MORTAR ANALYSIS
&
PAINT REMOVAL FIELD TESTING

for

BOSTWICK
BLADENSBURG, MARYLAND

Prepared by

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I. INTRODUCTION

This report is an analysis of mortar sampled from the mid-eighteenth century Bostwick House. John Milner Associates, Inc. collected both pointing and bedding mortar samples from joints on the brick building. One representative sample was selected for analysis: historic pointing mortar (MA01). The purpose of this analysis is to determine the physical composition of the earliest mortars for replication during the restoration of the building.

Mortar analysis is a visual and laboratory examination of cementitious building materials such as mortars, plasters, stuccos, and grouts for the purpose of determining composition and application techniques. The analysis is subjective, and primarily comparative in nature, and may be effectively used to assess the relationship between different parts of a structure or of a structure to similar sites elsewhere. The principal reason mortars are analyzed is to match historic mortars for repointing and reconstruction projects. It is critical that new mortars are physically compatible with adjacent materials and that the surface is aesthetically appropriate to the appearance of the significant historic period of the structure.

II. METHODOLOGY

Sampling

Samples were collected on September 25, 2007 by Alfonso Narvaez, Principal Conservator for JMA. The samples are as follows:

MA01- Pointing Mortar

Analysis

A freshly broken surface of the mortar sample was examined with a stereo-binocular microscope. Binder color and characteristics, proportion and characteristics of voids, and relationship between aggregate and binder were evaluated. The binder was matched to a color standard of the Munsell Color Chart.[1] A portion of each sample was ground in a marble mortar to disaggregate the material. The remainder of each sample was set aside for later use in evaluation of potential replication mixes.

Each sample was then separated into three components: the acid-soluble fraction, the 'fines' (e.g. pigment, acid-insoluble cement residue, or silt-to clay-sized mineral grains), and the aggregate or sand. Separation was accomplished by wet-chemical techniques. The acid-soluble fraction was first removed by digestion with diluted hydrochloric acid. The fines were separated from the aggregate by washing and filtration, then dried and weighed. The weight of acid soluble material was calculated by the difference in weight of the sample before processing and its weight after processing.

Weight percentages of acid-soluble material, fines, and aggregate in the sample were calculated as an aid for determining an appropriate replication mortar type. The aggregate was examined microscopically to identify the component materials, as well as evaluate the color, opacity, and shape of the sand grains, and the presence and nature of impurities. The particle size distribution of the aggregate was determined by sieve analysis.

[1] The Munsell System of Color Notation identifies color in terms of three attributes: hue, value, and chroma. Color standards are opaque pigmented films on coated paper mounted on charts for each hue.

III. FINDINGS

Observations

The mortar is very soft; it contains large clumps of lime in the matrix, and has fine to medium grain composition. The sample is a lime mortar and the binder matrix, sands, and fine particles are similar in overall color. The results of the wet-chemical and microscopic analyses are presented in the Summary Sheet in the Appendix.

The sample is taken from a 3/4" brick joint from the South Elevation. It was taken from an open joint and has large clumps of lime The sample breaks easily by hand with cleavage through the binder not the aggregate. The light yellowish brown binder is matte and textured. The binder to aggregate ratio is moderate. Void volume is approximately 15% primarily in the form of elongated, irregular voids from entrapped air. Voids tend to be larger than the medium aggregate.

The main portion of the sands is heavily medium grained. There are variable grain sizes within the composition. The sands are comprised of a variety of fine to medium particles. The sands vary in color and size. Most of the grains are opaque and range in color from light orange, reddish orange, to white, to dark gray in color (Munsell10YR 8.5/1). Smaller particles are translucent or transparent and vary in color from orange, to taupe, to clear. The majority of the particles are rounded measuring R0.7/S0.9

IV. RECOMMENDATIONS

The sample is lime-based mortars which were commonly used until the late nineteenth century.[2] Though they are less common, lime mortars are still used today so it is not possible to date the mortars based on their lime content alone. The ratio 1:5 is a very soft mortar. This ratio is common in historic mortars. The roundness of the grains and the orange color may be indicators of local sand. In rural areas, masons used locally found materials for their mortars such as sands from rivers and creeks. A mortar replication should take these properties of the mortars into account in the final binder: aggregate ratio.

