder)

#	Wash	Photo	Color	Mass	Solids	Tape	Mass	Abrade	Mass	QUV	Mass	Photo	Color	Tape	Mass	Abrade	Mass	Color
HB-113-H	yes	yes	yes	15.7926	no	no	no	no	no	5A	15.8542	yes	yes	no	no	3.5 L	15.8452	yes
HB-114-H	yes	yes	yes	21.8701	no	no	no	8 L	21.8675	no	no	yes	no	no	no	no	no	no
HB-115-H	yes	yes	yes	19.0923	0.3295	no	18.8208	no	no	no	no	no	no	no	no	no	no	no
HB-116-H	yes	yes	yes	16.2536	no	4A	16.2496	no	no	no	no	yes	no	no	no	no	no	no
HB-117-H	yes	yes	yes	21.3721	no	no	no	no	yes	5A	21.4513	no	yes	3A	21.4351	no	no	no
HB-118-H	yes	yes	yes	20.2638	no	no	no	no	no	5A	20.2772	yes	yes	no	no	1.5 L	20.2676	yes
HB-119-H	yes	yes	yes	20.7106	no	no	no	3 L	20.7062	no	no	yes	no	no	no	no	no	no
HB-120-H	yes	yes	yes	21.4641	0.3677	no	21.2895	no	no	no	no	no	no	no	no	no	no	no
HB-121-H	yes	yes	yes	17.4081	no	4A	17.4041	no	no	no	no	yes	no	no	no	no	no	no
HB-122-H	yes	yes	yes	20.1761	no	no	no	no	yes	4A	20.3808	no	yes	4A	20.3744	no	no	no
HB-123-H	yes	yes	yes	21.0010	no	no	no	no	no	yes	yes	yes	yes	no	no	yes	yes	yes
HB-124-H	yes	yes	yes	18.1894	no	no	no	3.5 L	18.1778	no	no	yes	no	no	no	no	no	no
HB-125-H	yes	yes	yes	18.9232	0.3008	no	18.7618	no	no	no	no	no	no	no	no	no	no	no
HB-126-H	yes	yes	yes	20.9084	no	5A	20.9019	no	no	no	no	yes	no	no	no	no	no	no
HB-127-H	yes	yes	yes	15.8565	no	no	no	no	yes	yes	yes	no	yes	yes	yes	no	no	no
HB-128-H	yes	yes	yes	17.2010	no	no	no	no	no	no	no	no	no	no	no	no	no	no

Virginia Limeworks lime putty

Wash I (Lime, Water, acrylic binder)

#	Wash	Photo	Color	Mass	Solids	Tape	Mass	Abrade	Mass	QUV	Mass	Photo	Color	Tape	Mass	Abrade	Mass	Color
HB-129-I	yes	yes	yes	16.8164	no	no	no	no	no	5A	16.5250	yes	yes	no	no	1.5 L	16.8410	yes
HB-130-I	yes	yes	yes	20.5600	no	no	no	14 L	20.5876	no	no	yes	no	no	no	no	no	no
HB-131-I	yes	yes	yes	21.0084	0.3781	no	20.8934	no	no	no	no	no	no	no	no	no	no	no
HB-132-I	yes	yes	yes	21.0229	no	4A	21.0162	no	no	no	no	yes	no	no	no	no	no	no
HB-133-I	yes	yes	yes	17.8749	no	no	no	no	yes	4A	17.9572	no	yes	1A	17.9337	no	no	no
HB-134-I	yes	yes	yes	22.2016	no	no	no	no	no	4A	22.2525	yes	yes	no	no	1 L	22.2612	yes
HB-135-I	yes	yes	yes	17.1971	no	no	no	5 L	17.1947	no	no	yes	no	no	no	no	no	no
HB-136-I	yes	yes	yes	16.8096	0.3668	no	16.8764	no	no	no	no	no	no	no	no	no	no	no
HB-137-I	yes	yes	yes	18.6019	no	4A	18.5904	no	no	no	no	yes	no	no	no	no	no	no
HB-138-I	yes	yes	yes	17.4517	no	no	no	no	yes	5A	17.4942	no	yes	5A	17.4840	no	no	no
HB-139-I	yes	yes	yes	22.8479	no	no	no	no	no	yes	yes	yes	yes	no	no	yes	yes	yes
HB-140-I	yes	yes	yes	17.0114	no	no	no	12 L	17.0014	no	no	yes	no	no	no	no	no	no
HB-141-I	yes	yes	yes	18.3403	0.4414	no	18.3237	no	no	no	no	no	no	no	no	no	no	no
HB-142-I	yes	yes	yes	21.8453	no	2A	21.8819	no	no	no	no	yes	no	no	no	no	no	no
HB-143-I	yes	yes	yes	19.9809	no	no	no	no	yes	yes	yes	no	yes	yes	yes	no	no	no
HB-144-I	yes	yes	yes	18.3464	no	no	no	no	no	no	no	no	no	no	no	no	no	no

No. of samples this page = 48
No. of brick samples total = 158

Limewash Experimental Matrix: Handmade Brick

Controls

Wash J

#	Wash	Photo	Color	Mass	QUV	Mass	Photo	Color										
HB-145-J	no	yes	yes	18.1914	yes	18.3174	yes	yes										
HB-146-J	no	yes	yes	20.1777	yes	20.1979	yes	yes										
HB-147-J	no	yes	yes	19.1610	yes	18.9945	yes	yes										
HB-148-J	no	yes	yes	18.8111	no	no	no	no										
HB-149-J	no	yes	yes	21.1410	no	no	no	no										
HB-150-J	no	yes	yes	17.7443	no	no	no	no										

Virginia Limeworks lime putty

Wash K (Lime, Water, "no acrylic")

#	Wash	Photo	Color	Mass	Solids	Tape	Mass	Abrade	Mass	QUV	Mass	Photo	Color	Tape	Mass	Abrade	Mass	Color
HB-151-K	yes	yes	yes	16.5452	no	no	no	no	no	5A	16.4367	yes	yes	no	no	2 L	16.4032	yes
HB-152-K	yes	yes	yes	17.4498	no	no	no	39 L	17.4157	no	no	yes	no	no	no	no	no	no
HB-153-K	yes	yes	yes	17.3868	0.2520	3A	16.9060	no	no	no	no	no	no	no	no	no	no	no
HB-154-K	yes	yes	yes	18.4522	no	4A	18.4352	no	no	no	no	yes	no	no	no	no	no	no
HB-155-K	yes	yes	yes	17.1379	no	no	no	no	yes	5A	17.1565	no	yes	3A	17.1301	no	no	no
HB-156-K	yes	yes	yes	17.9400	no	no	no	no	no	5A	17.1476	yes	yes	5A	17.6267	2.5 L	17.9092	yes
HB-157-K	yes	yes	yes	22.3237	0.3210	no	21.7012	no	no	no	no	yes	no	no	no	no	no	no
HB-158-K	yes	yes	yes	17.6356	no	no	no	28 L	17.5913	no	no	no	no	no	no	no	no	no

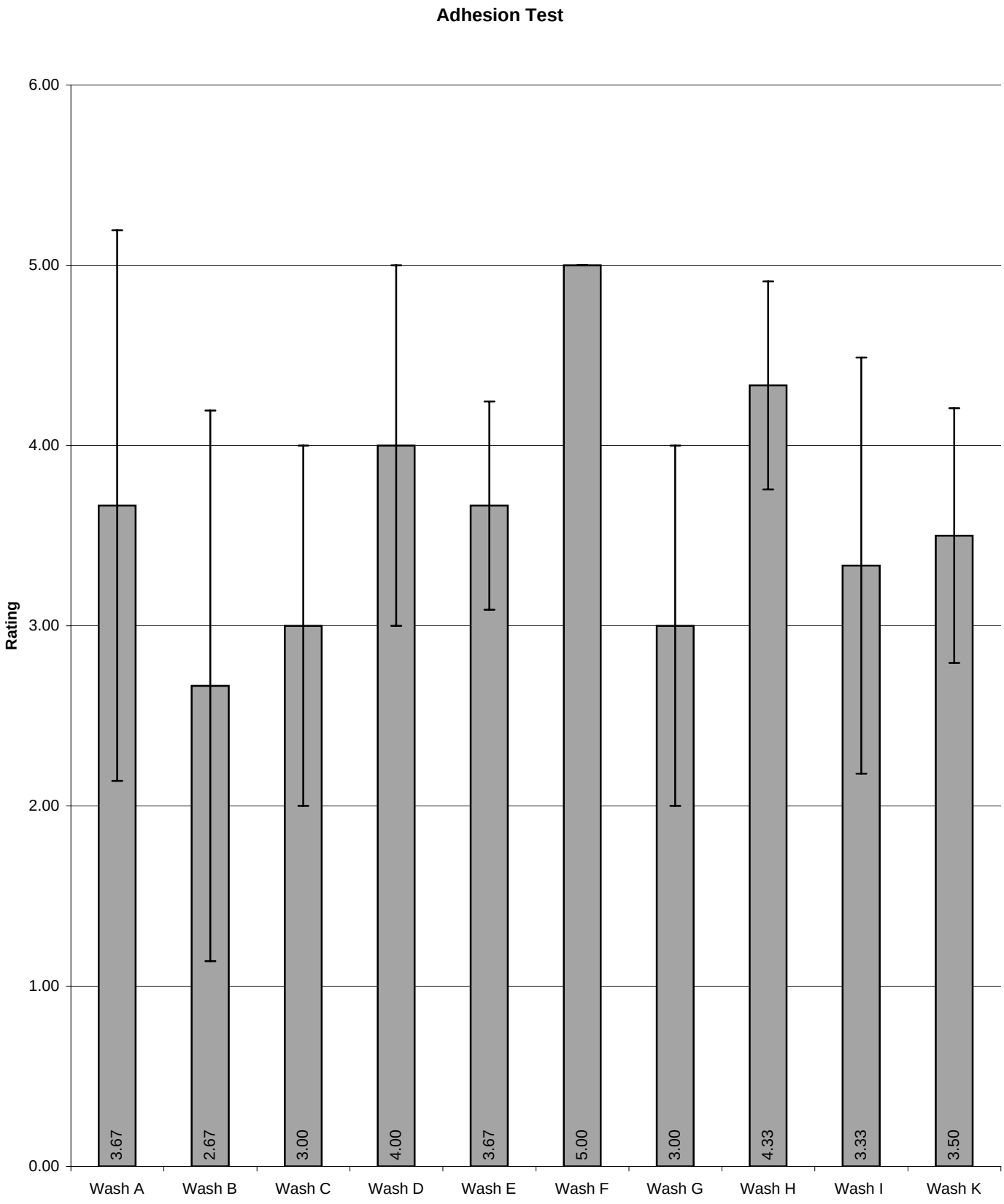
No. of samples this page = 14
No. of brick samples total = 158

Limewash Experiment: Handmade Brick

Adhesion Test

	Rating			Average	Std Dev.
HB-004-A	5.00		Wash A	3.67	1.53
HB-009-A	4.00				
HB-014-A	2.00				
				Average	Std Dev.
HB-020-B	1.00		Wash B	2.67	1.53
HB-025-B	4.00				
HB-030-B	3.00				
				Average	Std Dev.
HB-036-C	3.00		Wash C	3.00	1.00
HB-041-C	2.00				
HB-046-C	4.00				
				Average	Std Dev.
HB-052-D	5.00		Wash D	4.00	1.00
HB-057-D	3.00				
HB-062-D	4.00				
				Average	Std Dev.
HB-068-E	4.00		Wash E	3.67	0.58
HB-073-E	3.00				
HB-078-E	4.00				
				Average	Std Dev.
HB-084-F	5.00		Wash F	5.00	0.00
HB-089-F	5.00				
HB-094-F	5.00				
				Average	Std Dev.
HB-100-G	2.00		Wash G	3.00	1.00
HB-105-G	3.00				
HB-110-G	4.00				
				Average	Std Dev.
HB-116-H	4.00		Wash H	4.33	0.58
HB-121-H	4.00				
HB-126-H	5.00				
				Average	Std Dev.
HB-132-I	4.00		Wash I	3.33	1.15
HB-137-I	4.00				
HB-142-I	2.00				
				Average	Std Dev.
HB-153-K	3.00		Wash K	3.50	0.71
HB-154-K	4.00				

Limewash Experiment: Handmade Brick



Prepared by
Sarah Jackson

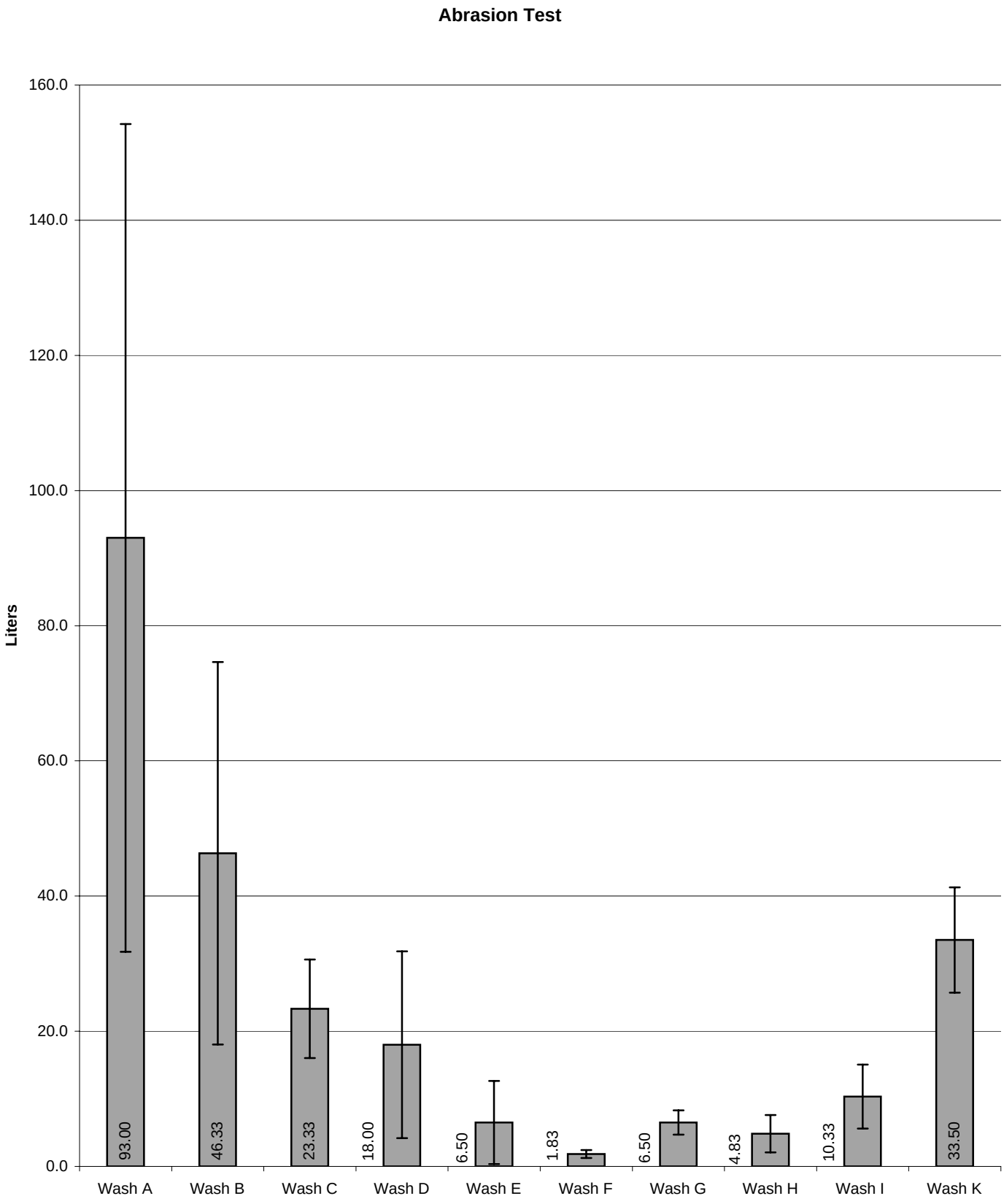
new hb data

Limewash Experiment: Handmade Brick

Abrasion Test

	Liters			Average	Std. Dev.
HB-002-A	27.00		**Wash A**	93.00	61.25
HB-007-A	104.00				
HB-012-A	148.00				
				Average	**Std. Dev.**
HB-018-B	72.00		**Wash B**	46.33	28.29
HB-023-B	51.00				
HB-028-B	16.00				
				Average	**Std. Dev.**
HB-034-C	21.00		**Wash C**	23.33	7.29
HB-039-C	17.50				
HB-044-C	31.50				
				Average	**Std. Dev.**
HB-050-D	16.50		**Wash D**	18.00	13.81
HB-055-D	5.00				
HB-060-D	32.50				
				Average	**Std. Dev.**
HB-066-E	13.50		**Wash E**	6.50	6.14
HB-071-E	4.00				
HB-076-E	2.00				
				Average	**Std. Dev.**
HB-082-F	1.50		**Wash F**	1.83	0.58
HB-087-F	2.50				
HB-092-F	1.50				
				Average	**Std. Dev.**
HB-098-G	8.00		**Wash G**	6.50	1.80
HB-103-G	7.00				
HB-108-G	4.50				
				Average	**Std. Dev.**
HB-114-H	8.00		**Wash H**	4.83	2.75
HB-119-H	3.00				
HB-124-H	3.50				
				Average	**Std. Dev.**
HB-130-I	14.00		**Wash I**	10.33	4.73
HB-135-I	5.00				
HB-140-I	12.00				
				Average	**Std. Dev.**
HB-152-K	39.00		**Wash K**	33.50	7.78
HB-157-K	28.00				

