Nathaniel Russell House
Charleston, SC
Mortar analysis report

Prepared for:
Will Hamilton
Historic Charleston Foundation
Charleston, SC 29401

Prepared By:
Meadors, Inc.
PO Box 21758
Charleston, SC 29413

Date: 09.19.2016

Introduction

Meadors Conservation was hired by Will Hamilton of Historic Charleston Foundation to sample and analyze one (1) pointing mortar sample from the main house and (1) bedding mortar sample from the north perimeter wall at the Nathaniel Russell House, located at 51 Meeting Street. The bedding mortar selected for analysis was sampled along the north perimeter wall adjacent to the driveway. The exterior pointing mortar sample was taken from the north side of the building adjacent to the 1840 addition. Acid-digestion and petrographic analysis were chosen as the mortar-analysis methods used to determine the primary characteristics of the existing bedding and pointing mortars. Acid-digestion involves digesting a mortar in an acid solution in order to separate the binder from the aggregate and ultimately calculate the approximate percentage of each component within the original material. Petrography allows for the analysis of thin sections of stone, mortars, and stuccos via the use of a polarized light microscope. Textural relationships of the sample can be assessed and the various mineral components definitively identified based upon their crystallography. The ultimate goal of this analysis was to use this information to formulate an appropriate replication mix for a future repair campaign to be completed in the near future.

Methodology

Wet chemical techniques were used to isolate and analyze the aggregate of each sample and to determine the approximate binder-aggregate ratio. Information obtained from this type of analysis aids in formulation of appropriate repair mortars based on the characteristics of the aggregate and approximate proportions of materials.

The samples were first characterized through microscopic examination of the each bulk sample with a stereo microscope. Detailed photomicrographs were taken of each bulk sample prior to analysis in order to accurately characterize the sample prior to chemical alteration. The samples were then carefully disaggregated by hand with a ceramic mortar and pestle and dried at 110^{o}C for 24 hours. Due to the presence of delicate shell fragments within the crawlspace bedding mortar, special care was taken during this step to not further disintegrate the shell aggregate.

Next, the samples were separated into three component parts including the acid soluble portion (binder), aggregate (sands, crushed stone, etc), and fines (clay, pigments,etc). Where present, shell aggregate within the sample was removed in order to preserve the aggregate before acid digestion. The crushed samples were immersed in a 14% solution of hydrochloric acid on a stir plate in order to dissolve the acid-soluble components of the binder.

Following the removal of these components, each sample was filtered using Whatman™ No 4 150mm filter paper. Through gravimetric analysis, the larger aggregate was separated from the fines, dried for 24 hours at 110^{o}C, and weighed to determine the weight ratios of the binder, aggregate, and fines. In order to determine the particle size distribution of the aggregate, each sample was sieved through standard ASTM sieves and photographed to allow for further characterization.

Concurrent with the wet chemical analysis, petrographic analysis was conducted according to ASTM C1324 in order to definitely identify the composition of the individual components. 1” x 2” thin sections were made of each sample and were impregnated with a blue epoxy to illustrate the porosity of the material analyzed. Samples were analyzed using a Motic BA310 trinocular polarizing microscope. Digital photomicrographs were taken of each sample and are included in the report.

Perimeter Wall
Bedding Mortar

Sample NatRus.WBM

Sample Sheet

Sample #: NatRus.WBM

Date Sampled: 8/11/2016

Sampled By: KDM

Sample Location: North Perimeter Wall Bedding Mortar

Type of mortar: Bedding mortar with shells

Visual Description of Bulk Sample: Sample is soft in hand sample with numerous shells present. Shell, clumps of clay, and brick are present within the binder matrix.

Surfaces: No visible surfaces present

Color: Beige

Munsell Color: 10YR 8/3 "Very pale brown"

Hardness: >5 (Mohs)

Weight: 20.78g

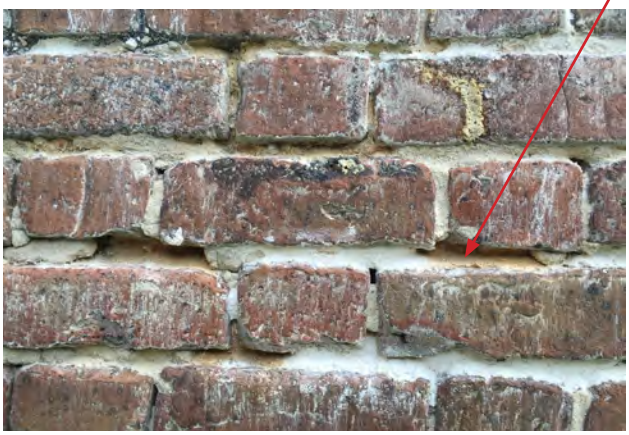


Figure 1: Photo of sampling location in on north perimeter wall.
Figure 2: Detail of sampling location.

Figure 3: Photo of bulk sample.

Figure 4: Close-up of bulk sample showing numerous shell fragments.

Acid Digestion

Figure 7: Powdered sample prior to addition of acid. Note round brown clay lumps within mortar (arrow).

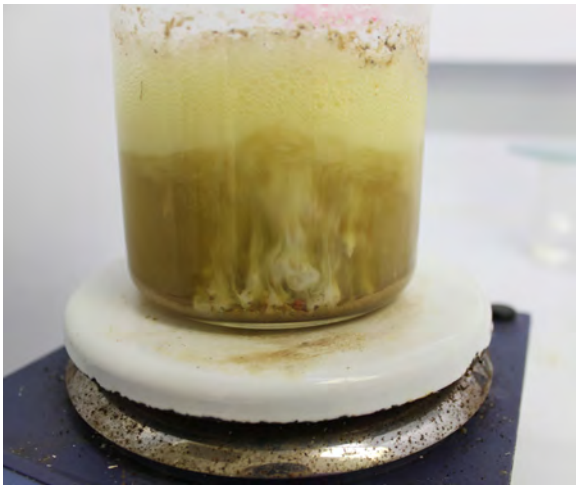


Figure 8: Effervescence of sample upon addition of acid.

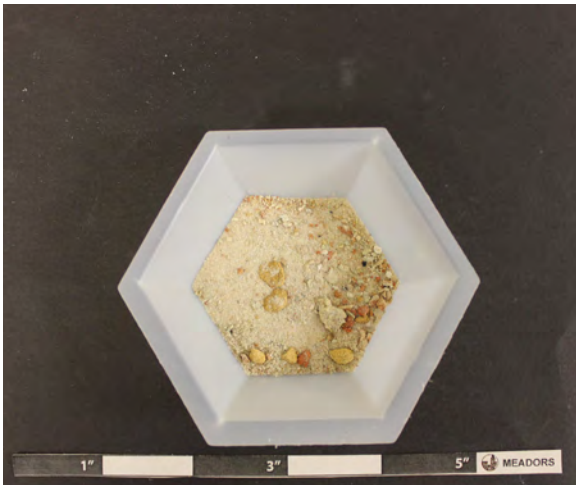


Figure 5: Photo of aggregate extracted from the sample.