The following guidelines should be considered before any repointing is completed.

Replication

In general, repointing mortars for historic building materials should not contain Portland cements or premixed masonry cements, and should match in strength, composition, and color with the historic mortar. These rules ensure proper strength, breathability, and appearance of the replacement mortar. Natural hydraulic limes have become available in the US and should be considered for building conservation work. Hydraulic lime mortars are more vapor permeable than cement-lime mortars, which aids water and salt removal within the masonry, and have better elasticity, allowing for building movement without cracking. However, hydraulic limes do require treatment after placement to ensure proper curing, which is vital for frost resistance. The choice of a contractor with experience using hydraulic limes is the key to a successful project.

[2] Harley J. McKee, *Introduction to Early American Masonry: Stone, Brick, Mortar and Plaster* (Washington, D.C.: Preservation Press, 1973). 62

For the masonry at the Bostwick, the replacement mortar must have good flexural strength, high permeability, and must exhibit a lower compressive strength than the existing masonry. It is recommended that a traditional natural hydraulic lime mortar such as NHL 3.5 in a 1:5 ratio (1 part natural hydraulic lime to 5 part sand) or a 1:4 ratio (1 part natural hydraulic lime to 4 parts sand) depending on the condition of the brick and the severity of exposure to weathering. Both will yield a Type K mortar but the 1:4 ratio is slightly harder at approximately 331 psi after one 730 days of cure whereas a 1:5 ratio is approximately 276 psi after 730 days of cure. Type K mortar is used for repointing historic masonry or structures constructed with a low strength brick. The color of the sand should match the historic sand as closely as possible to provide a close color match of the overall mortar. It should be correctly proportioned to meet ASTM C 144. Use well-graded masonry sand with angular particles that meets ASTM C 144 Standard Specification for Aggregate for Masonry Mortar.

Mortar Performance Characteristics

- Replacement mortar should match the physical properties of the existing mortar. Ideally the composition of the new mortar should duplicate that of the original. Unfortunately, current analysis techniques such as the Cliver and Jedrzejewska methods cannot accurately determine the actual original mix; there are far too many variables.[3] Current techniques can provide subjective data on properties of the mortar such as hardness, air content, and color; most also free the sand for matching. Actual values for weight percentages of sand and carbonate (through collection of carbon dioxide gas with the digestion of the mortar) can also be determined. However, no technique currently available can accurately determine the actual original mix; there are far too many variables.
- Replacement mortar is intended to be sacrificial because it is easily replaced. Mortar should, therefore, be softer than the existing masonry, which is less durable than new stone because of weathering and other treatments.
- Replacement mortar must be more porous than the surrounding masonry it supports, thus allowing moisture that may enter a wall to pass through it to the exterior. Hard, dense mortars prevent this moisture movement, causing accelerated deterioration in the masonry unit rather than in the mortar joint.

Mortar Sample Preparation

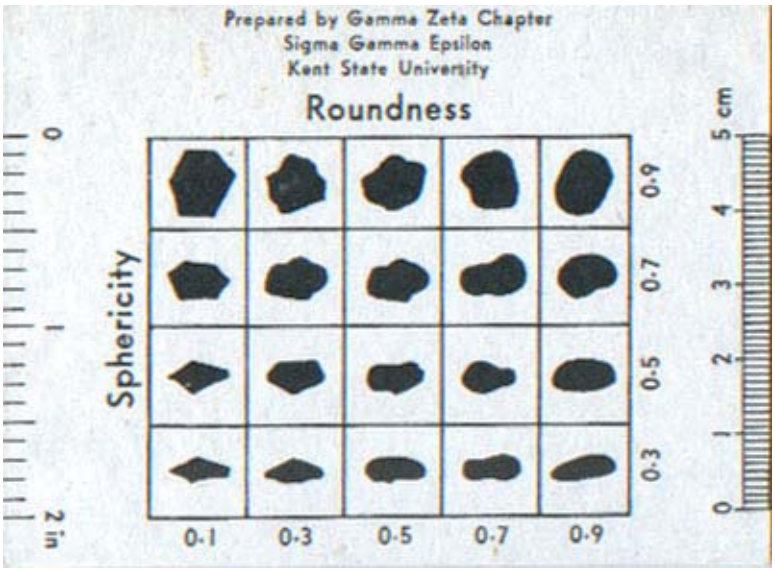
- Prepare a range of samples to determine the appropriate materials and proportions for the new mortar. Small batches of sample mortars can be prepared off-site until a preliminary mix is developed.
- Final samples should be prepared on site at actual repair locations to determine application method and final tooling, and to establish a performance standard.
- **Final selection of the replacement mortar mix to be used is the responsibility of the owner or architect of record, and should be based on evaluation of the cause of failure of the existing mortar, and the condition and type of the masonry.**