Limewash Experiment: Handmade Brick



Prepared by
Sarah Jackson

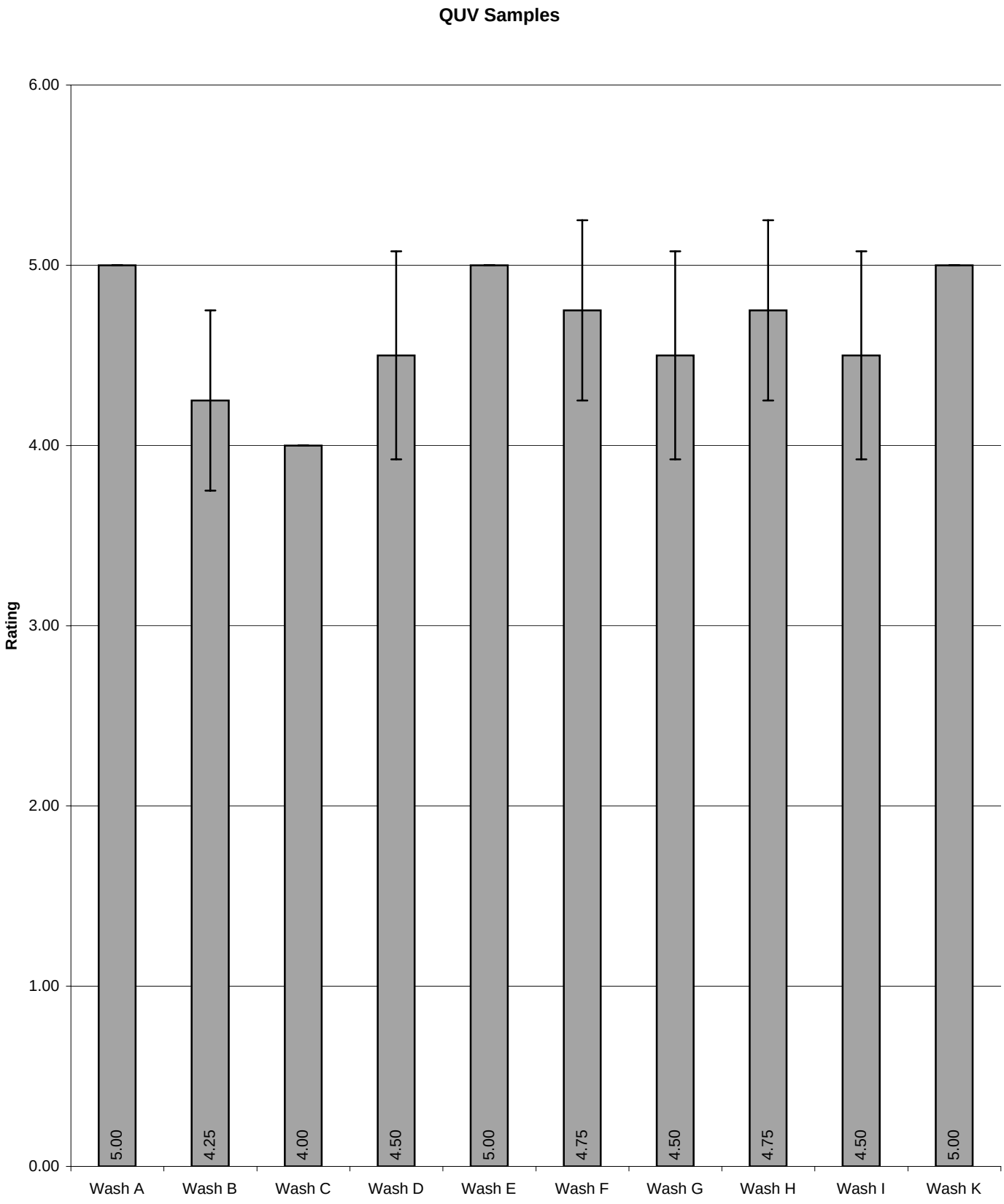
new hb data

Limewash Experiment: Handmade Brick

QUV Samples

	Rating			Average	Std. Dev
HB-001-A	5A		**Wash A**	5.00	0.00
HB-005-A	5A				
HB-006-A	5A				
HB-010-A	5A				
				Average	**Std. Dev**
HB-017-B	4A		**Wash B**	4.25	0.50
HB-021-B	4A				
HB-022-B	4A				
HB-026-B	5A				
				Average	**Std. Dev**
HB-033-C	4A		**Wash C**	4.00	0.00
HB-037-C	4A				
HB-038-C	4A				
HB-042-C	4A				
				Average	**Std. Dev**
HB-049-D	4A		**Wash D**	4.50	0.58
HB-053-D	5A				
HB-054-D	5A				
HB-058-D	4A				
				Average	**Std. Dev**
HB-065-E	5A		**Wash E**	5.00	0.00
HB-069-E	5A				
HB-070-E	5A				
HB-074-E	5A				
				Average	**Std. Dev**
HB-081-F	4A		**Wash F**	4.75	0.50
HB-085-F	5A				
HB-086-F	5A				
HB-090-F	5A				
				Average	**Std. Dev**
HB-097-G	5A		**Wash G**	4.50	0.58
HB-101-G	4A				
HB-102-G	4A				
HB-106-G	5A				
				Average	**Std. Dev**
HB-113-H	5A		**Wash H**	4.75	0.50
HB-117-H	5A				
HB-118-H	5A				
HB-122-H	4A				
				Average	**Std. Dev**
HB-129-I	5A		**Wash I**	4.50	0.58
HB-133-I	4A				
HB-134-I	4A				
HB-138-I	5A				
				Average	**Std. Dev**
HB-151-K	5A		**Wash K**	5.00	0.00
HB-155-K	5A				
HB-156-K	5A				

Limewash Experiment: Handmade Brick



Prepared by
Sarah Jackson

new hb data

Limewash Experiment: Handmade Brick
Colorimetry

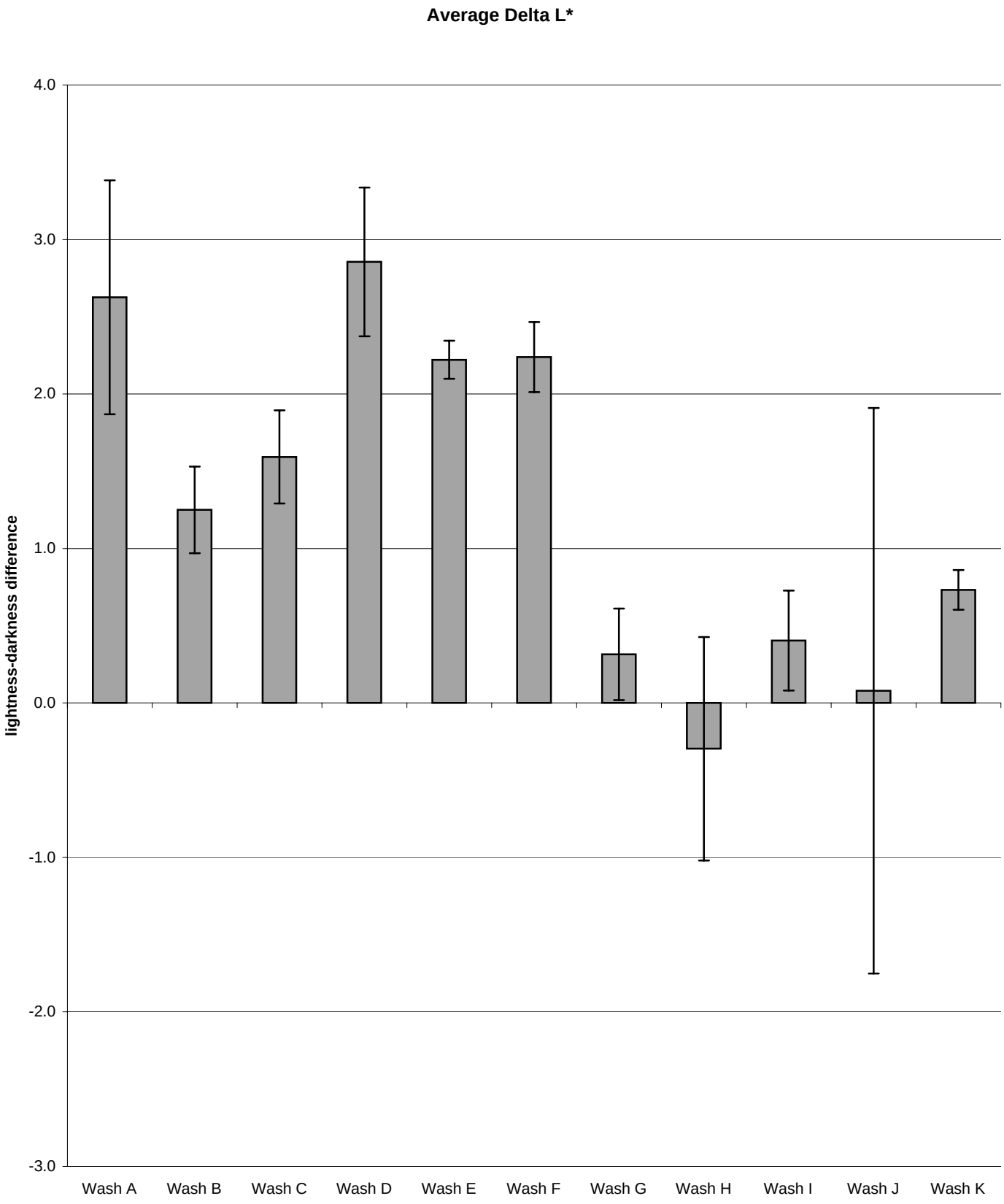
	Initial					After QUV			
Parameters:									
Std Status:	CREELL					CREELL			
Color Mode	L*a*b*					L*a*b*			
Observer	2–					2°			
Primary Illuminant	C					C			
		C/2–					C/2°		
	Name	L*	a*	b*		Name	L*	a*	b*
STD	Standard	97.0211	0.2315	1.8306		Standard	97.0280	0.1927	1.8565
	HB-001-A	90.6222	0.0331	11.6957		HB-001-A	94.2385	0.5181	3.7268
	HB-005-A	91.6527	-0.1709	10.8820		HB-005-A	94.1039	0.5388	3.9697
	HB-006-A	91.1757	0.1665	10.4696		HB-006-A	93.8253	0.7498	3.8505
	HB-010-A	92.1120	-0.4971	8.0959		HB-010-A	93.8965	0.1425	2.3419
	HB-017-B	93.7433	-0.0325	5.6080		HB-017-B	94.7335	0.2267	2.6053
	HB-021-B	93.8815	-0.0404	6.0528		HB-021-B	94.9705	0.2468	2.9819
	HB-022-B	93.8741	-0.1958	5.1198		HB-022-B	95.1708	0.0720	2.1730
	HB-026-B	93.6815	0.0274	6.1406		HB-026-B	95.3060	0.2725	3.6076
	HB-033-C	93.4805	-0.0423	6.4518		HB-033-C	95.3589	0.2484	2.2225
	HB-037-C	93.7410	-0.0669	4.3778		HB-037-C	95.1288	0.1259	1.5235
	HB-038-C	94.5345	-0.0161	5.3546		HB-038-C	95.8163	0.3287	2.5068
	HB-042-C	93.3343	-0.1479	4.0830		HB-042-C	95.1576	0.1079	1.3548
	HB-049-D	90.3333	0.4980	9.1089		HB-049-D	93.2849	0.6266	3.1449
	HB-053-D	91.8432	0.0281	8.4889		HB-053-D	95.1352	0.2740	2.7866
	HB-054-D	91.6548	-0.2741	9.2872		HB-054-D	94.6632	0.3877	3.3668
	HB-058-D	91.5916	-0.0221	7.9363		HB-058-D	93.7597	0.3217	2.3521
	HB-065-E	92.9651	0.0566	6.3055		HB-065-E	95.0584	0.1968	2.0615
	HB-069-E	92.0046	0.1598	6.3798		HB-069-E	94.3246	0.0539	1.9063
	HB-070-E	92.1341	-0.1027	6.4328		HB-070-E	94.4667	0.0325	1.5682
	HB-074-E	93.2041	-0.1165	6.7466		HB-074-E	95.3436	0.1236	2.1078
	HB-081-F	92.6182	0.2084	7.8946		HB-081-F	95.0977	0.1941	3.5366
	HB-085-F	92.6027	-0.0339	7.2941		HB-085-F	94.9895	0.1081	2.6250
	HB-086-F	93.0601	0.0466	7.1828		HB-086-F	95.1040	0.0805	3.5854
	HB-090-F	93.2038	0.0139	7.9010		HB-090-F	95.2504	0.2559	3.8304
	HB-097-G	94.1808	0.1759	1.0869		HB-097-G	94.2144	0.3291	0.4165
	HB-101-G	93.1928	0.3263	2.4087		HB-101-G	93.9246	0.3857	1.3113
	HB-102-G	93.6557	0.3154	1.3276		HB-102-G	93.9114	0.4047	0.5326
	HB-106-G	94.2322	0.2568	1.3257		HB-106-G	94.4710	0.3264	0.7077
	HB-113-H	93.8003	0.2332	0.6064		HB-113-H	92.4198	0.7531	1.4651
	HB-117-H	95.0956	0.0239	1.0943		HB-117-H	95.1932	0.1467	0.2289
	HB-118-H	94.9177	0.2912	1.4381		HB-117-H	94.9773	0.4183	0.7959
	HB-122-H	94.5461	0.1910	0.8654		HB-122-H	94.5836	0.3341	0.3290
	HB-129-I	94.2537	0.3078	1.3960		HB-129-I	94.2265	0.6186	1.4414
	HB-133-I	93.0878	0.3948	1.1068		HB-133-I	93.6453	0.3784	0.4242
	HB-134-I	93.8222	0.3266	0.8419		HB-134-I	94.5465	0.1761	-0.1417
	HB-138-I	94.3436	0.1505	0.9556		HB-138-I	94.7064	0.2506	0.0410
	HB-151-K	95.0738	0.3173	2.3582		HB-151-K	95.8605	0.4143	0.8568
	HB-155-K	94.9765	0.4527	2.5925		HB-155-K	95.5615	0.5368	1.6186
	HB-158-K	94.8678	0.2624	2.0308		HB-158-K	95.6910	0.4165	0.9518
	HB-160-L	94.8606	0.0158	0.8818		HB-160-L	94.4695	0.1488	0.8148
	HB-164-L	95.6418	-0.0624	0.6942		HB-164-L	95.0113	0.1701	-0.0477
	HB-165-L	95.0388	-0.0656	1.4539		HB-165-L	94.4921	0.4705	1.2509
	HB-169-L	94.5944	-0.0684	0.7680		HB-169-L	94.0299	0.1328	0.0232
	HB-176-M	95.3360	-0.1337	0.4801		HB-176-M	94.5518	0.4166	0.8879
	HB-180-M	94.8550	-0.0336	0.1337		HB-180-M	94.1788	0.1808	-0.4085
	HB-181-M	94.3858	0.0444	0.5649		HB-181-M	91.5959	0.5340	0.6352
	HB-185-M	95.7254	-0.0302	0.5736		HB-185-M	95.3055	0.2844	0.5130
	HB-192-N	94.7244	0.2666	0.1093		HB-192-N	94.9141	0.3807	-0.1228
	HB-196-N	93.1792	0.0764	0.3835		HB-196-N	92.7826	0.3914	-0.3195
	HB-197-N					HB-197-N	95.7164	0.4322	0.2798
	HB-201-N	94.2175	0.0591	0.3797		HB-201-N	94.9401	0.2775	-0.2669