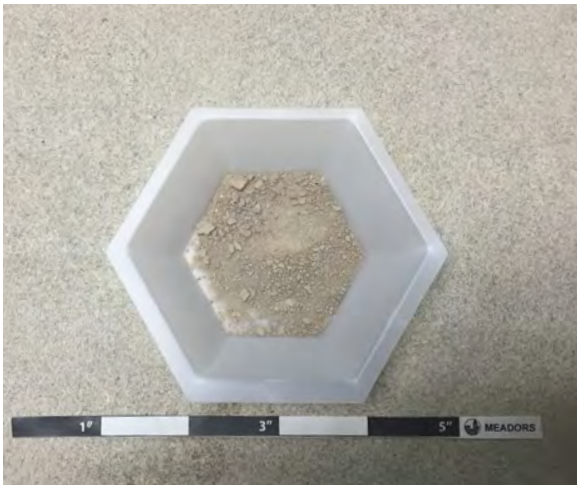
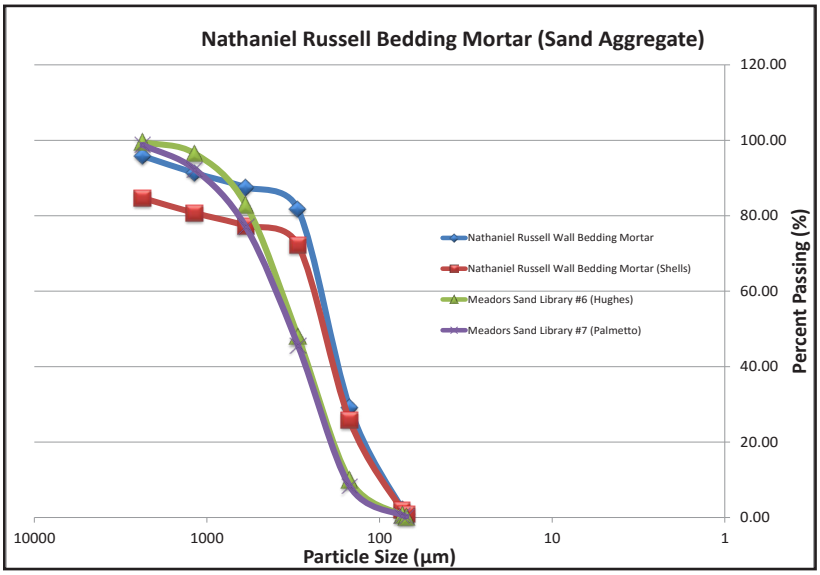


Figure 6: Photo of fines extracted from the sample.

Sieve Analysis

Sieve Number	% passing
8	84.70
16	80.74
30	77.34
50	72.24
100	25.78
200	1.98
pan	0.85



Graph 1: NatRus.WBM Sieve Analysis with aggregate resembling the profile of Sand Library Sample #06 & #07.

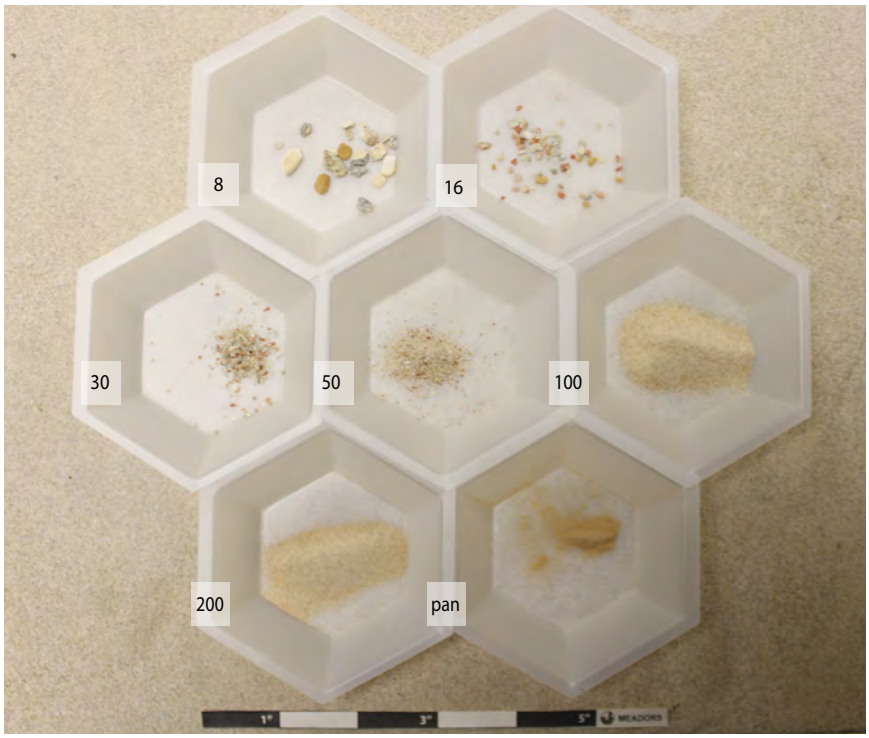


Figure 9: Photo of sample NatRus.WBM following sieve analysis showing aggregate retained within each corresponding sieve. Note: Accumulation of aggregate in the #100 & #200 Sieves.

Petrographic Analysis

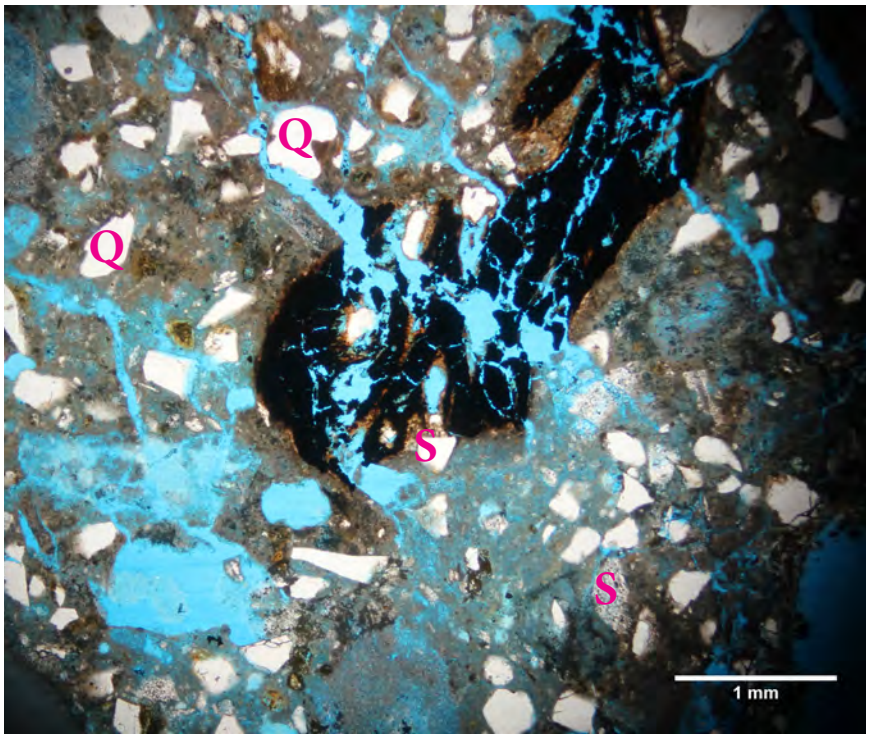


Figure 10: Plane Polarized light image of NatRus.WBM sample. The sample is densely packed with equidimensional grains of quartz (Q) and shell (S). Clay is visible throughout. A large black cinder is present within the mortar (40x magnification).