[3] Hanna Jedrzejewska, "Old Mortars in Poland: A New Method of Investigation" *Studies in Conservation* 5, no. 4 (1960): 132-138.

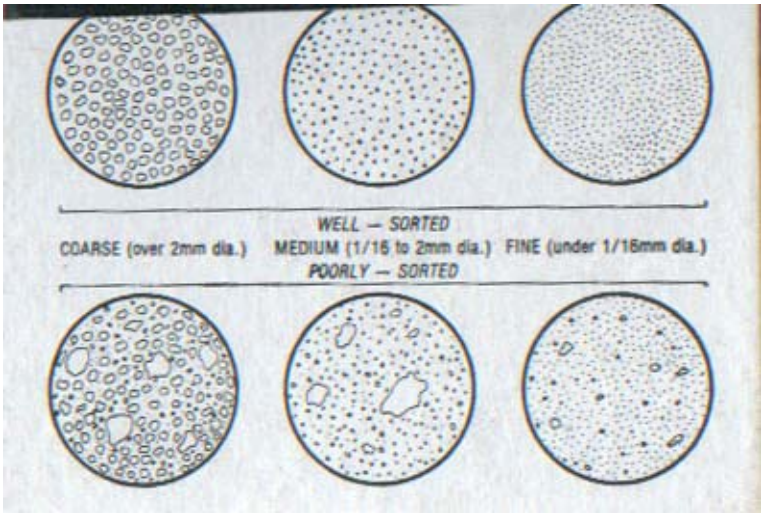
Good Repointing Practice

- Repoint all open mortar joints in masonry walls. Leaving joints open will lead to moisture penetration and may, in turn, lead to material degradation of internal structural components.
- Friable, cracked, disintegrated joints must be cut back to sound mortar before repointing.
- Rake out existing deteriorated mortar to a depth of ¾-inch to 1-inch beyond the face of the joint.
- Install new mortar tooled to match the profile of the original mortar joints.
- Pack all voids in bedding mortar with new mortar, and then repointed to prevent face loading of the masonry and consequent spalling (face loading also occurs when pointing mortar is much harder than the bedding mortar).
- Do not install mortar during temperatures below 45°F or above 85°F.
- Properly cure new mortar to ensure that it does not dry out too quickly using a combination of protection and water misting as required. Failure to properly cure the mortar may lead to premature failure of the new work.

APPENDIX



ROUNDNESS SCALE



GRAIN SIZE AND SORTING

MORTAR ANALYSIS SUMMARY SHEET

Project Name: Bostwick

Location: South Elevation, 30 feet west of southeast corner

Sample No.: MA01

Date: 10-17-07

Chemical Analysis

A. CALCULATIONS (weight in g.)

1. Container Weight:	106.32
2. Sample Weight	12.10
3. Filter Paper Weight	2.18
4. Container + Sand Weight:	114.96
5. Sand Weight:	8.64
6. Paper + Fines Weight:	3.63
7. Fines Weight:	1.45
8. Sand + Fines Weight:	10.09
9. Acid Soluble Weight	2.01
10. Weight Percent Sand	71.40%
11. Weight Percent Acid Soluble	16.61%
12. Weight Percent Fines	11.98%

B. PRE-TEST - Sample

Description: The sample is taken from a 3/4" brick joint from the South Elevation. The sample breaks easily by hand with cleavage through the binder not the aggregate. The light yellowish brown binder is matte and textured. The binder to aggregate ratio is moderate. Void volume is approximately 15% primarily in the form of elongated, irrregular voids from entrapped air. Voids tend to be larger than the medium aggregate.