Limewash Experiment: Handmade Brick
Colorimetry

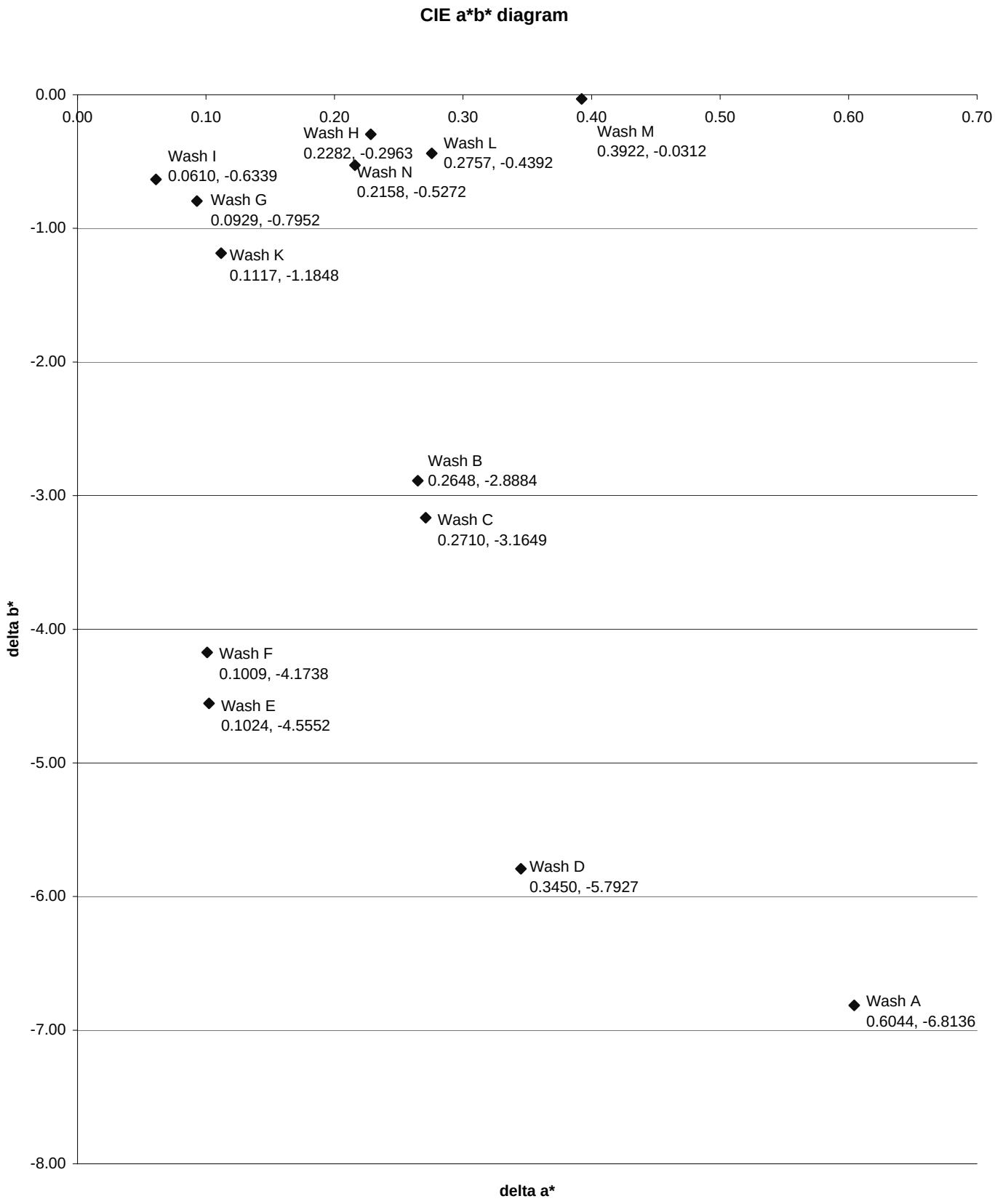
	▲ L*	▲ a*	▲ b*	▲ E*
HB-001-A	3.6163	0.4850	-7.9689	8.7645
HB-005-A	2.4512	0.7097	-6.9123	7.3683
HB-006-A	2.6496	0.5833	-6.6191	7.1535
HB-010-A	1.7845	0.6396	-5.7540	6.0582
HB-017-B	0.9902	0.2592	-3.0027	3.1724
HB-021-B	1.0890	0.2872	-3.0709	3.2709
HB-022-B	1.2967	0.2678	-2.9468	3.2306
HB-026-B	1.6245	0.2451	-2.5330	3.0191
HB-033-C	1.8784	0.2907	-4.2293	4.6368
HB-037-C	1.3878	0.1928	-2.8543	3.1797
HB-038-C	1.2818	0.3448	-2.8478	3.1420
HB-042-C	1.8233	0.2558	-2.7282	3.2913
HB-049-D	2.9516	0.1286	-5.9640	6.6557
HB-053-D	3.2920	0.2459	-5.7023	6.5889
HB-054-D	3.0084	0.6618	-5.9204	6.6738
HB-058-D	2.1681	0.3438	-5.5842	6.0002
HB-065-E	2.0933	0.1402	-4.2440	4.7342
HB-069-E	2.3200	-0.1059	-4.4735	5.0404
HB-070-E	2.3326	0.1352	-4.8646	5.3966
HB-074-E	2.1395	0.2401	-4.6388	5.1141
HB-081-F	2.4795	-0.0143	-4.3580	5.0140
HB-085-F	2.3868	0.1420	-4.6691	5.2457
HB-086-F	2.0439	0.0339	-3.5974	4.1376
HB-090-F	2.0466	0.2420	-4.0706	4.5626
HB-097-G	0.0336	0.1532	-0.6704	0.6885
HB-101-G	0.7318	0.0594	-1.0974	1.3204
HB-102-G	0.2557	0.0893	-0.7950	0.8399
HB-106-G	0.2388	0.0696	-0.6180	0.6662
HB-113-H	-1.3805	0.5199	0.8587	1.7069
HB-117-H	0.0976	0.1228	-0.8654	0.8795
HB-118-H	0.0596	0.1271	-0.6422	0.6574
HB-122-H	0.0375	0.1431	-0.5364	0.5564
HB-129-I	-0.0272	0.3108	0.0454	0.3153
HB-133-I	0.5575	-0.0164	-0.6826	0.8815
HB-134-I	0.7243	-0.1505	-0.9836	1.2307
HB-138-I	0.3628	0.1001	-0.9146	0.9890
HB-151-K	0.7867	0.0970	-1.5014	1.6978
HB-155-K	0.5850	0.0841	-0.9739	1.1392
HB-158-K	0.8232	0.1541	-1.0790	1.3659

Limewash Experiment: Handmade Brick
Colorimetry

	▲ L* Avg	▲ a* Avg	▲ b* Avg	▲ E* Avg	▲ L* SD	▲ a* SD	▲ b* SD	▲ E* SD
Wash A	2.6254	0.6044	-6.8136	7.3361	0.7572	0.0949	0.9138	1.1117
Wash B	1.2501	0.2648	-2.8884	3.1733	0.2804	0.0176	0.2423	0.1104
Wash C	1.5928	0.2710	-3.1649	3.5624	0.3019	0.0637	0.7120	0.7190
Wash D	2.8550	0.3450	-5.7927	6.4796	0.4815	0.2288	0.1801	0.3217
Wash E	2.2214	0.1024	-4.5552	5.0713	0.1228	0.1470	0.2622	0.2722
Wash F	2.2392	0.1009	-4.1738	4.7400	0.2271	0.1145	0.4554	0.4917
Wash G	0.3150	0.0929	-0.7952	0.8787	0.2957	0.0421	0.2147	0.3044
Wash H	-0.2964	0.2282	-0.2963	0.9500	0.7231	0.1946	0.7821	0.5223
Wash I	0.4044	0.0610	-0.6339	0.8541	0.3234	0.1955	0.4708	0.3878
Wash K	0.7316	0.1117	-1.1848	1.4010	0.1283	0.0373	0.2792	0.2809

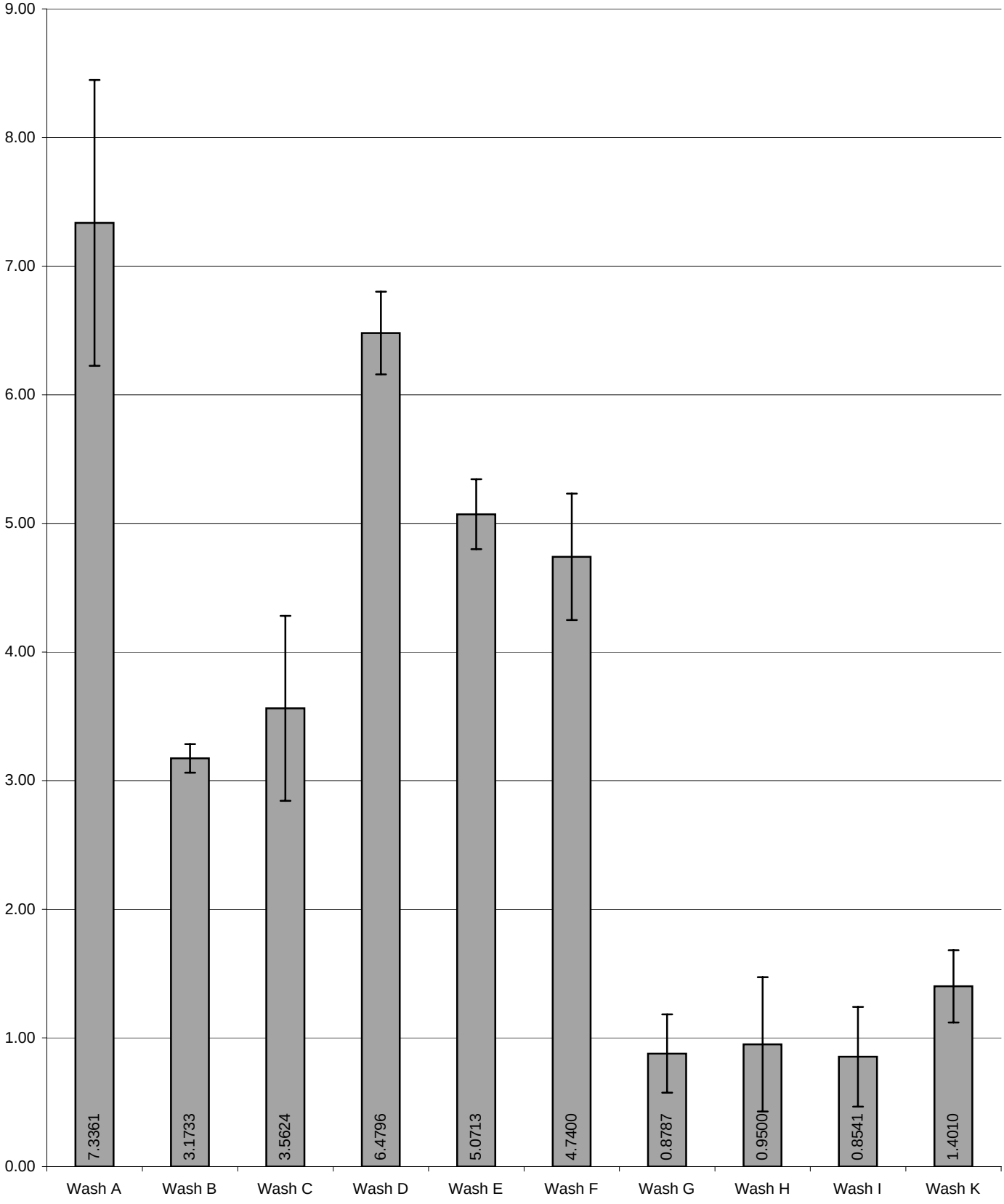

Average Delta L*
lightness-darkness difference
4.0
3.0
2.0
1.0
0.0
-1.0
-2.0
-3.0
Wash A
Wash B
Wash C
Wash D
Wash E
Wash F
Wash G
Wash H
Wash I
Wash J
Wash K

Limewash Experiment: Handmade Brick Colorimetry



Limewash Experiment: Handmade Brick

Colorimetry



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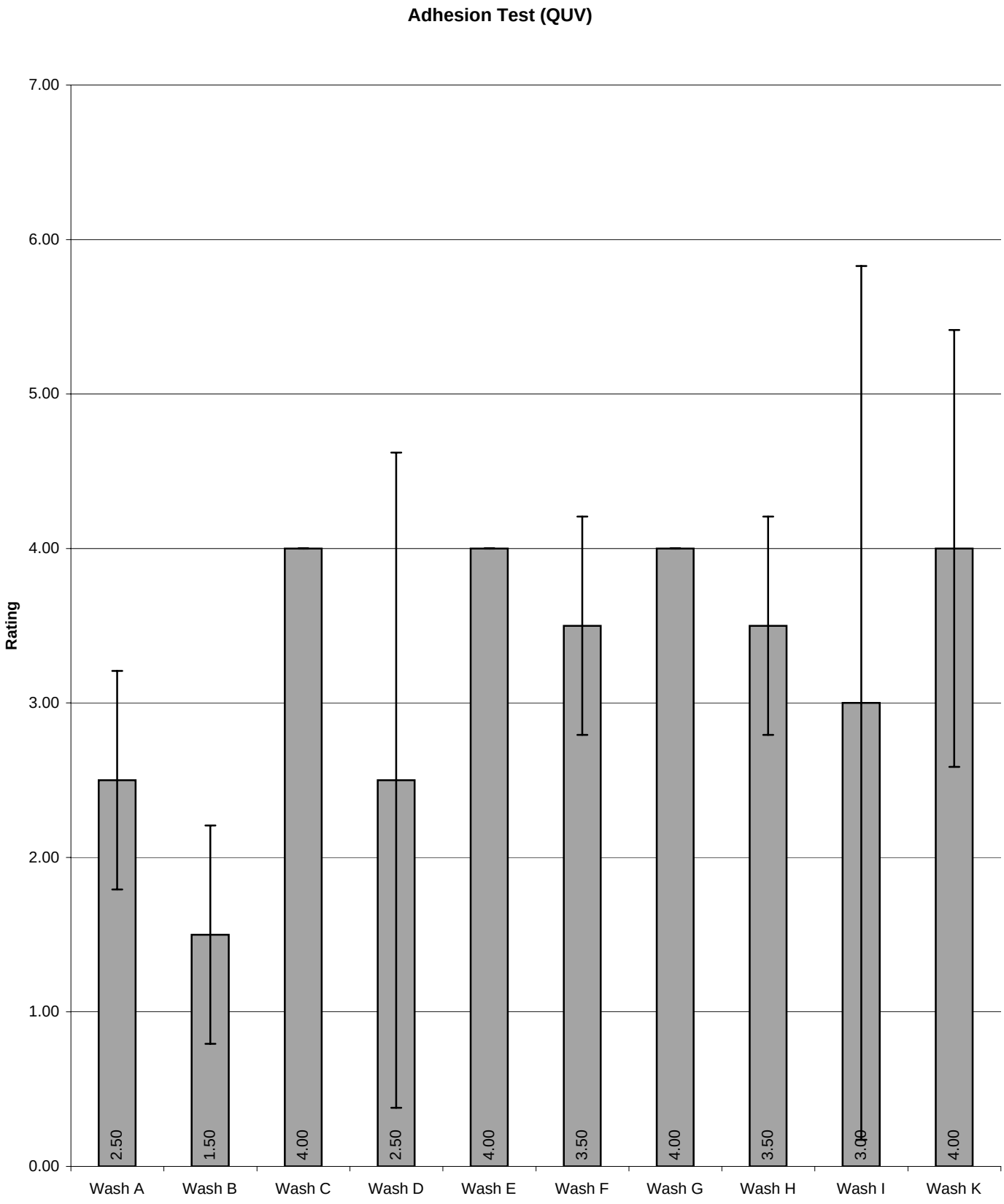
color data