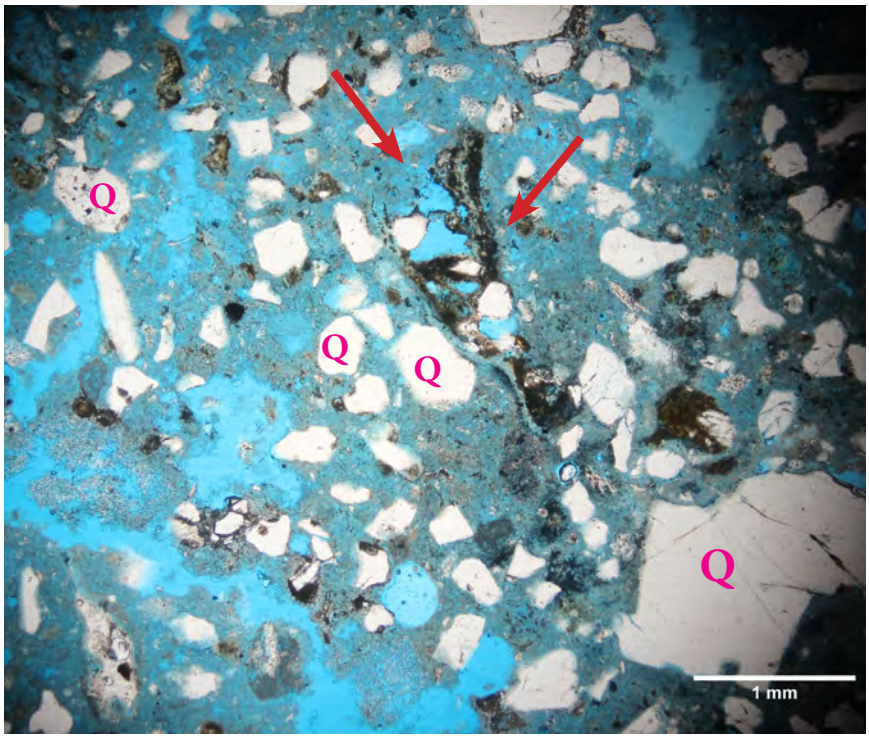


Figure 11: Plane Polarized light image of NatRus.WBM sample. Equidimensional quartz grains are present with clinkered clay (arrow), likely originating from the firing of the oyster shells (40x magnification).

Petrographic Analysis

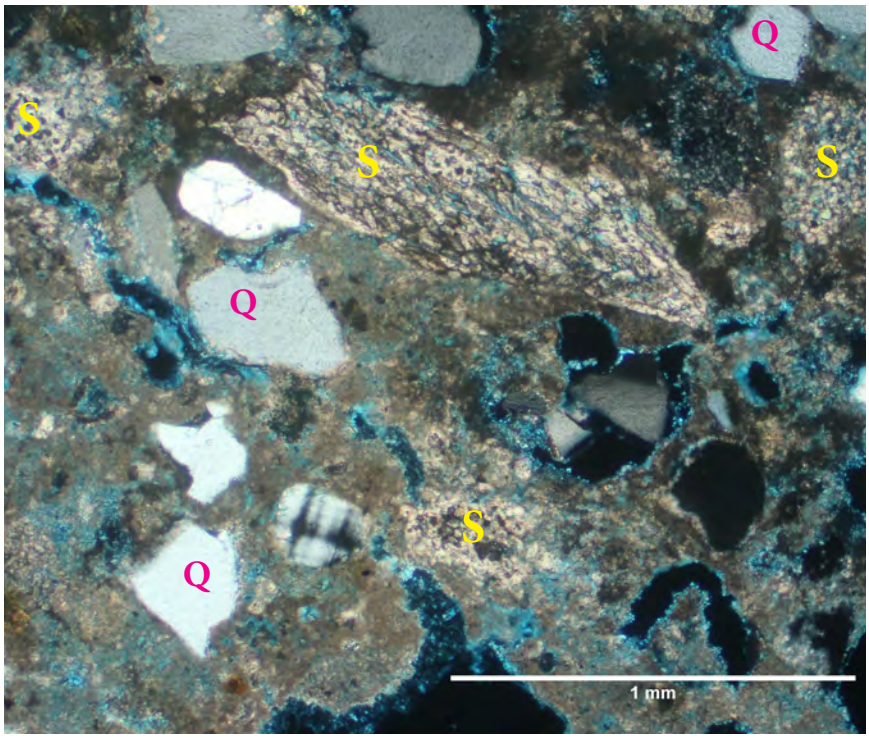


Figure 12: Cross Polarized light image of NatRus.WBM sample. Large unburned shells (S) are present throughout and are visible in hand sample. The binder is well carbonated at the center of the sample (100x magnification)

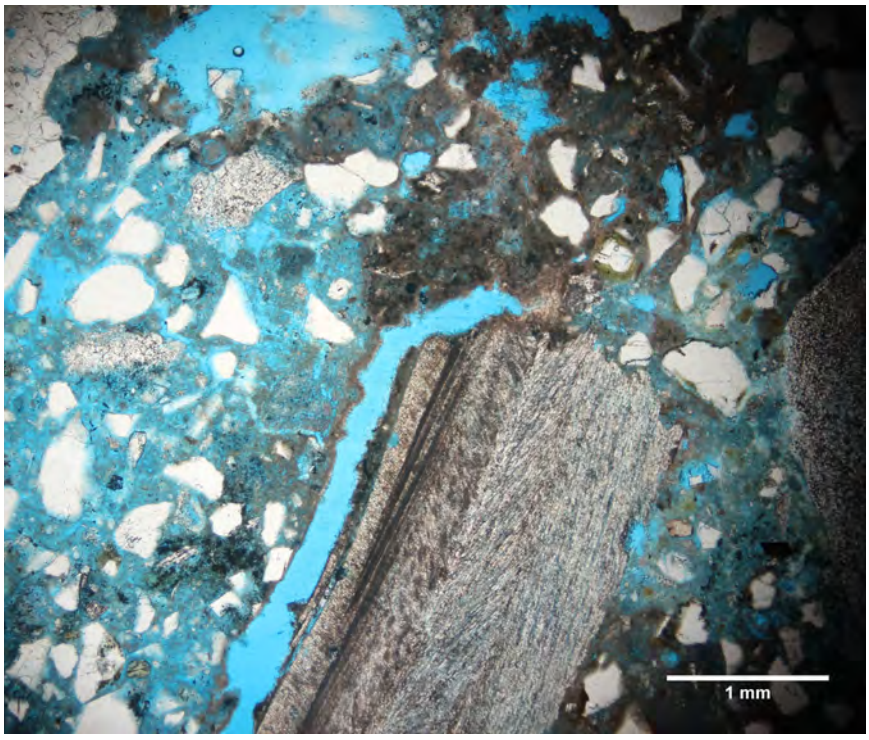


Figure 13: Plane Polarized light image of NatRus.WBM sample. Shringage cracks are present around large shell grains (40x magnification).