Color Munsell Value: Munsell: 10YR 8.5/1

	soft									hard
Relative Hardness:	1	2	3	4	**5**	6	7	8	9	10

C. POST-TEST - Sands
Color Munsell Value: Munsell: 10YR 8.5/1

Angularity: The particles are mostly rounded measuring R0.7/S0.9.

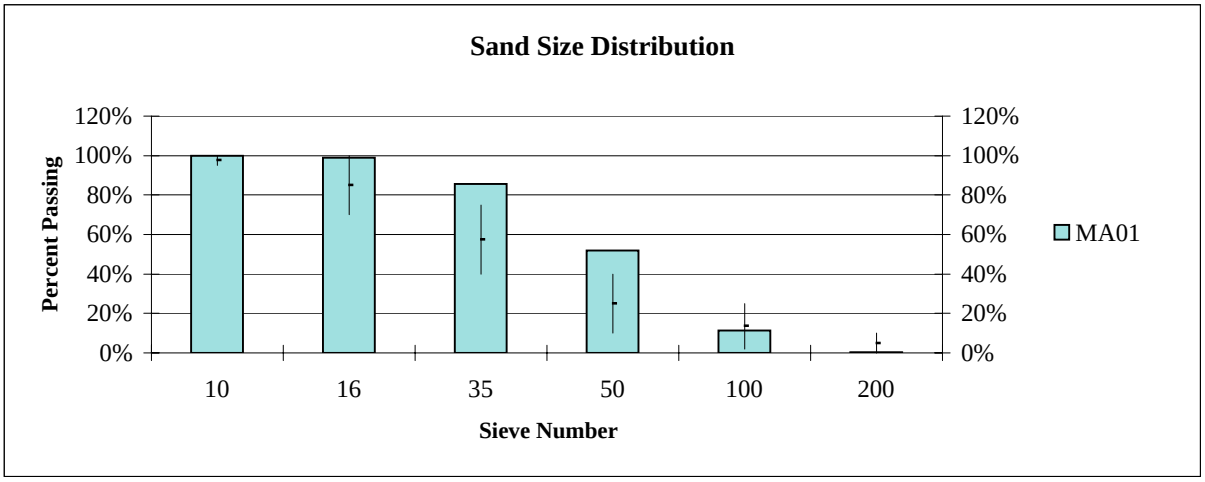
Composition: The sands vary in color and size. Most of the grains are opaque and range in color from light orange, reddish orange, to white, to dark gray in color. Smaller particles are tanslucent or transparent and vary in color from orange, to taupe, to clear.

Size:	Sieve No.	Weight	Percent Passing
	10	0.00 grams	100%
	16	0.08 grams	99%
	35	1.16 grams	86%
	50	2.90 grams	52%
	100	3.49 grams	11%
	200	0.95 grams	0%
	<200	0.04 grams	0%

D. POST-TEST - Fines

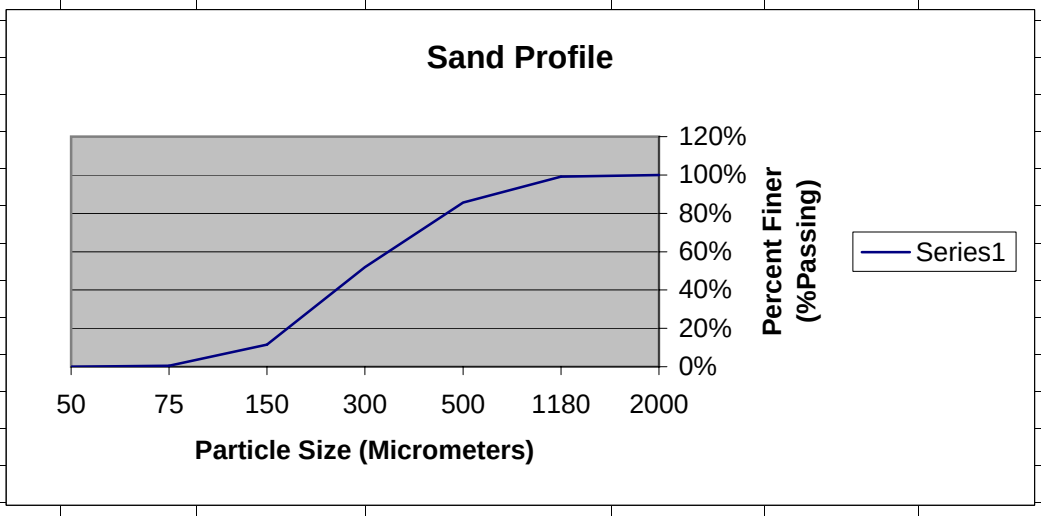
Color Munsell Value: N 7.25 Color Name: Light Gray