Limewash Experiment: Handmade Brick

Adhesion Test (QUV)

	Rating			Average	Std. Dev
HB-005-A	2.00		**Wash A**	2.50	0.71
HB-010-A	3.00				
				Average	**Std. Dev**
HB-021-B	1.00		**Wash B**	1.50	0.71
HB-026-B	2.00				
				Average	**Std. Dev**
HB-037-C	4.00		**Wash C**	4.00	0.00
HB-042-C	4.00				
				Average	**Std. Dev**
HB-053-D	1.00		**Wash D**	2.50	2.12
HB-058-D	4.00				
				Average	**Std. Dev**
HB-069-E	4.00		**Wash E**	4.00	0.00
HB-074-E	4.00				
				Average	**Std. Dev**
HB-085-F	4.00		**Wash F**	3.50	0.71
HB-090-F	3.00				
				Average	**Std. Dev**
HB-101-G	4.00		**Wash G**	4.00	0.00
HB-106-G	4.00				
				Average	**Std. Dev**
HB-117-H	3.00		**Wash H**	3.50	0.71
HB-122-H	4.00				
				Average	**Std. Dev**
HB-133-I	1.00		**Wash I**	3.00	2.83
HB-138-I	5.00				
				Average	**Std. Dev**
HB-155-K	3.00		**Wash K**	4.00	1.41
HB-156-K	5.00				

Limewash Experiment: Handmade Brick



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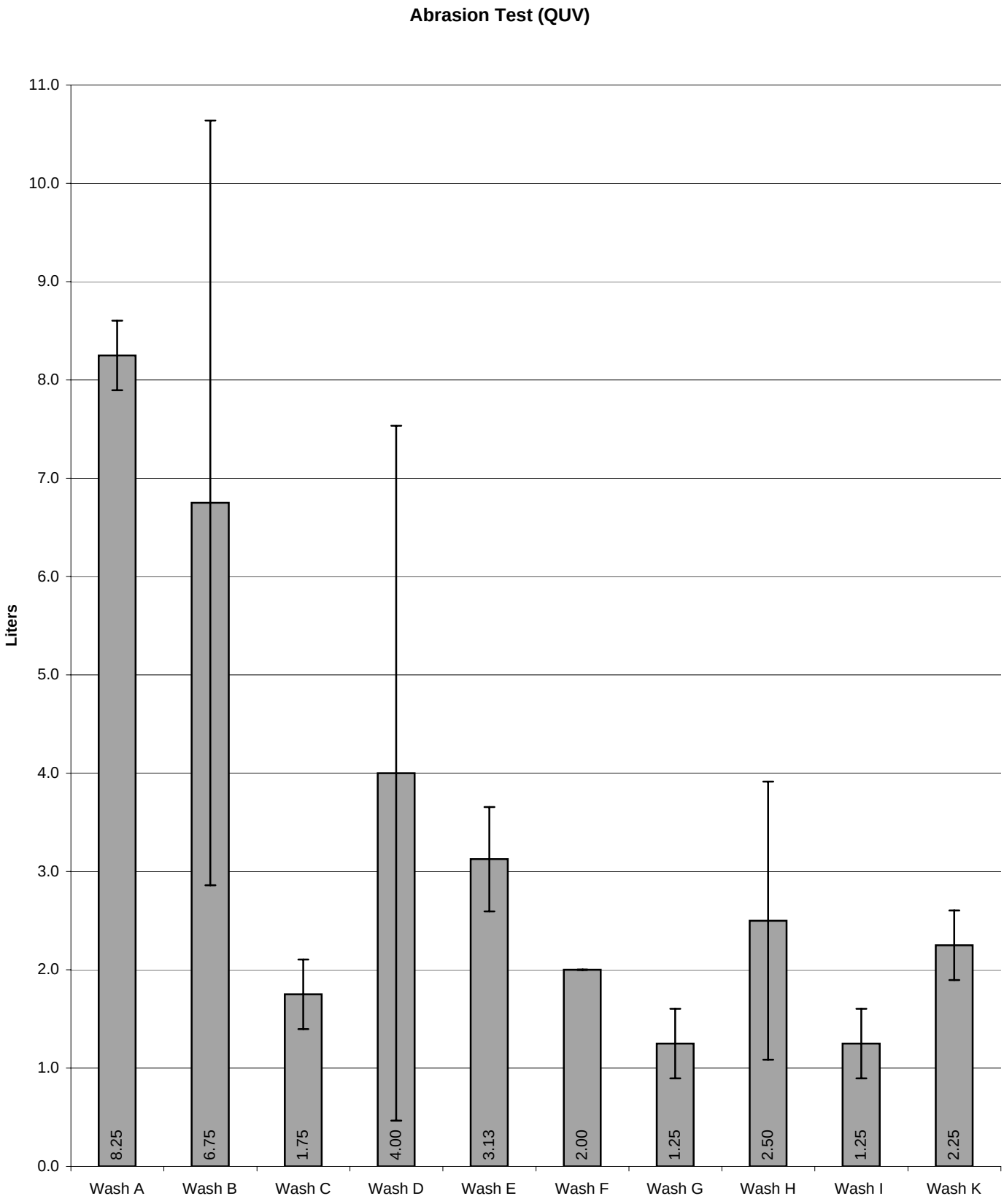
new hb data

Limewash Experiment: Handmade Brick

Abrasion Test (QUV)

	Liter			Average	Std. Dev.
HB-001-A	8.00		**Wash A**	8.25	0.35
HB-006-A	8.50				
				Average	**Std. Dev.**
HB-017-B	9.50		**Wash B**	6.75	3.89
HB-022-B	4.00				
				Average	**Std. Dev.**
HB-033-C	2.00		**Wash C**	1.75	0.35
HB-038-C	1.50				
				Average	**Std. Dev.**
HB-049-D	1.50		**Wash D**	4.00	3.54
HB-054-D	6.50				
				Average	**Std. Dev.**
HB-065-E	2.75		**Wash E**	3.13	0.53
HB-070-E	3.50				
				Average	**Std. Dev.**
HB-081-F	2.00		**Wash F**	2.00	0.00
HB-086-F	2.00				
				Average	**Std. Dev.**
HB-097-G	1.50		**Wash G**	1.25	0.35
HB-102-G	1.00				
				Average	**Std. Dev.**
HB-113-H	3.50		**Wash H**	2.50	1.41
HB-118-H	1.50				
				Average	**Std. Dev.**
HB-129-I	1.50		**Wash I**	1.25	0.35
HB-134-I	1.00				
				Average	**Std. Dev.**
HB-151-K	2.00		**Wash K**	2.25	0.35
HB-158-K	2.50				

Limewash Experiment: Handmade Brick



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new hb data

Limewash Experiment: Handmade Brick

Overall Rating

	Rating	Adhesion	Abrasion	QUV	QUV-Adhesion	QUV-Abrasion	
Best	10	F	A	A, E, K	C, E, G	A	
	9	H	B		K	B	
	8	D	K			D	
	7	E	C	H, F		E	
	6	A	D		F,H	H	
	5	K	I	D, G, I		K	
	4	I	G		I	F	
	3	G, C	E		A,D	C	
	2		H	B		G	
Worst	1	B	F	C	B	I	

	Samples	Adhesion	Abrasion	QUV	QUV-Adhesion	QUV-Abrasion	Sum
	Wash A	6	10	10	3	10	39
	Wash B	1	9	2	1	9	22
	Wash C	3	7	1	10	3	24
	Wash D	8	6	5	3	8	30
	Wash E	7	3	10	10	7	37
	Wash F	10	1	7	6	4	28
	Wash G	3	4	5	10	2	24
	Wash H	9	2	7	6	6	30
	Wash I	4	5	5	4	1	19
	Wash K	5	8	10	9	5	37

	Wash	**Total**					
Best	**A**	**39**					
	E, K	**37**					
	H, D	**30**					
	F	**28**					
	C, G	**24**					
	B	**22**					
Worst	**I**	**19**					

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Results

Modern Brick

Limewash Experimental Matrix: Modern Brick

Graymont, "Ivory" hydrated lime

Wash A (Class C, Molasses, Alum, Salt, Lime, Water)

#	Wash	Photo	Color	Mass	Solids	Tape	Mass	Abrade	Mass	QUV	Mass	Photo	Color	Tape	Mass	Abrade	Mass	Color
MB-001-A	yes	yes	yes	yes	no	no	no	no	no	yes	yes	yes	yes	no	no	yes	yes	yes
MB-002-A	yes	yes	yes	yes	no	no	no	yes	yes	no	no	yes	no	no	no	no	no	no
MB-003-A	yes	yes	yes	yes	yes	no	yes	no	no	no	no	no	no	no	no	no	no	no
MB-004-A	yes	yes	yes	yes	no	yes	yes	no	no	no	no	yes	no	no	no	no	no	no
MB-005-A	yes	yes	yes	yes	no	no	no	no	yes	yes	yes	no	yes	yes	yes	no	no	no
MB-006-A	yes	yes	yes	yes	no	no	no	no	no	yes	yes	yes	yes	no	no	yes	yes	yes
MB-007-A	yes	yes	yes	yes	no	no	no	yes	yes	no	no	yes	no	no	no	no	no	no
MB-008-A	yes	yes	yes	yes	yes	no	yes	no	no	no	no	no	no	no	no	no	no	no
MB-009-A	yes	yes	yes	yes	no	yes	yes	no	no	no	no	yes	no	no	no	no	no	no
MB-010-A	yes	yes	yes	yes	no	no	no	no	yes	yes	yes	no	yes	yes	yes	no	no	no
MB-011-A	yes	yes	yes	yes	no	no	no	no	no	yes	yes	yes	yes	no	no	yes	yes	yes
MB-012-A	yes	yes	yes	yes	no	no	no	yes	yes	no	no	yes	no	no	no	no	no	no
MB-013-A	yes	yes	yes	yes	yes	no	yes	no	no	no	no	no	no	no	no	no	no	no
MB-014-A	yes	yes	yes	yes	no	yes	yes	no	no	no	no	yes	no	no	no	no	no	no
MB-015-A	yes	yes	yes	yes	no	no	no	no	yes	yes	yes	no	yes	yes	yes	no	no	no
MB-016-A	yes	yes	yes	yes	no	no	no	no	no	no	no	no	no	no	no	no	no	no

Graymont, Niagara lime putty

Wash B (Class C, Molasses, Alum, Salt, Lime, Water)

#	Wash	Photo	Color	Mass	Solids	Tape	Mass	Abrade	Mass	QUV	Mass	Photo	Color	Tape	Mass	Abrade	Mass	Color
MB-017-B	yes	yes	yes	yes	no	no	no	no	no	yes	yes	yes	yes	no	no	yes	yes	yes
MB-018-B	yes	yes	yes	yes	no	no	no	yes	yes	no	no	yes	no	no	no	no	no	no
MB-019-B	yes	yes	yes	yes	yes	no	yes	no	no	no	no	no	no	no	no	no	no	no
MB-020-B	yes	yes	yes	yes	no	yes	yes	no	no	no	no	yes	no	no	no	no	no	no
MB-021-B	yes	yes	yes	yes	no	no	no	no	yes	yes	yes	no	yes	yes	yes	no	no	no
MB-022-B	yes	yes	yes	yes	no	no	no	no	no	yes	yes	yes	yes	no	no	yes	yes	yes
MB-023-B	yes	yes	yes	yes	no	no	no	yes	yes	no	no	yes	no	no	no	no	no	no
MB-024-B	yes	yes	yes	yes	yes	no	yes	no	no	no	no	no	no	no	no	no	no	no
MB-025-B	yes	yes	yes	yes	no	yes	yes	no	no	no	no	yes	no	no	no	no	no	no
MB-026-B	yes	yes	yes	yes	no	no	no	no	yes	yes	yes	no	yes	yes	yes	no	no	no
MB-027-B	yes	yes	yes	yes	no	no	no	no	no	yes	yes	yes	yes	no	no	yes	yes	yes
MB-028-B	yes	yes	yes	yes	no	no	no	yes	yes	no	no	yes	no	no	no	no	no	no
MB-029-B	yes	yes	yes	yes	yes	no	yes	no	no	no	no	no	no	no	no	no	no	no
MB-030-B	yes	yes	yes	yes	no	yes	yes	no	no	no	no	yes	no	no	no	no	no	no
MB-031-B	yes	yes	yes	yes	no	no	no	no	yes	yes	yes	no	yes	yes	yes	no	no	no
MB-032-B	yes	yes	yes	yes	no	no	no	no	no	no	no	no	no	no	no	no	no	no

Virginia Limeworks lime putty

Wash C (Class C, Molasses, Alum, Salt, Lime, Water)

#	Wash	Photo	Color	Mass	Solids	Tape	Mass	Abrade	Mass	QUV	Mass	Photo	Color	Tape	Mass	Abrade	Mass	Color
MB-033-C	yes	yes	yes	yes	no	no	no	no	no	yes	yes	yes	yes	no	no	yes	yes	yes
MB-034-C	yes	yes	yes	yes	no	no	no	yes	yes	no	no	yes	no	no	no	no	no	no
MB-035-C	yes	yes	yes	yes	yes	no	yes	no	no	no	no	no	no	no	no	no	no	no
MB-036-C	yes	yes	yes	yes	no	yes	yes	no	no	no	no	yes	no	no	no	no	no	no
MB-037-C	yes	yes	yes	yes	no	no	no	no	yes	yes	yes	no	yes	yes	yes	no	no	no
MB-038-C	yes	yes	yes	yes	no	no	no	no	no	yes	yes	yes	yes	no	no	yes	yes	yes
MB-039-C	yes	yes	yes	yes	no	no	no	yes	yes	no	no	yes	no	no	no	no	no	no
MB-040-C	yes	yes	yes	yes	yes	no	yes	no	no	no	no	no	no	no	no	no	no	no
MB-041-C	yes	yes	yes	yes	no	yes	yes	no	no	no	no	yes	no	no	no	no	no	no
MB-042-C	yes	yes	yes	yes	no	no	no	no	yes	yes	yes	no	yes	yes	yes	no	no	no
MB-043-C	yes	yes	yes	yes	no	no	no	no	no	yes	yes	yes	yes	no	no	yes	yes	yes
MB-044-C	yes	yes	yes	yes	no	no	no	yes	yes	no	no	yes	no	no	no	no	no	no
MB-045-C	yes	yes	yes	yes	yes	no	yes	no	no	no	no	no	no	no	no	no	no	no
MB-046-C	yes	yes	yes	yes	no	yes	yes	no	no	no	no	yes	no	no	no	no	no	no
MB-047-C	yes	yes	yes	yes	no	no	no	no	yes	yes	yes	no	yes	yes	yes	no	no	no
MB-048-C	yes	yes	yes	yes	no	no	no	no	no	no	no	no	no	no	no	no	no	no