Results of Analysis

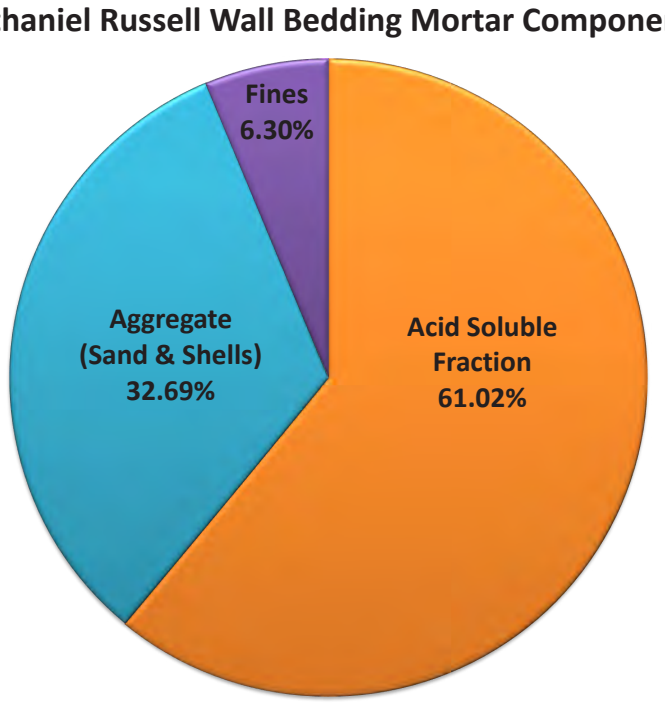


Figure 14: Findings from the Acid Digestion. Note: Finely ground shell aggregate too small to physically remove from the sample prior to acid digestion has been accounted for in the acid soluble fraction.

Mortar Sample

The bedding mortar sampled by Meadors Conservation contained visible shell aggregate that was significantly larger than the other aggregate within the sample. The mortar at this location appeared to be in poor condition and easily disaggregated when handled. The mortar sample appeared to be a soft and highly permeable mass with no visible layers. Multiple repointing campaigns were visible throughout the wall.

Components of the Foundation Bedding Mortar Sample

Analysis performed by Meadors Conservation on one bedding mortar sample from the north perimeter wall of the Nathaniel Russell House property determined that the sample constituted of 61.02% soluble binder, 32.69% aggregate, and 6.30% fines. Prior to acid digestion, large crushed shell aggregate was removed from the sample to preserve the shells as “aggregate”. However due to the prevalence of crushed oyster shells throughout the samples, not all of the shell could be removed and a portion was dissolved within the acid. The higher proportion of acid soluble material accounts for the very fine shell aggregate.

The proportion of the acid soluble portion (binder) to the aggregate (sands, crushed shells, etc) and fines (clays, pigments, etc) was determined to be similar to that of a 1:2 to 1:2.25 mix. No evidence of Portland cement or a hydraulic component was found.

Recommendations

This mortar is primarily an unwashed, overly fine-grained, and narrowly graded aggregate with approximately 6% clays. This mix is consistent with pre-1830 mortar mixes found in Charleston, SC. It is likely that the aggregate portion of the mortar was composed of approximately 1/4 to 1/3 oyster shells and 2/3 to 3/4 sand aggregate. As indicated by the sieve analysis, the oyster shell aggregate portion was significantly larger in size than the quartz aggregate, ranging in diameter from 2.38 mm to 1.19mm, with a majority of the particles larger than the No. 8 (2.38 mm) sieve.

Microscopic and sieve analysis conducted on the insoluble aggregate portion indicated that the aggregate was composed of semi-translucent angular silica quartz and crushed oyster shell. Microphotographs depict the range in sizes of the oyster shell from large pieces greater than 2mm to finely ground microscopic shells. The sample is well carbonated on the interior of the sample, but the carbonation decreases on the outer edges. The lime source appears to originate from burned oyster shells. Large lime blebs are present that retain the micro-texture of the original shells. Inert clinker, like a contaminate from the unwashed oyster shells, is visible in the petrographic sample.

The binder is sparse and highly porous. Shrinkage cracks were common throughout the sample, especially adjacent to large unburned oyster shell aggregate. Charcoal and cinders were also dispersed throughout the sample, likely originating from the burning of the oyster shells for lime. Of particular note is a large particle of burned silt with clay shrinkage cracks.

Recommendations for Restoration Materials

Traditional historic mortars within Charleston often contained mixes of lime, clay, and sand in varying ratios to create a workable mix that could be applied on soft Charleston bricks. Technical skill and knowledge was required to mix, apply, and successfully cure these traditional mixes. Over time, as new faster setting materials with increased durability developed such as Portland cement, traditional mixes fell out of favor. As this occurred, the once ubiquitous knowledge and technical skill required to make, apply, and cure these materials was also lost, making recreation of this historic material today a significantly challenging and expensive process.

Fortunately, several types of binders exist today that are based on historically used materials that serve as appropriate restoration mixes. Natural Hydraulic Limes (NHLs) is one such material that originates from the burning and grinding of limestone with a high clay content. The varying clay content within the host stone creates the different grades of natural hydraulic limes including feebly hydraulic lime (less than 10% clay), moderately hydraulic lime (11% to 20% clay), and eminently hydraulic lime (21% to 30%). An increased clay content imparts an increased degree of hydraulicity to the lime, allowing the material to be used in extreme environments.

Due to their hydraulicity, or ability to set under water, NHL mortars have increased workability but have low elastic modulus, water vapor permeance, and thermal expansion coefficient similar to that of non-hydraulic lime mortars and stuccos and much lower than Portland cement mixes. Therefore these limes serve as a compatible and almost always universally safe material when used on historic substrates. However, the use of this material can be considered compatible with the original material, but is not accurate for the time period of the Nathaniel Russell House.

Recommendations

Replication Bedding Mortar

The following mix is recommended as a historically appropriate mortar that would replicate the existing historic mortar.

1 part hydrated lime
2 parts local aggregate composed of crushed oyster shell and local sands (see recommended mixture)
1/256 part Yellow Oxide Pigment (Red)

For increased workability, the following mix is recommended in place of the pure lime-sand-shell mortar. NHL mortars have been proven to be compatible when applied adjacent to sound historic lime mortars.

1 part NHL 3.5
2 parts aggregate composed of crushed oyster shell and local sands (see recommended mixture)
1/256 part Yellow Oxide Pigment (Red)

Note: The addition of pigment is recommended to create visual match to the original mortar. If visual continuity between the old and new material is not a priority, the addition of pigment can be ignored as the omission of such materials will not negatively affect the weatherability or longevity of the new replication mortar.

Recommendations for Replication Mortar Materials

1 NHL (St.Astier NHL 3.5)
Available at Hughes Lumber, 82 Mary St. Charleston SC (843.577.6671)
2 Parts Aggregate
0.75 Sand
"Yard Sand" at Hughes Lumber, 82 Mary St. Charleston, SC (843-577-6671)
OR
"Masonry Sand" at Palmetto Sand, 556 Wire Road. Dorchester, SC (843-563-5014)
0.25 Parts Crushed Oyster Shell
"Bocci Mix" Available at Carolina Suppliers & Materials, Inc, 2115 Monrovia Street. Charleston SC (843-723-6588)
OR
Mycosupply (http://www.mycosupply.com)
1/256 Parts Yellow Oxide Pigment-Red Shade (Yellow 6940 Pigment) (Bayferrox 940)
Available from Edison Coatings in 1 lb. and 5 lb. containers as Dry Color Pak, 3 Northwest Drive, Plainville, CT 06062 (860-747-2220), http://www.edisoncoatings.com

The required volume of pigment necessary to achieve the desired color may vary when combined with the aggregate. Cured samples should be compared to the original to ensure an aesthetic match. All parts for each specified mortar mix should be mixed by volume and not by weight. Dry ingredients should be well mixed prior to the addition of a water. **Larger batches may require less pigment than smaller batches.**

Nathaniel Russell House
Pointing Mortar

Sample NatRus.PM

Sample Sheet

Sample #: NatRus.PM

Date Sampled: 8/11/2016

Sampled By: KDM

Sample Location: North Exterior Wall, Adjacent to 1840 Addition

Type of mortar: Decorative pointing mortar

Visual Description of Bulk Sample: Pointing mortar is hard and indurate with a tuck point joint profile. Sample is brittle and does not disaggregate easily. Evidence of historic beige shell bedding mortar is present on back of sample, indicating pointing mortar is likely original to the construction of the building.