E. NOTES: There was high effervescence during acid digestion. The sample digested quickly with large bubbles.



Note: Each vertical line represents the range allowable in a mortar sand for a given particle size as specified by ASTM C 144 Standard Specification for Aggregate for Masonry Mortar. Allowable percentages are different for natural and manufactured sands; this chart represents the absolute maximum and minimum of both aggregate types considered together. The bars represent the particle size distribution of the sample.

			ASTM C 144				
		Allowable Aggregate Size for Masonry Mortar					
			Percent Passing				
Sieve Size	MA01	Max. Allowat	Min. Allowable	Median			
10	100%	100%	95%	98%			
16	99%	100%	70%	85%			
35	86%	75%	40%	58%			
50	52%	40%	10%	25%			
100	11%	25%	2%	14%			
200	0%	10%	0%	5%			
Sieve	Screen Size	Mass of Container	Mass of Sample and Container	Mass of Sample Retained	Percent of Mass Retained	Percent of Total Mass Retained	of Total Mass Passing
10	2000	1.6	1.6	0	0.00%	0.00%	100.00%
16	1180	1.6	1.68	0.08	0.93%	0.93%	99.07%
35	500	1.6	2.76	1.16	13.46%	14.39%	85.61%
50	300	1.6	4.5	2.9	33.64%	48.03%	51.97%
100	150	1.6	5.09	3.49	40.49%	88.52%	11.48%
200	75	1.6	2.55	0.95	11.02%	99.54%	0.46%
Pan	50	1.6	1.64	0.04	0.46%	100.00%	0.00%
			Total Sample Retained	8.62			



PAINT REMOVAL TESTS

JMA conducted a series of tests on the exterior masonry walls of Bostwick on September 25-26, 2005, to determine the best process for removing paint from the exterior brick. Ten different products were tested. The products ranged in toxicity, chemical composition and dwell times (See Table 1 at the end of the document). Only a highly alkaline stripper penetrated all the paint coatings.

After the paint was removed, it was revealed that the joints have undergone many repointing campaigns. Some of the repair work has been done poorly, leaving mortar feathered over the top of the bricks. Some joint repair work has been done with Portland cement. It is probable that removal of all of the feathered mortar will cause damage to the brick faces. It is clear that large areas of mortar have been lost. The high build up paint may have exacerbated this problem by not allowing the masonry walls to breath and by trapping moisture in the walls. Some of the joints are friable and need to be repointed to stabilize the wall structure. The current paint system is contributing to the deterioration of the joints.

Recommendation

It is recommended to use two applications of the Peel Away 1 to remove all the paint to the substrate. This compound requires neutralization after application to restore the pH of the brick as well as to prevent a white haze from forming on the surface. Additionally, all friable joints should be repointed to match the original mortar. Once this has been completed, it is not necessary to repaint the building but the client should keep in mind that there may be a lot of unsightly intact mortar joints that may cause harm to the brick if they are removed. If it is desirable to paint the building, a breathable paint system should be installed to prevent future deterioration of the joints.