No. of samples this page = 48
No. of brick samples total = 158

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Limewash Experimental Matrix: Modern Brick

Graymont, "Ivory" hydrated lime

Wash D (Lime, Molasses, Casein, Clove Oil, Water)

#	Wash	Photo	Color	Mass	Solids	Tape	Mass	Abrade	Mass	QUV	Mass	Photo	Color	Tape	Mass	Abrade	Mass	Color
MB-049-D	yes	yes	yes	yes	no	no	no	no	no	yes	yes	yes	yes	no	no	yes	yes	yes
MB-050-D	yes	yes	yes	yes	no	no	no	yes	yes	no	no	yes	no	no	no	no	no	no
MB-051-D	yes	yes	yes	yes	yes	no	yes	no	no	no	no	no	no	no	no	no	no	no
MB-052-D	yes	yes	yes	yes	no	yes	yes	no	no	no	no	yes	no	no	no	no	no	no
MB-053-D	yes	yes	yes	yes	no	no	no	no	yes	yes	yes	no	yes	yes	yes	no	no	no
MB-054-D	yes	yes	yes	yes	no	no	no	no	no	yes	yes	yes	yes	no	no	yes	yes	yes
MB-055-D	yes	yes	yes	yes	no	no	no	yes	yes	no	no	yes	no	no	no	no	no	no
MB-056-D	yes	yes	yes	yes	yes	no	yes	no	no	no	no	no	no	no	no	no	no	no
MB-057-D	yes	yes	yes	yes	no	yes	yes	no	no	no	no	yes	no	no	no	no	no	no
MB-058-D	yes	yes	yes	yes	no	no	no	no	yes	yes	yes	no	yes	yes	yes	no	no	no
MB-059-D	yes	yes	yes	yes	no	no	no	no	no	yes	yes	yes	yes	no	no	yes	yes	yes
MB-060-D	yes	yes	yes	yes	no	no	no	yes	yes	no	no	yes	no	no	no	no	no	no
MB-061-D	yes	yes	yes	yes	yes	no	yes	no	no	no	no	no	no	no	no	no	no	no
MB-062-D	yes	yes	yes	yes	no	yes	yes	no	no	no	no	yes	no	no	no	no	no	no
MB-063-D	yes	yes	yes	yes	no	no	no	no	yes	yes	yes	no	yes	yes	yes	no	no	no
MB-064-D	yes	yes	yes	yes	no	no	no	no	no	no	no	no	no	no	no	no	no	no

Graymont, Niagara lime putty

Wash E (Lime, Molasses, Casein, Clove Oil, Water)

#	Wash	Photo	Color	Mass	Solids	Tape	Mass	Abrade	Mass	QUV	Mass	Photo	Color	Tape	Mass	Abrade	Mass	Color
MB-065-E	yes	yes	yes	yes	no	no	no	no	no	yes	yes	yes	yes	no	no	yes	yes	yes
MB-066-E	yes	yes	yes	yes	no	no	no	yes	yes	no	no	yes	no	no	no	no	no	no
MB-067-E	yes	yes	yes	yes	yes	no	yes	no	no	no	no	no	no	no	no	no	no	no
MB-068-E	yes	yes	yes	yes	no	yes	yes	no	no	no	no	yes	no	no	no	no	no	no
MB-069-E	yes	yes	yes	yes	no	no	no	no	yes	yes	yes	no	yes	yes	yes	no	no	no
MB-070-E	yes	yes	yes	yes	no	no	no	no	no	yes	yes	yes	yes	no	no	yes	yes	yes
MB-071-E	yes	yes	yes	yes	no	no	no	yes	yes	no	no	yes	no	no	no	no	no	no
MB-072-E	yes	yes	yes	yes	yes	no	yes	no	no	no	no	no	no	no	no	no	no	no
MB-073-E	yes	yes	yes	yes	no	yes	yes	no	no	no	no	yes	no	no	no	no	no	no
MB-074-E	yes	yes	yes	yes	no	no	no	no	yes	yes	yes	no	yes	yes	yes	no	no	no
MB-075-E	yes	yes	yes	yes	no	no	no	no	no	yes	yes	yes	yes	no	no	yes	yes	yes
MB-076-E	yes	yes	yes	yes	no	no	no	yes	yes	no	no	yes	no	no	no	no	no	no
MB-077-E	yes	yes	yes	yes	yes	no	yes	no	no	no	no	no	no	no	no	no	no	no
MB-078-E	yes	yes	yes	yes	no	yes	yes	no	no	no	no	yes	no	no	no	no	no	no
MB-079-E	yes	yes	yes	yes	no	no	no	no	yes	yes	yes	no	yes	yes	yes	no	no	no
MB-080-E	yes	yes	yes	yes	no	no	no	no	no	no	no	no	no	no	no	no	no	no

Virginia Limeworks lime putty

Wash F (Lime, Molasses, Casein, Clove Oil, Water)

#	Wash	Photo	Color	Mass	Solids	Tape	Mass	Abrade	Mass	QUV	Mass	Photo	Color	Tape	Mass	Abrade	Mass	Color
MB-081-F	yes	yes	yes	yes	no	no	no	no	no	yes	yes	yes	yes	no	no	yes	yes	yes
MB-082-F	yes	yes	yes	yes	no	no	no	yes	yes	no	no	yes	no	no	no	no	no	no
MB-083-F	yes	yes	yes	yes	yes	no	yes	no	no	no	no	no	no	no	no	no	no	no
MB-084-F	yes	yes	yes	yes	no	yes	yes	no	no	no	no	yes	no	no	no	no	no	no
MB-085-F	yes	yes	yes	yes	no	no	no	no	yes	yes	yes	no	yes	yes	yes	no	no	no
MB-086-F	yes	yes	yes	yes	no	no	no	no	no	yes	yes	yes	yes	no	no	yes	yes	yes
MB-087-F	yes	yes	yes	yes	no	no	no	yes	yes	no	no	yes	no	no	no	no	no	no
MB-088-F	yes	yes	yes	yes	yes	no	yes	no	no	no	no	no	no	no	no	no	no	no
MB-089-F	yes	yes	yes	yes	no	yes	yes	no	no	no	no	yes	no	no	no	no	no	no
MB-090-F	yes	yes	yes	yes	no	no	no	no	yes	yes	yes	no	yes	yes	yes	no	no	no
MB-091-F	yes	yes	yes	yes	no	no	no	no	no	yes	yes	yes	yes	no	no	yes	yes	yes
MB-092-F	yes	yes	yes	yes	no	no	no	yes	yes	no	no	yes	no	no	no	no	no	no
MB-093-F	yes	yes	yes	yes	yes	no	yes	no	no	no	no	no	no	no	no	no	no	no
MB-094-F	yes	yes	yes	yes	no	yes	yes	no	no	no	no	yes	no	no	no	no	no	no
MB-095-F	yes	yes	yes	yes	no	no	no	no	yes	yes	yes	no	yes	yes	yes	no	no	no
MB-096-F	yes	yes	yes	yes	no	no	no	no	no	no	no	no	no	no	no	no	no	no

No. of samples this page = 48
No. of brick samples total = 158

Prepared by
Sarah Jackson

Limewash Experimental Matrix: Modern Brick

Graymont, "Ivory" hydrated lime

Wash G (Lime, Water, acrylic binder)

#	Wash	Photo	Color	Mass	Solids	Tape	Mass	Abrade	Mass	QUV	Mass	Photo	Color	Tape	Mass	Abrade	Mass	Color
MB-097-G	yes	yes	yes	yes	no	no	no	no	no	yes	yes	yes	yes	no	no	yes	yes	yes
MB-098-G	yes	yes	yes	yes	no	no	no	yes	yes	no	no	yes	no	no	no	no	no	no
MB-099-G	yes	yes	yes	yes	yes	no	yes	no	no	no	no	no	no	no	no	no	no	no
MB-100-G	yes	yes	yes	yes	no	yes	yes	no	no	no	no	yes	no	no	no	no	no	no
MB-101-G	yes	yes	yes	yes	no	no	no	no	yes	yes	yes	no	yes	yes	yes	no	no	no
MB-102-G	yes	yes	yes	yes	no	no	no	no	no	yes	yes	yes	yes	no	no	yes	yes	yes
MB-103-G	yes	yes	yes	yes	no	no	no	yes	yes	no	no	yes	no	no	no	no	no	no
MB-104-G	yes	yes	yes	yes	yes	no	yes	no	no	no	no	no	no	no	no	no	no	no
MB-105-G	yes	yes	yes	yes	no	yes	yes	no	no	no	no	yes	no	no	no	no	no	no
MB-106-G	yes	yes	yes	yes	no	no	no	no	yes	yes	yes	no	yes	yes	yes	no	no	no
MB-107-G	yes	yes	yes	yes	no	no	no	no	no	yes	yes	yes	yes	no	no	yes	yes	yes
MB-108-G	yes	yes	yes	yes	no	no	no	yes	yes	no	no	yes	no	no	no	no	no	no
MB-109-G	yes	yes	yes	yes	yes	no	yes	no	no	no	no	no	no	no	no	no	no	no
MB-110-G	yes	yes	yes	yes	no	yes	yes	no	no	no	no	yes	no	no	no	no	no	no
MB-111-G	yes	yes	yes	yes	no	no	no	no	yes	yes	yes	no	yes	yes	yes	no	no	no
MB-112-G	yes	yes	yes	yes	no	no	no	no	no	no	no	no	no	no	no	no	no	no

Graymont, Niagara lime putty

Wash H (Lime, Water, acrylic binder)

#	Wash	Photo	Color	Mass	Solids	Tape	Mass	Abrade	Mass	QUV	Mass	Photo	Color	Tape	Mass	Abrade	Mass	Color
MB-113-H	yes	yes	yes	yes	no	no	no	no	no	yes	yes	yes	yes	no	no	yes	yes	yes
MB-114-H	yes	yes	yes	yes	no	no	no	yes	yes	no	no	yes	no	no	no	no	no	no
MB-115-H	yes	yes	yes	yes	yes	no	yes	no	no	no	no	no	no	no	no	no	no	no
MB-116-H	yes	yes	yes	yes	no	yes	yes	no	no	no	no	yes	no	no	no	no	no	no
MB-117-H	yes	yes	yes	yes	no	no	no	no	yes	yes	yes	no	yes	yes	yes	no	no	no
MB-118-H	yes	yes	yes	yes	no	no	no	no	no	yes	yes	yes	yes	no	no	yes	yes	yes
MB-119-H	yes	yes	yes	yes	no	no	no	yes	yes	no	no	yes	no	no	no	no	no	no
MB-120-H	yes	yes	yes	yes	yes	no	yes	no	no	no	no	no	no	no	no	no	no	no
MB-121-H	yes	yes	yes	yes	no	yes	yes	no	no	no	no	yes	no	no	no	no	no	no
MB-122-H	yes	yes	yes	yes	no	no	no	no	yes	yes	yes	no	yes	yes	yes	no	no	no
MB-123-H	yes	yes	yes	yes	no	no	no	no	no	yes	yes	yes	yes	no	no	yes	yes	yes
MB-124-H	yes	yes	yes	yes	no	no	no	yes	yes	no	no	yes	no	no	no	no	no	no
MB-125-H	yes	yes	yes	yes	yes	no	yes	no	no	no	no	no	no	no	no	no	no	no
MB-126-H	yes	yes	yes	yes	no	yes	yes	no	no	no	no	yes	no	no	no	no	no	no
MB-127-H	yes	yes	yes	yes	no	no	no	no	yes	yes	yes	no	yes	yes	yes	no	no	no
MB-128-H	yes	yes	yes	yes	no	no	no	no	no	no	no	no	no	no	no	no	no	no

Virginia Limeworks lime putty

Wash I (Lime, Water, acrylic binder)

#	Wash	Photo	Color	Mass	Solids	Tape	Mass	Abrade	Mass	QUV	Mass	Photo	Color	Tape	Mass	Abrade	Mass	Color
MB-129-I	yes	yes	yes	yes	no	no	no	no	no	yes	yes	yes	yes	no	no	yes	yes	yes
MB-130-I	yes	yes	yes	yes	no	no	no	yes	yes	no	no	yes	no	no	no	no	no	no
MB-131-I	yes	yes	yes	yes	yes	no	yes	no	no	no	no	no	no	no	no	no	no	no
MB-132-I	yes	yes	yes	yes	no	yes	yes	no	no	no	no	yes	no	no	no	no	no	no
MB-133-I	yes	yes	yes	yes	no	no	no	no	yes	yes	yes	no	yes	yes	yes	no	no	no
MB-134-I	yes	yes	yes	yes	no	no	no	no	no	yes	yes	yes	yes	no	no	yes	yes	yes
MB-135-I	yes	yes	yes	yes	no	no	no	yes	yes	no	no	yes	no	no	no	no	no	no
MB-136-I	yes	yes	yes	yes	yes	no	yes	no	no	no	no	no	no	no	no	no	no	no
MB-137-I	yes	yes	yes	yes	no	yes	yes	no	no	no	no	yes	no	no	no	no	no	no
MB-138-I	yes	yes	yes	yes	no	no	no	no	yes	yes	yes	no	yes	yes	yes	no	no	no
MB-139-I	yes	yes	yes	yes	no	no	no	no	no	yes	yes	yes	yes	no	no	yes	yes	yes
MB-140-I	yes	yes	yes	yes	no	no	no	yes	yes	no	no	yes	no	no	no	no	no	no
MB-141-I	yes	yes	yes	yes	yes	no	yes	no	no	no	no	no	no	no	no	no	no	no
MB-142-I	yes	yes	yes	yes	no	yes	yes	no	no	no	no	yes	no	no	no	no	no	no
MB-143-I	yes	yes	yes	yes	no	no	no	no	yes	yes	yes	no	yes	yes	yes	no	no	no
MB-144-I	yes	yes	yes	yes	no	no	no	no	no	no	no	no	no	no	no	no	no	no

No. of samples this page = 48
No. of brick samples total = 158

Prepared by
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Limewash Experimental Matrix: Modern Brick

Controls

Wash J

#	Wash	Photo	Color	Mass	QUV	Mass	Photo	Color										
MB-145-J	no	yes	yes	yes	yes	yes	yes	yes										
MB-146-J	no	yes	yes	yes	yes	yes	yes	yes										
MB-147-J	no	yes	yes	yes	yes	yes	yes	yes										
MB-148-J	no	yes	yes	yes	no	no	no	no										
MB-149-J	no	yes	yes	yes	no	no	no	no										
MB-150-J	no	yes	yes	yes	no	no	no	no										

Virginia Limeworks lime putty

Wash K (Lime, Water, "no acrylic")

#	Wash	Photo	Color	Mass	Solids	Tape	Mass	Abrade	Mass	QUV	Mass	Photo	Color	Tape	Mass	Abrade	Mass	Color
MB-151-K	yes	yes	yes	yes	no	no	no	no	no	yes	yes	yes	yes	no	no	yes	yes	yes
MB-152-K	yes	yes	yes	yes	no	no	no	yes	yes	no	no	yes	no	no	no	no	no	no
MB-153-K	yes	yes	yes	yes	yes	no	yes	no	no	no	no	no	no	no	no	no	no	no
MB-154-K	yes	yes	yes	yes	no	yes	yes	no	no	no	no	yes	no	no	no	no	no	no
MB-155-K	yes	yes	yes	yes	no	no	no	no	yes	yes	yes	no	yes	yes	yes	no	no	no
MB-156-K	yes	yes	yes	yes	no	no	no	no	no	yes	yes	yes	yes	no	no	yes	yes	yes
MB-157-K	yes	yes	yes	yes	no	no	no	yes	yes	no	no	yes	no	no	no	no	no	no
MB-158-K	yes	yes	yes	yes	yes	no	yes	no	no	no	no	no	no	no	no	no	no	no