Surfaces: Only one layer was present in hand sample.

Color: 7.5Y 9/2 "White"

Munsell Color: 10YR 9/1 to 8.5/1 "White"

Hardness: <5 (Mohs)

Weight: 6.76g

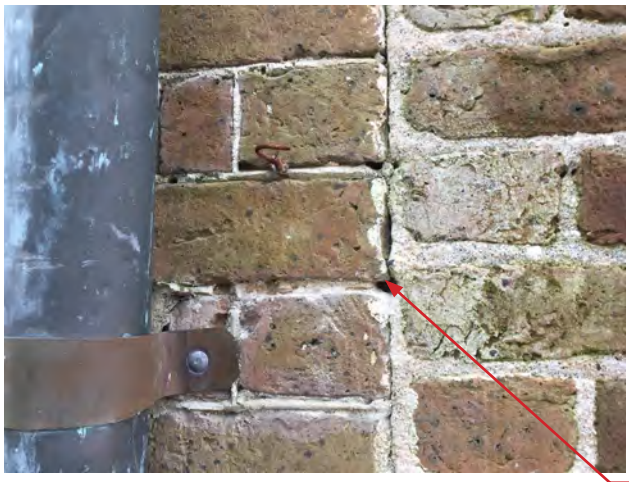


Figure 15: Photo of sample location.
Figure 16: Close-up of sample location.

Figure 17: Photo of bulk sample.

Figure 18: Detail of bulk sample with visible shell aggregate.

Acid Digestion

Figure 19: Sample prior to addition of acid.

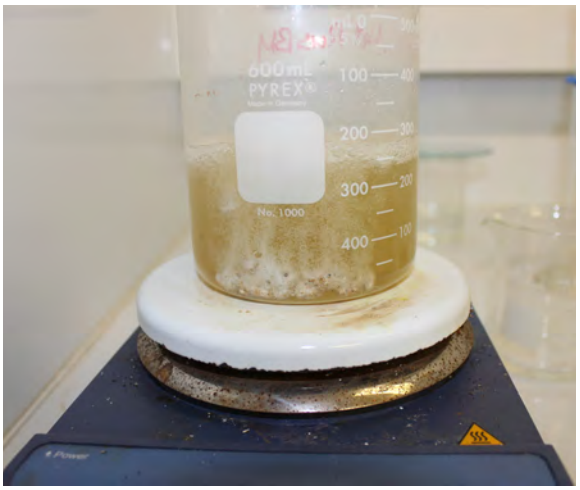


Figure 20: Effervescence of sample upon addition of acid.

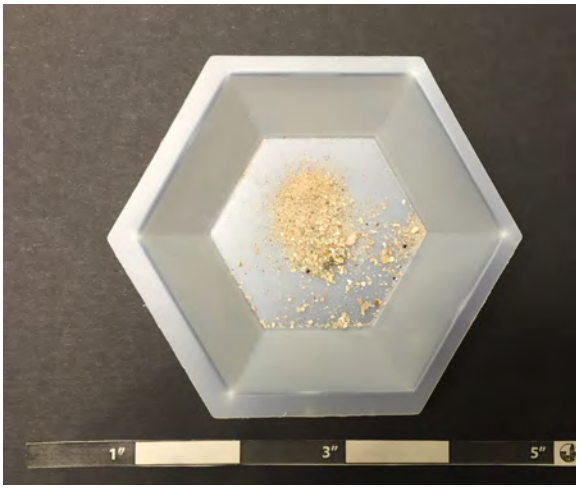


Figure 21: Photo of aggregate extracted from the sample.

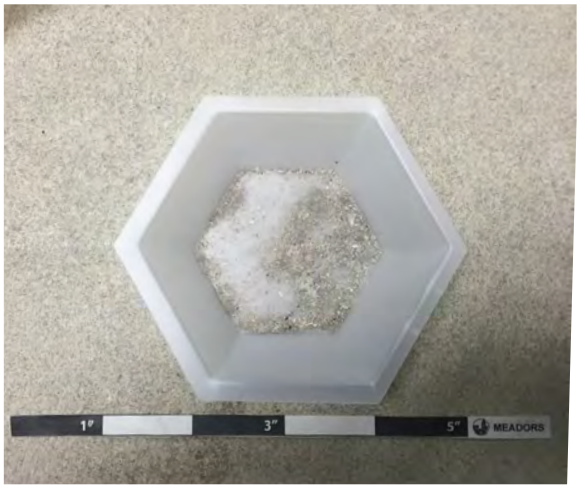
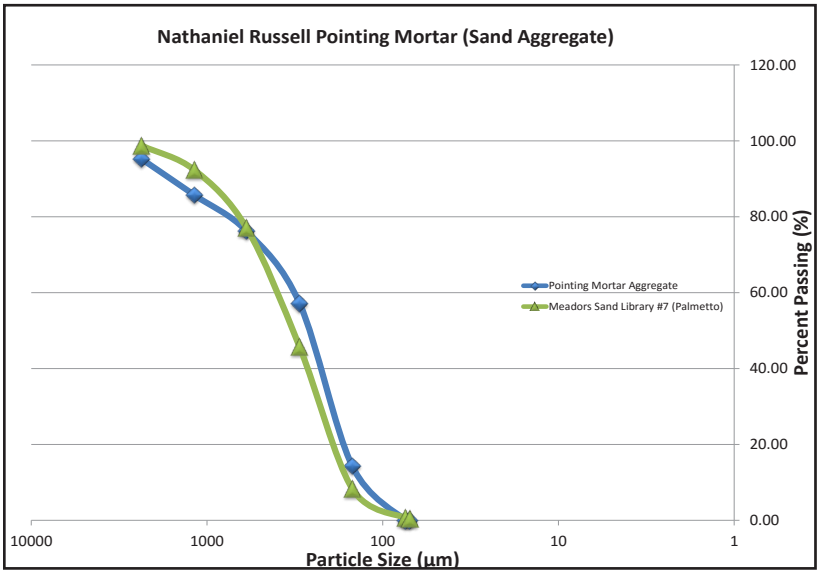


Figure 22: Photo of fines extracted from the sample.

Sieve Analysis

Sieve Number	% passing
8	95.24
16	85.71
30	76.19
50	57.14
100	14.29
200	0.00
pan	0.00



Graph 1: NatRus.PM Sieve Analysis with aggregate resembling the profile of Sand Library Sample #07.