Figure 1: During Testing, Exterior Masonry Wall Prior To Test

Figure 2: After Testing

Figure 3: Ten products were tried on the masonry. (1-8 shown)

Figure 4: Ten products were tried on the masonry. (9 & 10 shown)

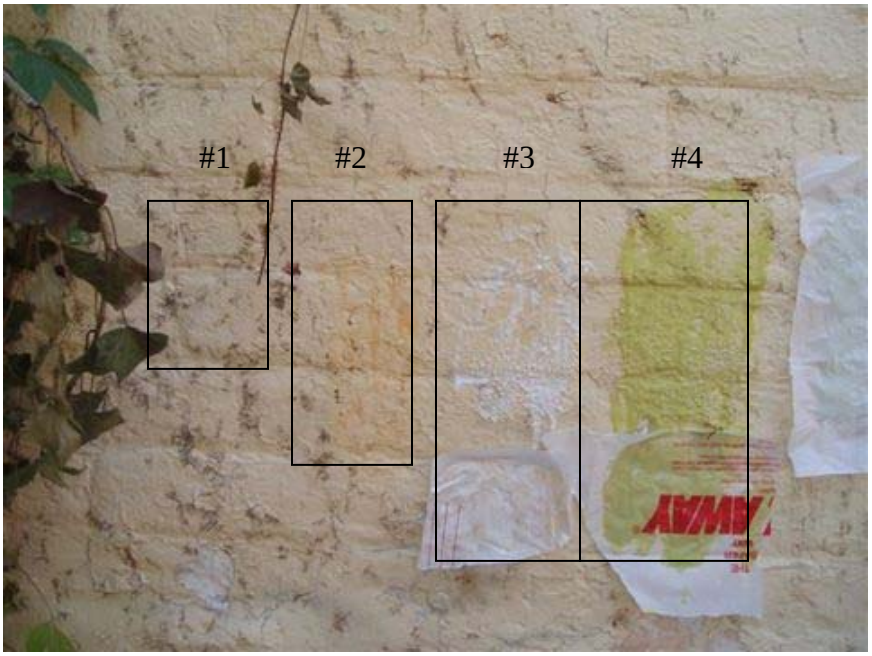


Figure 5:Area 1-Mineral Spirits, Area 2 –S301, Area 3 –S302, Area 4 – S303.

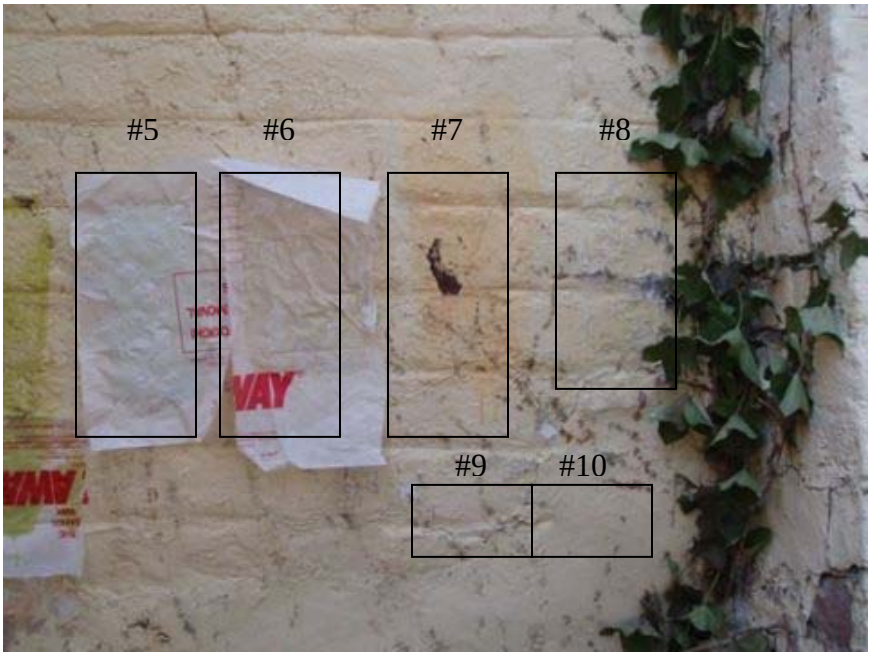


Figure 6: Area 5-Peel Away 1, Area 6 – Peel Away 7, Area 7 –Citristrip, Area 8 –3M Safest Gel, Area 9-Jasco Green , Area 10-Klean Strip.