No. of samples this page = 14
No. of brick samples total = 158

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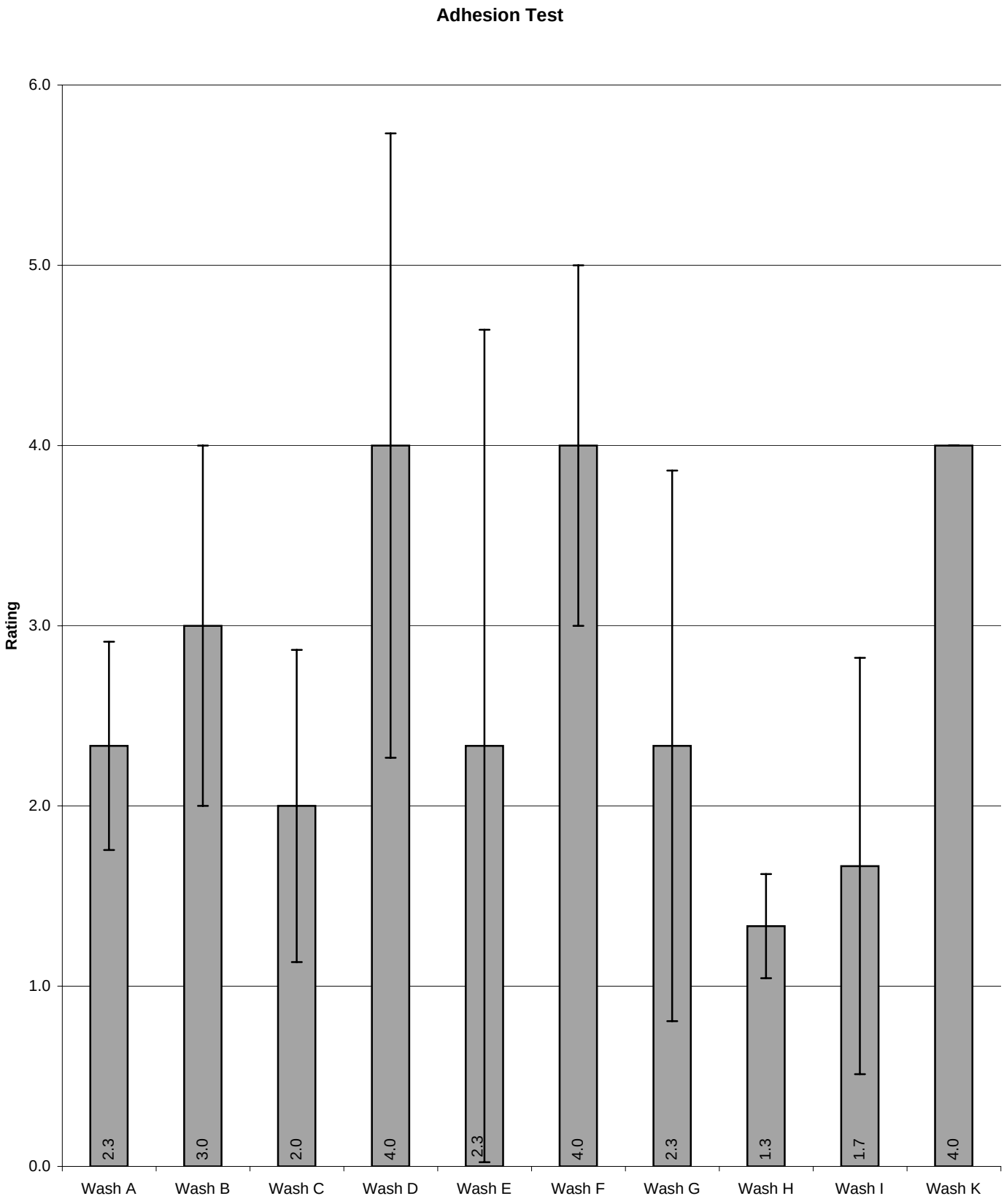
Limewash Experiment: Modern Brick

Adhesion Test

	Rating			Avg	Std Dev
MB-004-A	3A		**Wash A**	2.3	0.6
MB-009-A	2A		**Wash B**	3.0	1.0
MB-014-A	2A		**Wash C**	2.0	0.9
			Wash D	4.0	1.7
MB-020-B	2A		**Wash E**	2.3	2.3
MB-025-B	3A		**Wash F**	4.0	1.0
MB-030-B	4A		**Wash G**	2.3	1.5
			Wash H	1.3	0.3
MB-036-C	1.5A		**Wash I**	1.7	1.2
MB-041-C	1.5A		**Wash K**	4.0	0.0
MB-046-C	3A				
MB-052-D	2A				
MB-057-D	5A				
MB-062-D	5A				
MB-068-E	1A				
MB-073-E	1A				
MB-078-E	5A				
MB-084-F	3A				
MB-089-F	5A				
MB-094-F	4A				
MB-100-G	1A				
MB-105-G	2A				
MB-110-G	4A				
MB-116-H	1.5A				
MB-121-H	1A				
MB-126-H	1.5A				
MB-132-I	1A				
MB-137-I	1A				
MB-142-I	3A				
MB-153-K	4A				
MB-154-K	4A				

Limewash Experiment: Modern Brick



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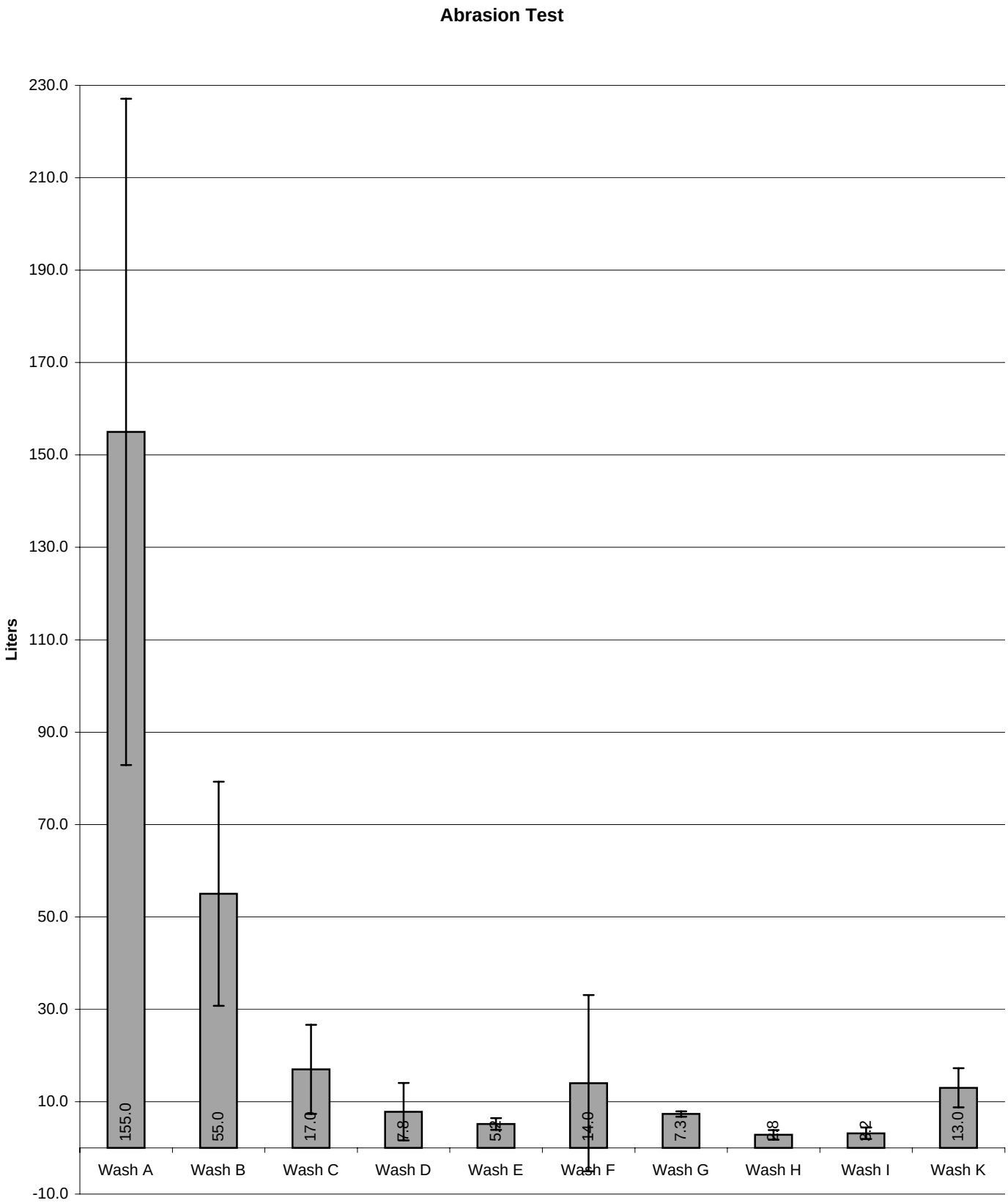
mb data

Limewash Experiment: Modern Brick

Abrasion Test

	Liters			Avg	Std Dev
MB-002-A	104.0		**Wash A**	155.0	72.1
MB-007-A	16.0				
MB-012-A	206.0				
MB-018-B	81.0		**Wash B**	55.0	24.2
MB-023-B	33.0				
MB-028-B	51.0				
MB-034-C	13.0		**Wash C**	17.0	9.6
MB-039-C	10.0				
MB-044-C	28.0				
MB-050-D	4.5		**Wash D**	7.8	6.2
MB-055-D	15.0				
MB-060-D	4.0				
MB-066-E	6.5		**Wash E**	5.2	1.3
MB-071-E	4.0				
MB-076-E	5.0				
MB-082-F	4.0		**Wash F**	14.0	19.1
MB-087-F	2.0				
MB-092-F	36.0				
MB-098-G	7.0		**Wash G**	7.3	0.6
MB-103-G	8.0				
MB-108-G	7.0				
MB-114-H	4.0		**Wash H**	2.8	1.0
MB-119-H	2.0				
MB-124-H	2.5				
MB-130-I	4.5		**Wash I**	3.2	1.3
MB-135-I	3.0				
MB-140-I	2.0				
MB-152-K	10.0		**Wash K**	13.0	4.2
MB-157-K	16.0				

Limewash Experiment: Modern Brick



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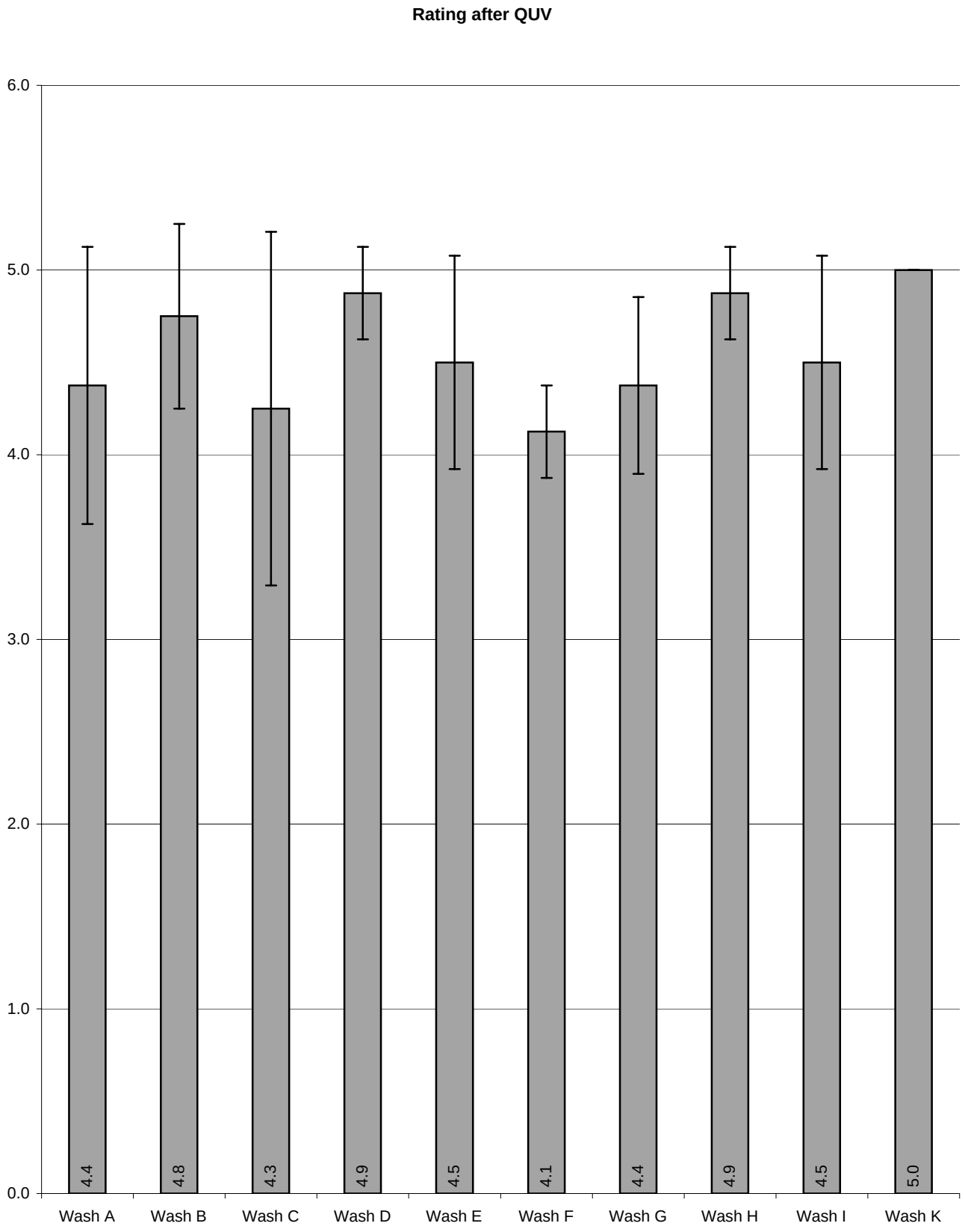
mb data

Limewash Experiment: Modern Brick

Rating after QUV

	Rating			Avg	Std Dev
MB-001-A	5A		**Wash A**	4.4	0.8
MB-005-A	5A				
MB-006-A	3.5A				
MB-010-A	4A				
MB-017-B	5A		**Wash B**	4.8	0.5
MB-021-B	5A				
MB-022-B	4A				
MB-026-B	5A				
MB-033-C	5A		**Wash C**	4.3	1.0
MB-037-C	3A				
MB-038-C	5A				
MB-042-C	4A				
MB-049-D	4.5A		**Wash D**	4.9	0.3
MB-053-D	5A				
MB-054-D	5A				
MB-058-D	5A				
MB-065-E	4A		**Wash E**	4.5	0.6
MB-069-E	4A				
MB-070-E	5A				
MB-074-E	5A				
MB-081-F	4A		**Wash F**	4.1	0.3
MB-085-F	4A				
MB-086-F	4A				
MB-090-F	4.5A				
MB-097-G	4A		**Wash G**	4.4	0.5
MB-101-G	4.5A				
MB-102-G	4A				
MB-106-G	5A				
MB-113-H	5A		**Wash H**	4.9	0.3
MB-117-H	5A				
MB-118-H	4.5A				
MB-122-H	5A				
MB-129-I	5A		**Wash I**	4.5	0.6
MB-133-I	4A				
MB-134-I	4A				
MB-138-I	5A				
MB-151-K	5A		**Wash K**	5.0	0.0
MB-155-K	5A				
MB-156-K	5A				

Limewash Experiment: Modern Brick



Prepared by
Sarah Jackson

mb data

Limewash Experiment: Modern Brick
Colorimetry

Parameters:	
Std Status:	CREELL
Color Mode	L*a*b*
Observer	2°
Primary Illuminant	C