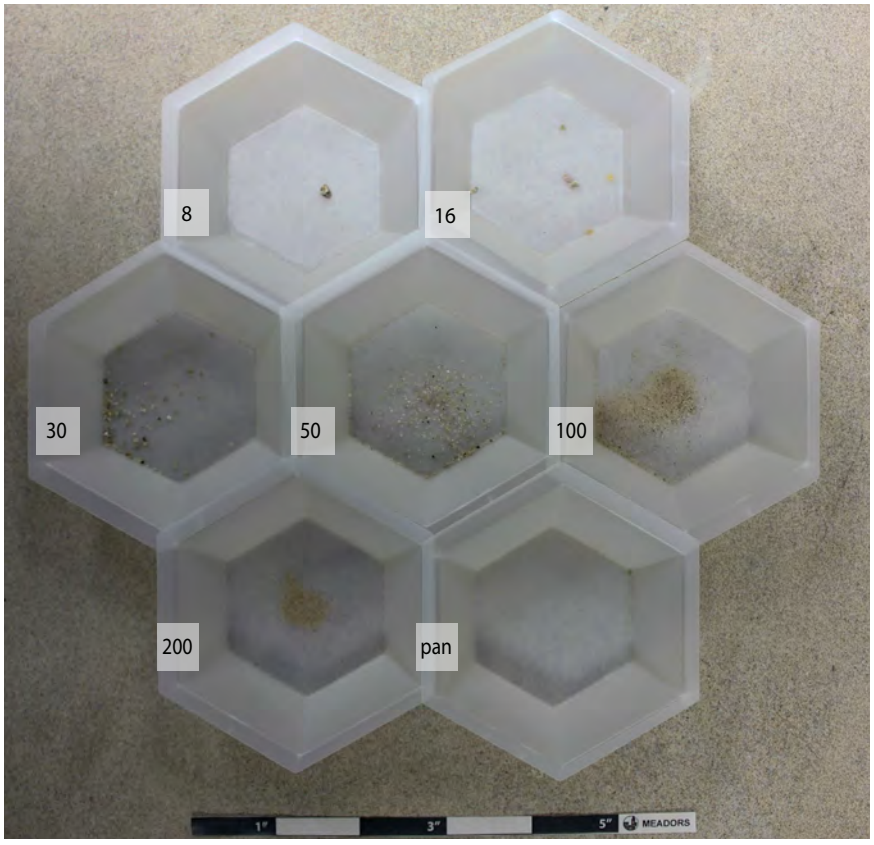


Figure 23: Photo of sample NatRus.PM following sieve analysis showing aggregate retained within each corresponding sieve.

Petrographic Analysis

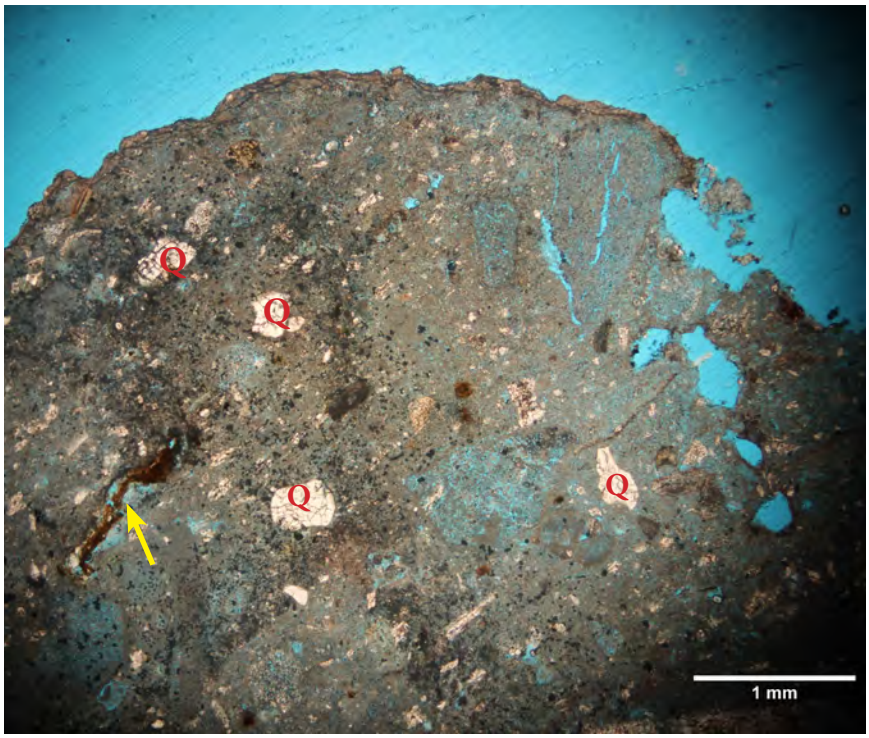


Figure 24: Plane polarized light image of NatRus.PM sample. The tuck pointed joint profile is preserved in this sample. The aggregate is sparse and the binder is well carbonated. A carbonated lime and dirt crust is present on the outer edge. Clinkered clay is visible (arrow) (40x magnification).

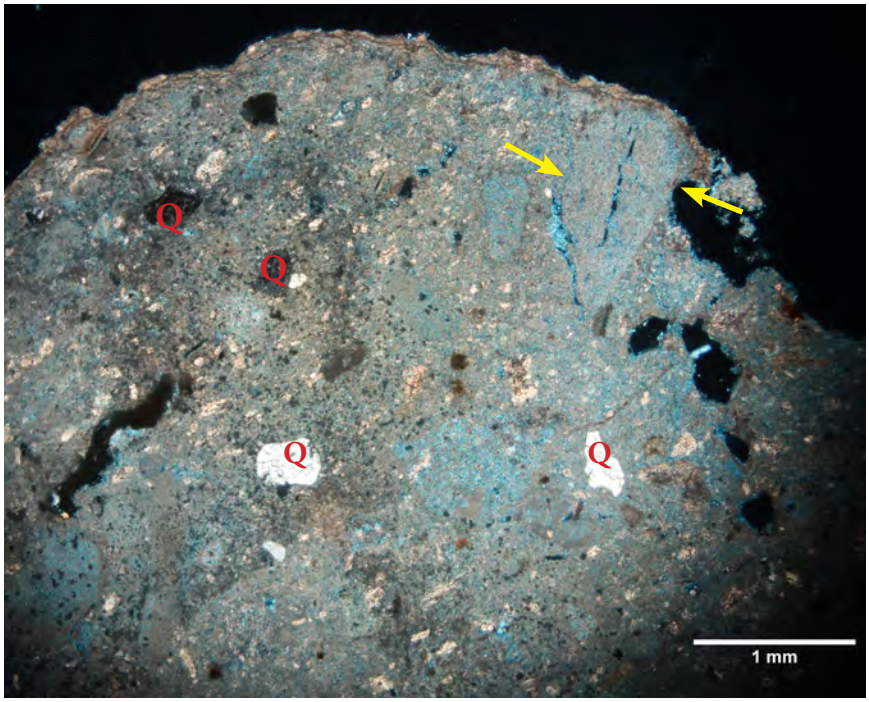


Figure 25: Cross polarized light image of NatRus.PM sample. The binder is very porous and appears to be composed of a high concentration of lime. Shrinkage cracks are minimal. Note the absence of large aggregate and location of lime shrinkage cracks (arrow) (40x magnification).