Figure 7: Area 3-S303, This product removed most paint layers after heavy wire brushing. It may be possible to use this product along with other mechanical removal means.

Figure 8: Area 5-Peel Away 1, this product worked best and removed all the paint layers. Some moderate wire brushing was necessary. Two applications of this product have been recommended to keep wire brushing to a minimum.

Figure 9: Detail of Area 5 showing poor mortar repairs that may be difficult to remove during restoration. Note feathering of mortar over brick faces.

TABLE 1

PROJECT:	BOSTWICK	**DATE OF TEST:**	09/25/07 to 09/26/07	**OTHER CONDITIONS:**	
SUBSTRATE:	BRICK	**CONSERVATOR:**	LMB	**RH:**	68%
ELEMENT:	EXTERIOR WALL	**AIR TEMP:**	86° +-	**pH SUBSTRATE PRE-TESTING:**	7
ISSUE:	PAINT REMOVAL				

KEY	LOCATION	PRODUCT	ACTIVE INGREDIENTS	pH	DILUTION	DWELL	pH AFTER	TOXCITIY	RESULTS
1	Side Elevation	MINERAL SPIRITS	Mineral Spirits	NA	none	30 min.	7	Low	POOR: Swab- No Change
2	Side Elevation	S-301	Aromatic Alcohol, Propylene Glycol, Naphthalene, hydroxy Ethanoic Acid, Water	2	none	2 hr & 24 hr.	7	Low	POOR: Slight Movement but material did not set up well
3	Side Elevation	S-303	Aromatic Alcohol, Triethanolamine, Water	8	none	3 hr & 24 hr.	7	Low	FAIR: Removed 2-3 layers. Required Wire Brushing
4	Side Elevation	S-305	Aromatic Alcohol, Hydroxycarboxylic Acid, Hydrogen Peroxide	3	none	4 hr & 24 hr.	7	Low	POOR: Slight Movement.
5	Side Elevation	PEELAWAY 1	Calcium, Magnesium, Sodium Hydroxides	13	none	5 hr & 24 hr.	7	Low	**BEST**: Removed down to substrate.
6	Side Elevation	PEELAWAY 7	Dibasic Ester, n-Methyl-2-Pyrrolidone, Aluminum Silicate, Nonylphenol Ethoxylate	3.2	none	6 hr & 24 hr.	7	Low	POOR: Slight Movement.
7	Side Elevation	CITRISTRIP	Citrus Terpines, Ethylene Glycol Monobutyl Ether, Ethyl Alcohol	NA	none	6 hr & 24 hr.	7	Low	POOR: Slight Movement.
9	Side Elevation	3M SAFETEST GEL	Dimethyl Adipate, Dimethyl Glutarate, Hydrated Aluminosilicate	7	none	6 hr & 24 hr.	7	Low	POOR: Slight Movement.

TABLE 1

PROJECT:	BOSTWICK	**DATE OF TEST:**	09/25/07 to 09/26/07	**OTHER CONDITIONS:**		
SUBSTRATE:	BRICK	**CONSERVATOR:**	LMB	**RH:**	68%	
ELEMENT:	EXTERIOR WALL	**AIR TEMP:**	86° +-	**pH SUBSTRATE PRE-TESTING:**	7	
ISSUE:	PAINT REMOVAL					

KEY	LOCATION	PRODUCT	ACTIVE INGREDIENTS	pH	DILUTION	DWELL	pH AFTER	TOXCITIY	RESULTS
9	Side Elevation	JASSCO GREEN	Dimethyl Glutarate, Dimethyl Adipate, Dimethyl Sulfoxide	NA	none	1 hr.	7	LOW	POOR: No Change
10	Side Elevation	KLEAN STRIP STRIP X STRIPPER (KS3)	Methylene Cloride, Methanol, Isopropanol, ethylene Glycol Monobutyl, Ether, Water	6.8	none	1 hr.	7	MED	POOR: No Change