Initial

		C/2°		
	Name	L*	a*	b*
STD	Standard	97.1057	0.2901	1.7414
	MB-001-A	91.6672	-0.6254	10.0202
	MB-005-A	92.5355	-0.1744	9.6637
	MB-006-A	92.1415	-0.4747	9.4443
	MB-010-A	92.3311	-0.1380	9.7260
	MB-017-B	93.9037	-0.4548	5.0737
	MB-021-B	94.1429	-0.2356	5.8193
	MB-022-B	94.4673	-0.2418	5.1564
	MB-026-B	94.6427	-0.1340	5.6934
	MB-022-C	92.3084	-0.3185	5.5219
	MB-037-C	94.3642	-0.1577	6.0211
	MB-038-C	93.7265	-0.0941	7.0270
	MB-042-C	93.3898	-0.2719	6.6950
	MB-049-D	89.7680	-0.4965	11.1610
	MB-053-D	92.1765	-0.3794	8.2157
	MB-054-D	92.3310	-0.4147	8.1796
	MB-058-D	91.3289	-0.1326	11.0065
	MB-065-E	90.5007	-0.7205	7.6625
	MB-069-E	91.2824	-0.2656	8.4127
	MB-070-E	91.7818	-0.1208	8.4598
	MB-074-E	92.4762	-0.0861	6.7412
	MB-081-F	90.7224	-0.5873	10.0939
	MB-085-F	92.0080	-0.3561	8.9234
	MB-086-F	92.1664	-0.3229	9.9651
	MB-090-F	91.2782	-0.3153	7.9532
	MB-097-G	92.8522	0.0395	0.1650
	MB-101-G	94.0794	-0.0675	1.0247
	MB-102-G	93.5565	-0.2245	1.4189
	MB-106-G	94.5765	-0.0341	0.9811
	MB-113-H	94.2593	-0.0993	0.7907
	MB-117-H	94.1959	-0.2900	1.6454
	MB-118-H	94.7322	-0.1418	1.0963
	MB-122-H	95.1546	0.0844	0.6949
	MB-129-I	94.2980	-0.0124	1.1495
	MB-133-I	93.9190	0.1313	0.3503
	MB-134-I	92.8785	-0.0847	0.3776
	MB-138-I	94.4497	-0.0283	1.3588
	MB-145-J	42.3917	19.8771	23.4520
	MB-146-J	41.8506	20.4021	24.0612
	MB-147-J	40.9484	19.8734	20.6471
	MB-156-K	96.1597	0.0569	2.1194
	MB-155-K	96.0146	0.1213	2.2355
	MB-151-K	95.2503	-0.2811	3.2955

After QUV

	C/2°		
Name	L*	a*	b*
Standard	97.0202	0.0543	2.0444
MB-001-A	94.4042	-0.0822	3.0513
MB-005-A	95.2742	0.2352	3.7843
MB-006-A	94.5799	0.0008	2.8209
MB-010-A	94.5064	0.2292	4.5492
MB-017-B	95.0720	-0.0658	1.7645
MB-021-B	95.5938	-0.0200	2.5679
MB-022-B	95.7113	-0.0257	2.1497
MB-026-B	95.2861	0.1353	3.7283
MB-033-C	93.7219	-0.0413	1.8667
MB-037-C	95.7959	-0.0059	2.7939
MB-038-C	95.7764	0.1217	2.4399
MB-042-C	95.3325	-0.0368	1.8219
MB-049-D	92.5991	0.0486	1.9270
MB-053-D	95.1550	-0.1186	2.4538
MB-054-D	95.1440	-0.0665	2.0699
MB-058-D	94.3629	-0.0213	1.6643
MB-065-E	91.0350	0.0161	-0.2017
MB-069-E	92.7725	-0.0587	0.3701
MB-070-E	93.2591	-0.0229	0.6604
MB-074-E	94.9721	-0.1079	2.2381
MB-081-F	93.2761	-0.0406	1.4461
MB-085-F	94.0850	-0.0362	1.3759
MB-086-F	94.4021	-0.0799	1.8409
MB-090-F	93.8777	-0.1948	1.4040
MB-097-G	92.6254	0.1567	-0.1740
MB-101-G	92.8761	0.4879	0.5701
MB-102-G	93.8282	0.0353	-0.1647
MB-106-G	93.0597	0.7388	1.6527
MB-113-H	94.0793	0.0545	-0.0722
MB-117-H	94.1654	0.0341	-0.0669
MB-118-H	94.5240	0.0604	-0.0814
MB-122-H	95.0587	0.0992	0.2404
MB-129-I	93.9836	0.3586	0.7197
MB-133-I	94.3742	0.1673	0.1090
MB-134-I	92.0313	0.3453	0.0526
MB-138-I	92.4156	0.7938	1.8695
MB-145-J	41.0141	20.6939	24.7233
MB-146-J	40.2549	21.5343	25.8836
MB-147-J	40.3796	20.1919	21.3626
MB-151-K	96.0142	0.1449	0.7673
MB-146-K	96.0929	0.2835	1.0179
MB-156-K	95.0999	0.7795	2.1505

Limewash Experiment: Modern Brick
Colorimetry

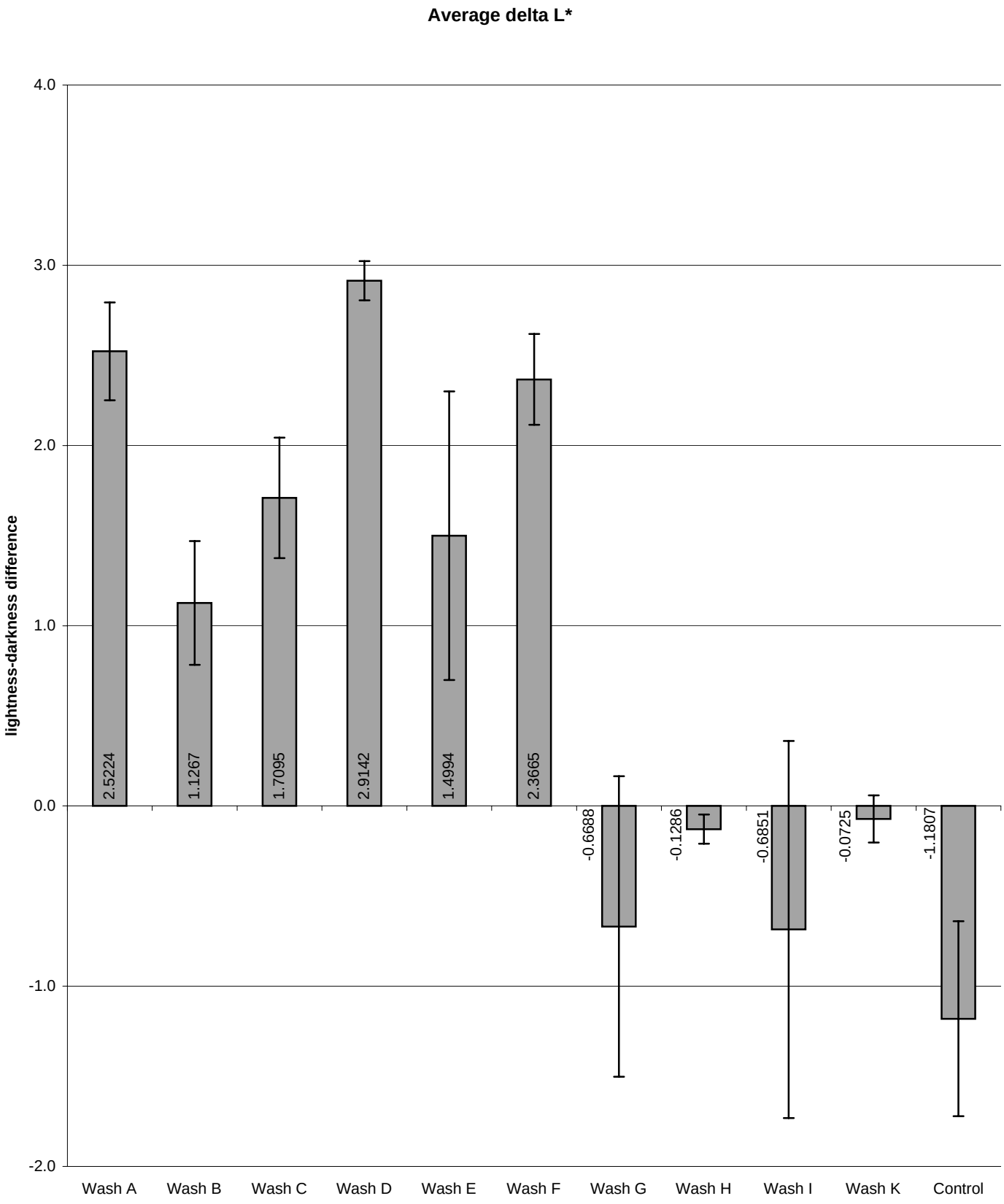
Change from Intial to After QUV

	▲L*	▲a*	▲b*	▲E
MB-001-A	2.7370	0.5432	-6.9689	7.5068
MB-005-A	2.7387	0.4096	-5.8794	6.4989
MB-006-A	2.4384	0.4755	-6.6234	7.0740
MB-010-A	2.1753	0.3672	-5.1768	5.6273
MB-017-B	1.1683	0.3890	-3.3092	3.5309
MB-021-B	1.4509	0.2156	-3.2514	3.5670
MB-022-B	1.2440	0.2161	-3.0067	3.2611
MB-026-B	0.6434	0.2693	-1.9651	2.0852
MB-033-C	1.4135	0.2772	-3.6552	3.9288
MB-037-C	1.4317	0.1518	-3.2272	3.5338
MB-038-C	2.0499	0.2158	-4.5871	5.0289
MB-042-C	1.9427	0.2351	-4.8731	5.2513
MB-049-D	2.8311	0.5451	-9.2340	9.6736
MB-053-D	2.9785	0.2608	-5.7619	6.4915
MB-054-D	2.8130	0.3482	-6.1097	6.7352
MB-058-D	3.0340	0.1113	-9.3422	9.8231
MB-065-E	0.5343	0.7366	-7.8642	7.9167
MB-069-E	1.4901	0.2069	-8.0426	8.1821
MB-070-E	1.4773	0.0979	-7.7994	7.9387
MB-074-E	2.4959	-0.0218	-4.5031	5.1486
MB-081-F	2.5537	0.5467	-8.6478	9.0335
MB-085-F	2.0770	0.3199	-7.5475	7.8346
MB-086-F	2.2357	0.2430	-8.1242	8.4297
MB-090-F	2.5995	0.1205	-6.5492	7.0473
MB-097-G	-0.2268	0.1172	-0.3390	0.4244
MB-101-G	-1.2033	0.5554	-0.4546	1.4011
MB-102-G	0.2717	0.2598	-1.5836	1.6276
MB-106-G	-1.5168	0.7729	0.6716	1.8301
MB-113-H	-0.1800	0.1538	-0.8629	0.8948
MB-117-H	-0.0305	0.3241	-1.7123	1.7430
MB-118-H	-0.2082	0.2022	-1.1777	1.2129
MB-122-H	-0.0959	0.0148	-0.4545	0.4647
MB-129-I	-0.3144	0.3710	-0.4298	0.6490
MB-133-I	0.4552	0.0360	-0.2413	0.5165
MB-134-I	-0.8472	0.4300	-0.3250	1.0041
MB-138-I	-2.0341	0.8221	0.5107	2.2526
MB-145-J	-1.3776	0.8168	1.2713	2.0448
MB-146-J	-1.5957	1.1322	1.8224	2.6738
MB-147-J	-0.5688	0.3185	0.7155	0.9679
MB-151-K	-0.1455	0.0880	-1.3521	1.3628
MB-146-K	0.0783	0.1622	-1.2176	1.2308
MB-156-K	-0.1504	1.0606	-1.1450	1.5680

Limewash Experiment: Modern Brick
Colorimetry

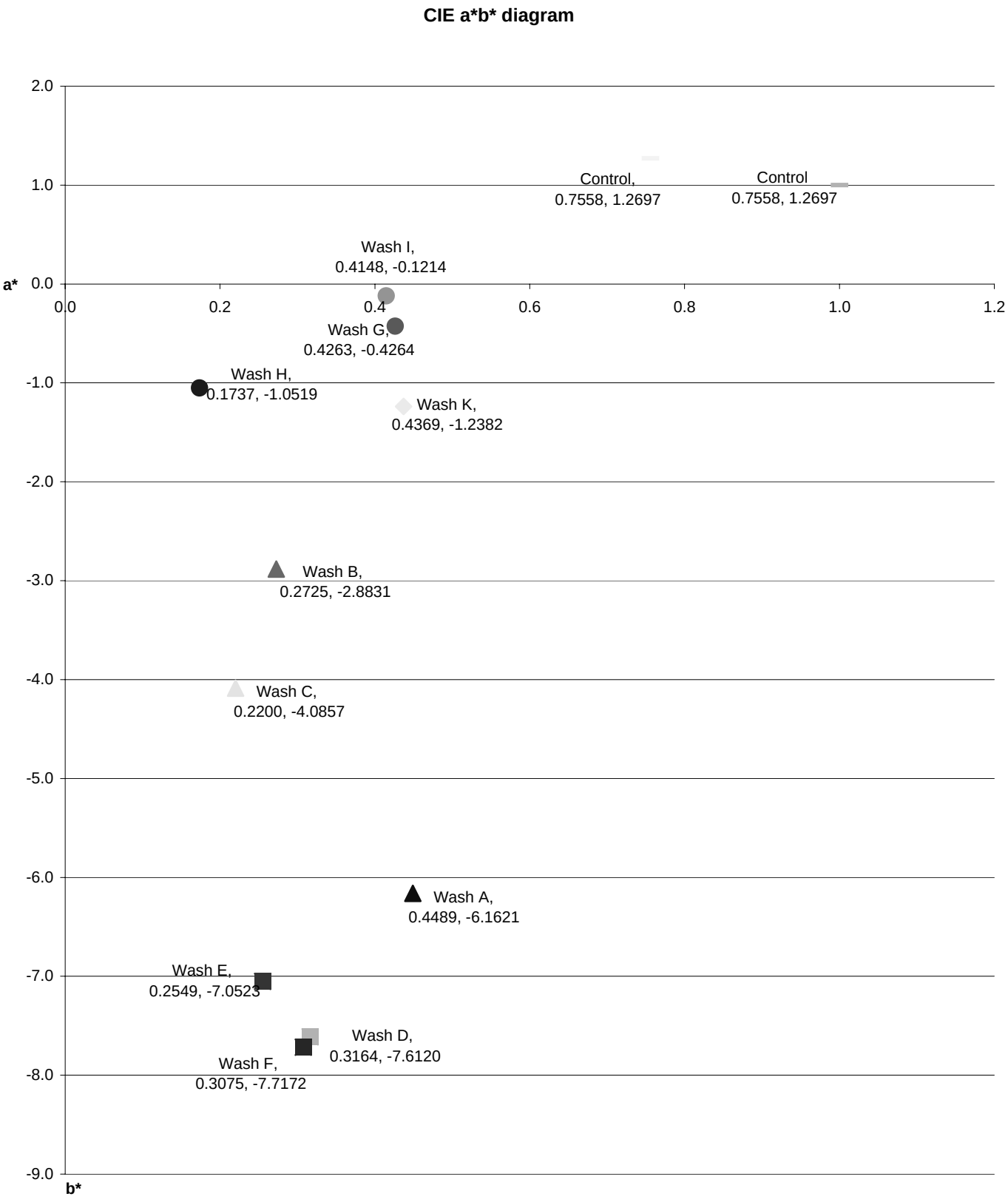
	Avg ▲L*	SD ▲L*	Avg ▲a*	SD ▲a*	Avg ▲b*	SD ▲b*	Avg ▲E	SD ▲E
Wash A	2.5224	0.2710	0.4489	0.0771	-6.1621	0.7988	6.6767	0.8124
Wash B	1.1267	0.3436	0.2725	0.0817	-2.8831	0.6259	3.1110	0.6974
Wash C	1.7095	0.3342	0.2200	0.0522	-4.0857	0.7733	4.4357	0.8342
Wash D	2.9142	0.1090	0.3164	0.1812	-7.6120	1.9412	8.1809	1.8138
Wash E	1.4994	0.8010	0.2549	0.3344	-7.0523	1.7026	7.2965	1.4370
Wash F	2.3665	0.2518	0.3075	0.1794	-7.7172	0.8990	8.0863	0.8482
Wash G	-0.6688	0.8336	0.4263	0.2944	-0.4264	0.9225	1.3208	0.6228
Wash H	-0.1286	0.0810	0.1737	0.1279	-1.0519	0.5306	1.0789	0.5385
Wash I	-0.6851	1.0462	0.4148	0.3222	-0.1214	0.4284	1.1056	0.7919
Wash K	-0.0725	0.1306	0.4369	0.5414	-1.2382	0.1051	1.3872	0.1699
Control	-1.1807	0.5410	0.7558	0.4103	1.2697	0.5535	1.8955	0.8627