Petrographic Analysis

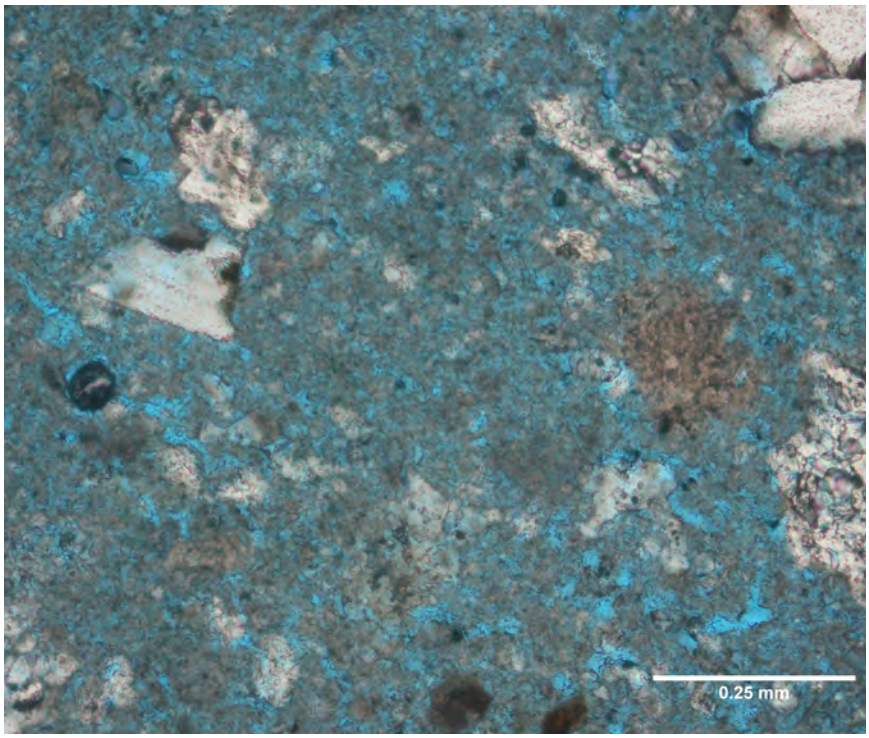


Figure 26: Plane polarized light image of NatRus.PM sample. Close up of the pointing mortar binder. The binder is largely composed of fine grained lime and finely ground oyster shells. The break down of the shell into calcite minerals likely provides stability to the mix (200x magnification).

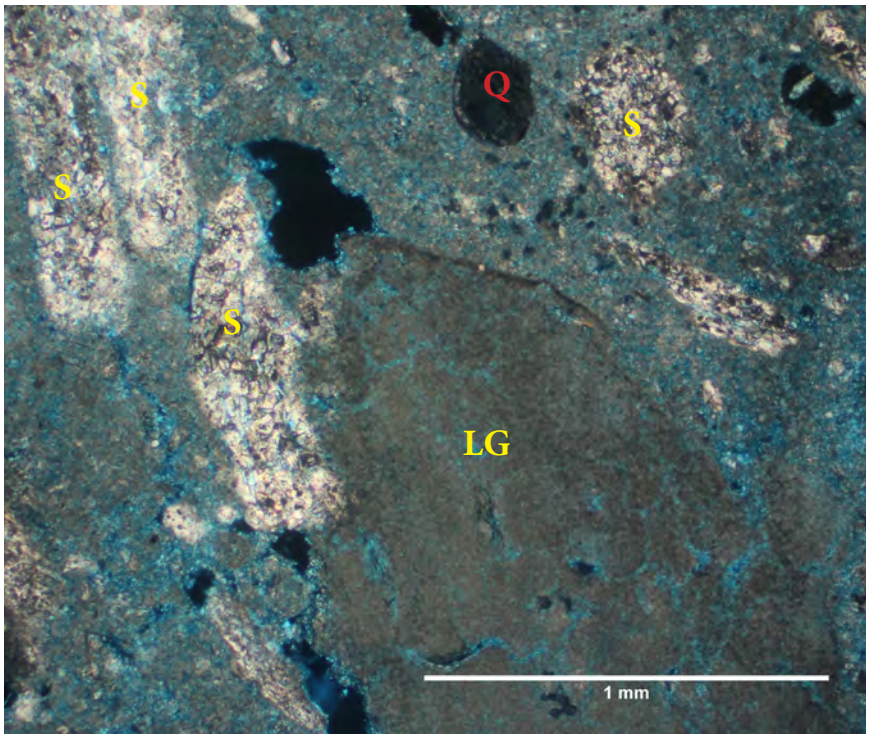


Figure 27: Cross polarized light image of NatRus.PM sample. Large lime shells and lime grains (LG) are present at select locations (100x magnification).

Petrographic Analysis

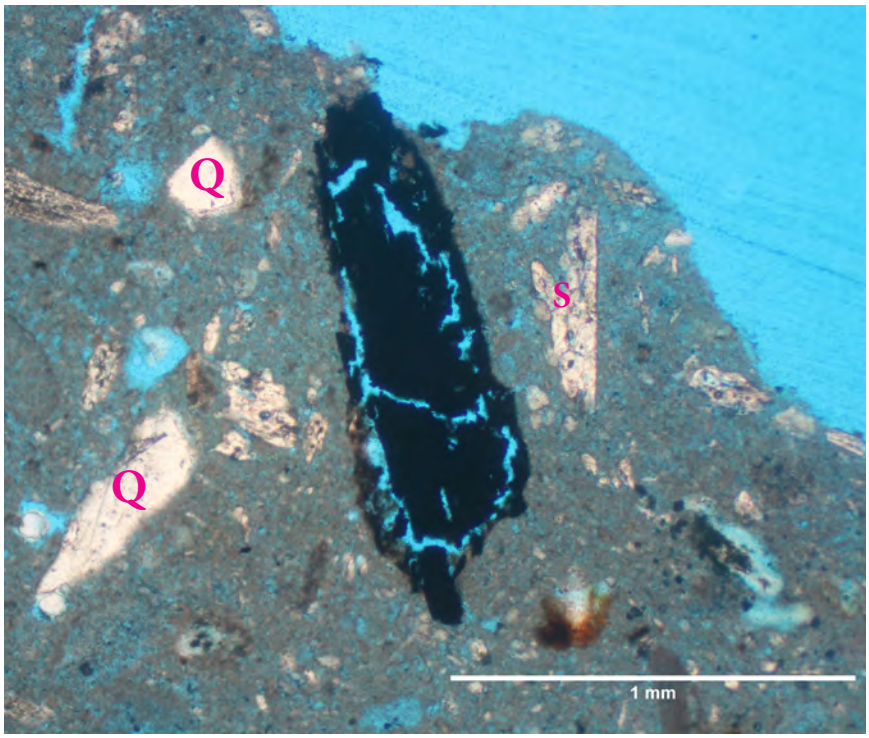


Figure 28: Plane polarized light image of NatRus.PM sample. Cinders and rare quartz (Q) aggregate are visible within the sample (100x magnification).