Limewash Experiment: Modern Brick
Colorimetry

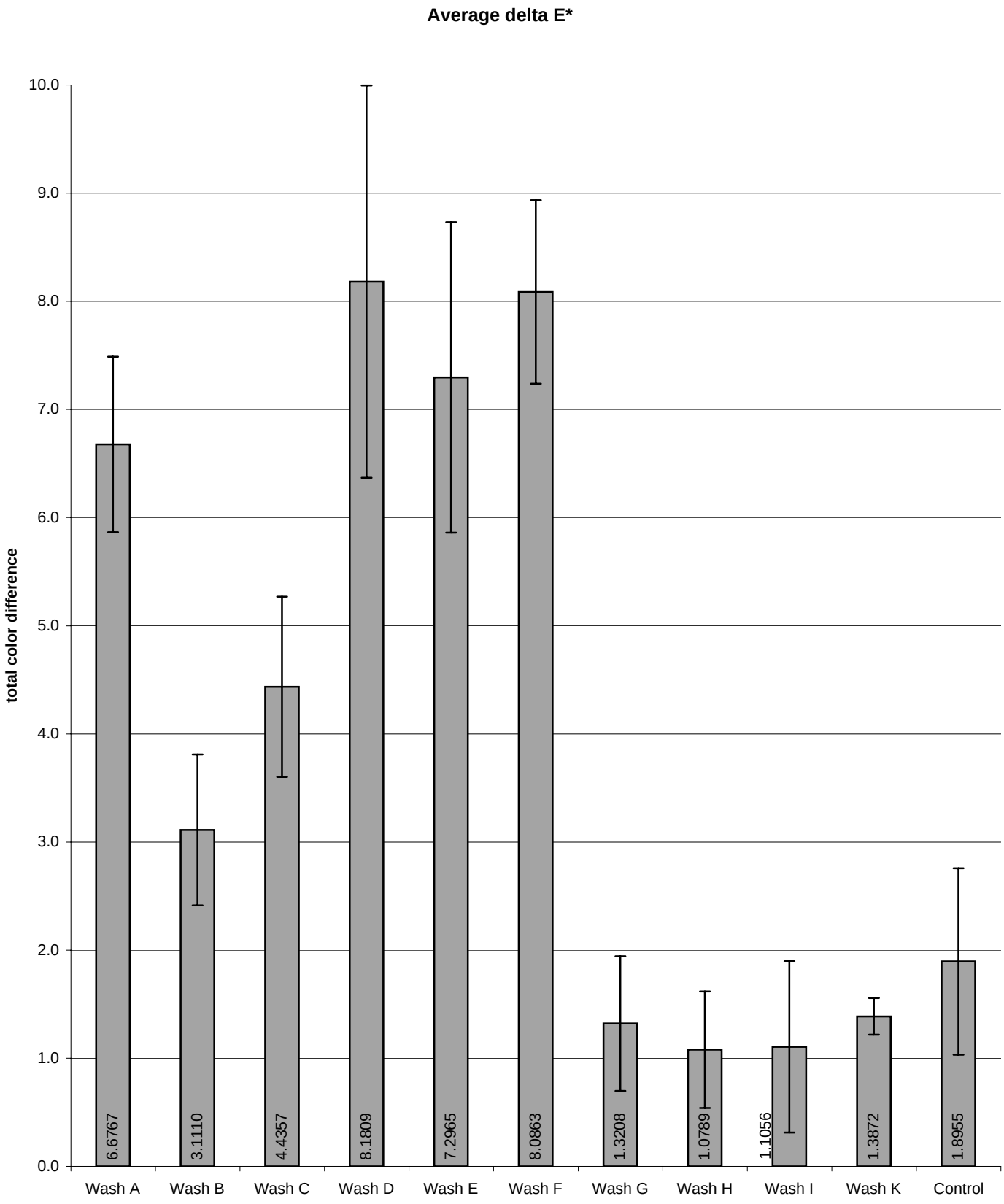


Prepared by
Sarah Jackson

Limewash Experiment: Modern Brick
Colorimetry



Limewash Experiment: Modern Brick
Colorimetry

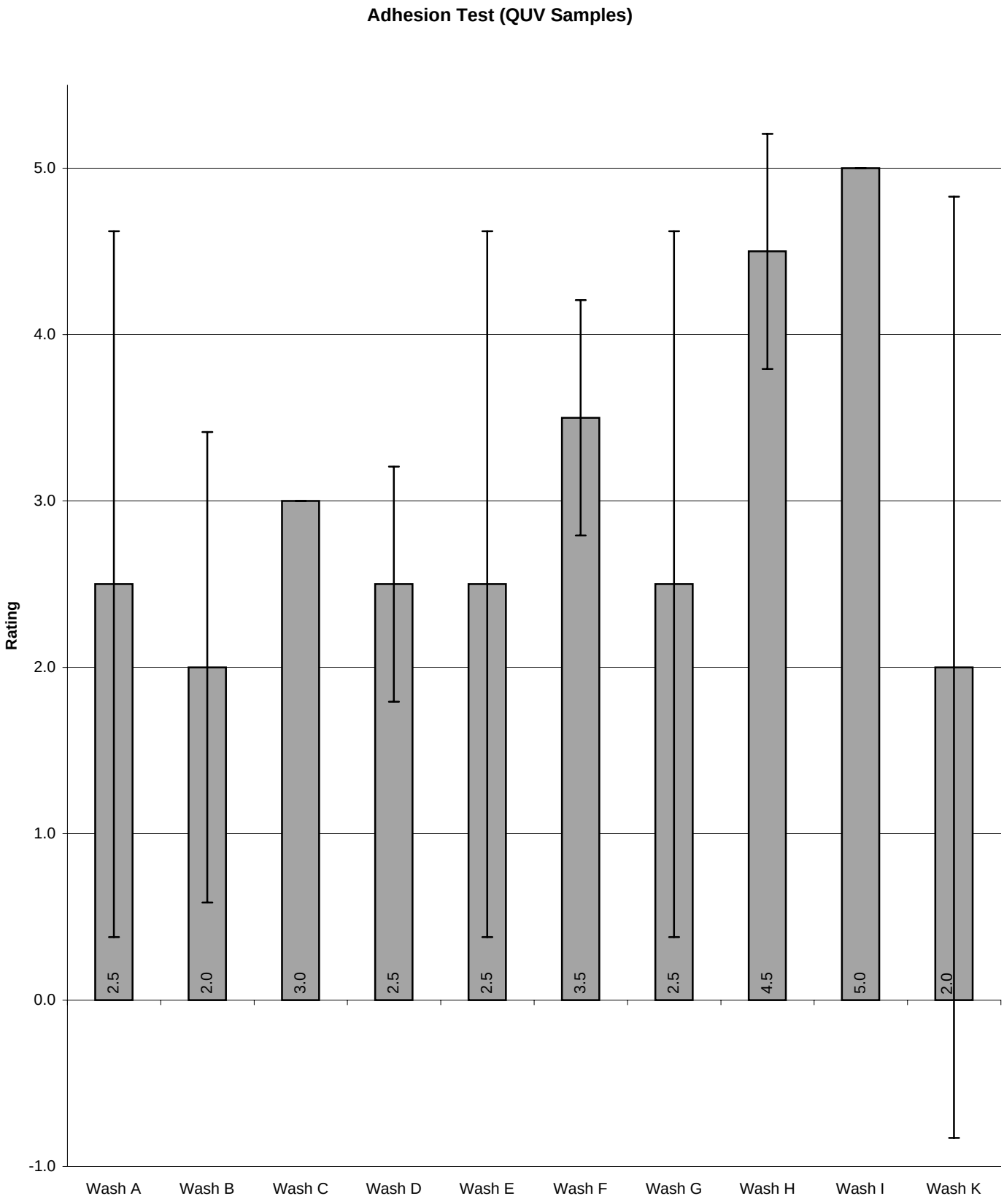


Limewash Experiment: Modern Brick

Adhesion Test (QUV)

	Rating			Avg	Std Dev
MB-005-A	4A		**Wash A**	2.5	2.1
MB-010-A	1A		**Wash B**	2.0	1.4
			Wash C	3.0	0.0
MB-021-B	1A		**Wash D**	2.5	0.7
MB-026-B	3A		**Wash E**	2.5	2.1
			Wash F	3.5	0.7
MB-037-C	3A		**Wash G**	2.5	2.1
MB-042-C	3A		**Wash H**	4.5	0.7
			Wash I	5.0	0.0
MB-053-D	2A		**Wash K**	2.0	2.8
MB-058-D	3A				
MB-069-E	1A				
MB-074-E	4A				
MB-085-F	3A				
MB-090-F	4A				
MB-101-G	1A				
MB-106-G	4A				
MB-117-H	4A				
MB-122-H	5A				
MB-133-I	5A				
MB-138-I	5A				
MB-155-K	4A				
MB-156-K	0A				

Limewash Experiment: Modern Brick



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Sarah Jackson

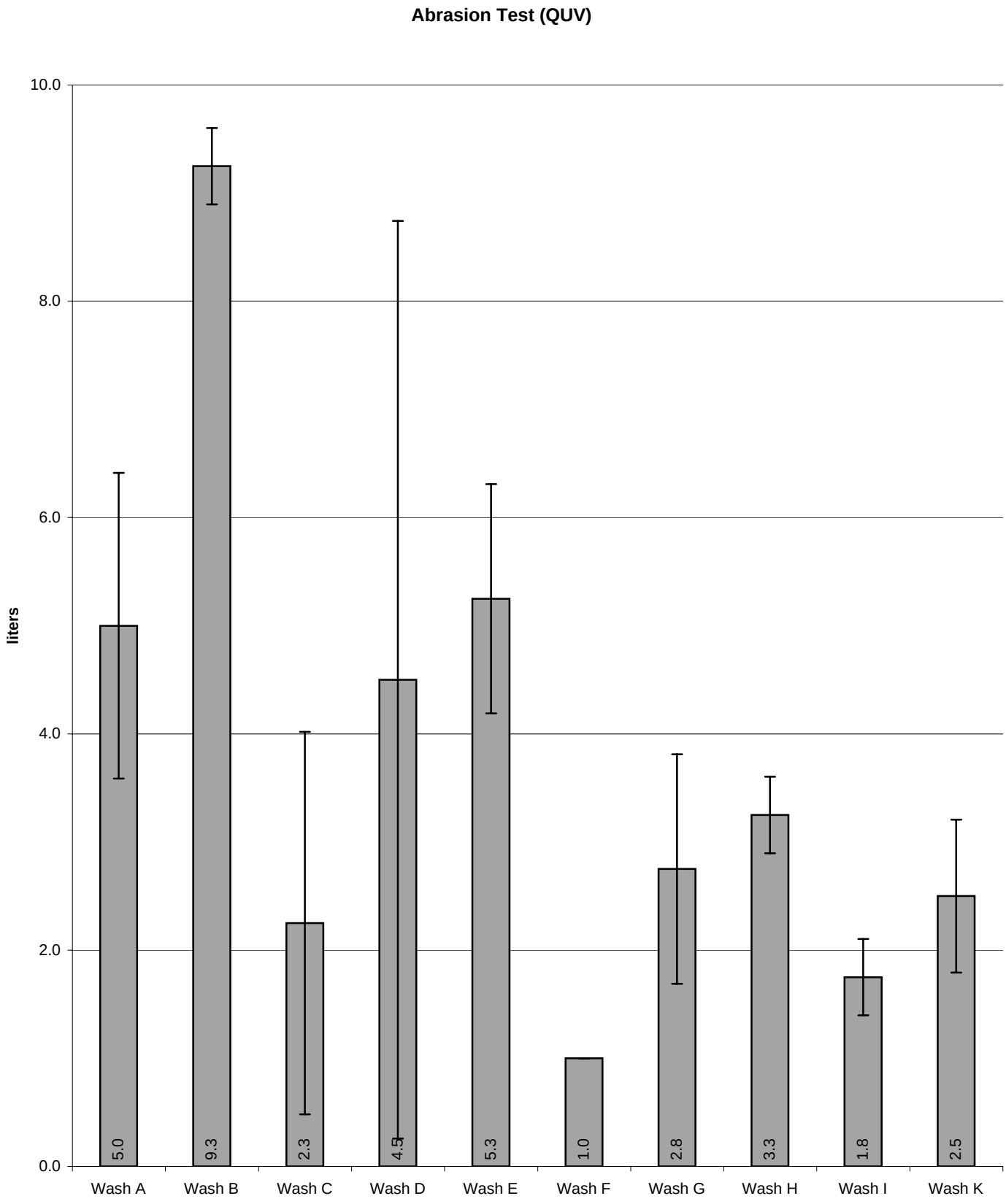
mb data

Limewash Experiment: Modern Brick

Abrasion Test (QUV)

MB-001-A	4.0		**Wash A**	5.0	1.4
MB-006-A	6.0				
MB-017-B	9.5		**Wash B**	9.3	0.4
MB-022-B	9.0				
MB-033-C	1.0		**Wash C**	2.3	1.8
MB-038-C	3.5				
MB-049-D	1.5		**Wash D**	4.5	4.2
MB-054-D	7.5				
MB-065-E	4.5		**Wash E**	5.3	1.1
MB-070-E	6.0				
MB-081-F	1.0		**Wash F**	1.0	0.0
MB-086-F	1.0				
MB-097-G	3.5		**Wash G**	2.8	1.1
MB-102-G	2.0				
MB-113-H	3.5		**Wash H**	3.3	0.4
MB-118-H	3.0				
MB-129-I	1.5		**Wash I**	1.8	0.4
MB-134-I	2.0				
MB-151-K	2.0		**Wash K**	2.5	0.7
MB-158-K	3.0				

Limewash Experiment: Modern Brick



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mb data

Limewash Experiment: Modern Brick

Overall Rating

	Rating	Adhesion	Abrasion	QUV	QUV-Adhesion	QUV-Abrasion	
Best	10	K	A	K	I	B	
	9	F	B	D, H	H	E	
	8	D	C		F	A	
	7	B	K	B	C	D	
	6	A	F	E, I	D	H	
	5	G	G		A, E, G	G	
	4	E	D	G		K	
	3	C	E	A		C	
	2	I	I	F	B	I	
Worst	1	H	H	C	K	F	

	Samples	Adhesion	Abrasion	QUV	QUV-Adhesion	QUV-Abrasion	Sum
	Wash A	6	10	3	5	8	32
	Wash B	7	9	7	2	10	35
	Wash C	3	8	1	7	3	22
	Wash D	8	4	9	6	7	34
	Wash E	4	3	6	5	9	27
	Wash F	9	6	2	8	1	26
	Wash G	5	5	4	5	5	24
	Wash H	1	1	9	9	6	26
	Wash I	2	2	6	10	2	22
	Wash K	10	7	10	1	4	32

	Wash	**Total**					
Best	**B**	**35**					
	D	**34**					
	A, K	**32**					
	E	**27**					
	F, H	**26**					
	G	**24**					
Worst	**C, I**	**22**					