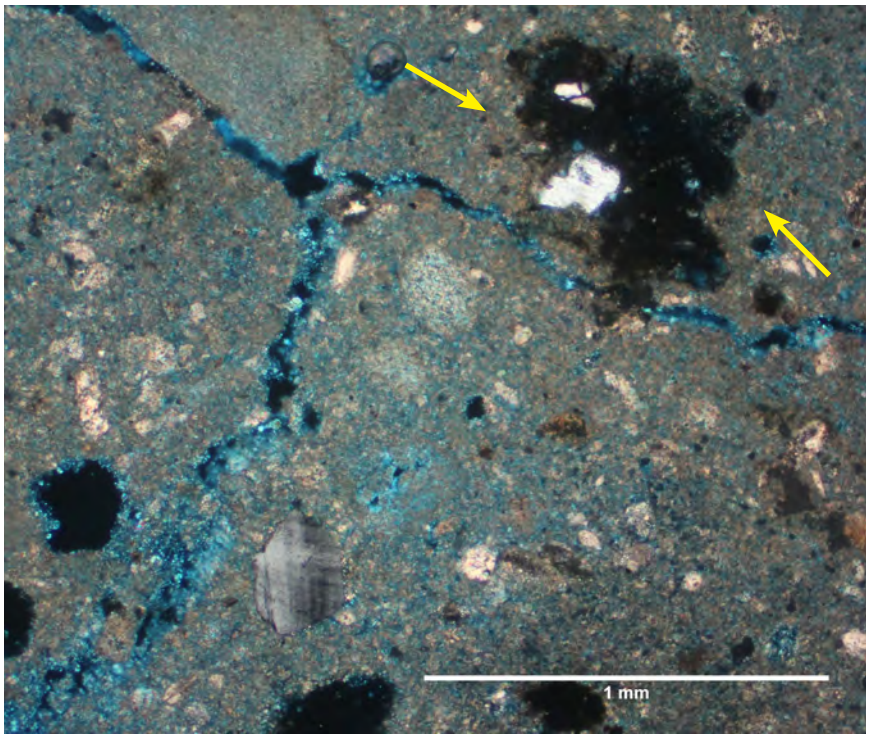


Figure 29: Cross polarized light image of NatRus.PM sample. Several shringage cracks are present within the sample. Cinders (arrow) have been mixed into the mortar likely from partially burned shells (100x magnification).

Results of Analysis

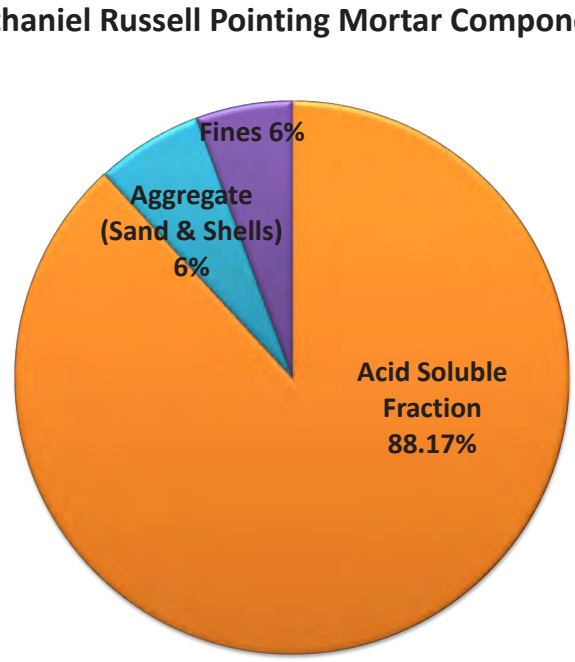


Figure 30: Findings from the Acid Digestion. Note: Finely ground shell aggregate that were unable to be physically removed prior to acid digestion have been accounted for in the acid soluble fraction.

Pointing Mortar Sample

The pointing mortar sampled by Meadors Conservation on the north elevation of the house was white in color and had a visible a tuck pointed joint profile. The mortar did not easily disaggregate when handled. Small shells were visible in bulk sample and minimal cracking was visible on the exterior joint profile. The mortar is highly permeable and indurate. During sampling, tan colored shell bedding mortar was observed within the joint, similar in color and composition to sample NatRus.WBM, indicating that the pointing mortar was likely from the original construction.

Components of the Pointing Mortar Sample

Analysis performed by Meadors Conservation on the pointing mortar sample from the north wall of the Nathaniel Russell House determined that the sample constituted of 88.17% soluble binder, 6% aggregate, and 6% fines. The high percentage of acid soluble material is due to the large percentage of calcite grains within the binder matrix. These grains, derived from finely crushed oyster shell, serves a dual purpose as an aggregate and as the source for the lime, known as “shell-lime”. The use of oyster shell aggregate greatly reduces the presence of shrinkage cracks, which is a common issue in high calcium lime mortars. The presence of a large acid soluble fraction is expected as a high lime concentration is necessary to create a pliable mortar and a crisp tuck point joint profile

The proportion of the acid soluble portion (binder) to the aggregate (sands, crushed stone, etc) and fines (clays, pigments, etc) was determined to be similar to that of a 1:1 mix (with lime putty) or 2:1 mix as a dry hydrate. No evidence of Portland cement or a hydraulic component was found in the

Recommendations

pointing sample. The aggregate component is believed to be composed of 1 part fine grained sand to 3 parts crushed oyster shell. This is an estimated ratio based on petrographic analysis and acid digestion values.

This mix is consistent with 19th century pointing mortar mixes found in Charleston, SC. As indicated by the sieve analysis, the aggregate was narrowly graded with the greatest percentage of particles in the No. 50 Sieve (0.0117mm) to the No. 100 Sieve (0.0059mm). The aggregate appears to have been intentionally sieved to reduce the size of the aggregate and allow for a crisp mortar joint. Additionally, very few clay particles can be seen mixed with the binder, a sharp contrast to the bedding mortar sample. Larger aggregate would likely create uneven lines as the tuck pointing tool was dragged across the fresh mortar and the color of the unsieved masonry would likely detract from the architectural intent of the crisp tucked joint. The ratio of sand to crushed lime appears to have been a widely known but scarcely recorded trade secret, as many historic examples of this pointing mortar can be seen in Charleston but little documentation exists.

Microscopic and sieve analysis conducted on the insoluble aggregate portion indicated that the aggregate was composed of semi-translucent round silica quartz and crushed and partially burned oyster shells. Analysis of the thin sections indicates that the mortar is well carbonated, especially on the outer edges. The lime source for the binder is believed to derive specifically from burned oyster shells. Partially uncarbonated lime blebs containing the original shell micro-texture is also visible in several samples. Partially burned shell, clay clinker, and burned silt are minor portions of the mix.

Production of Shell-Lime

Based upon the evidence, it appears that the original masons at the Nathaniel Russell House were experts in their field and were some of the finest in the city. While the process of shell burning has been researched previously, it is important to detail the process in order to understand the components and micro-textures seen during analysis. The process of creating shell-lime appears to be relatively simple, but requires great skill and finesse in order to create a high quality product.

During this time period, Native American middens of fresh and saltwater shells were common throughout the Lowcountry served as an available source of lime. Following collection, the shells were lightly washed to remove impurities. As discussed previously, impurities such as clay clinker can be seen in thin section, indicating the shells were not completely clean prior to firing. The shells were then placed in a kiln surrounded by firewood and set on fire in order to calcine the shells. As the petrographic slides show, a complete burn was not always possible as many partially burned shells can be seen in the samples. Following several hours of burning, the shells would calcine and turn completely white. Heated water was quickly mixed with the lime to provide added energy into the chemical reaction and begin the slaking process. Shortly after the addition of water, a strong exothermic reaction would have occurred as the mixture was stirred furiously. Once the lime was broken down into a smooth batter like consistency, it could be sieved and stored for fine detailed work or put into immediate use for simple masonry. Based upon the samples, it does not appear the lime putty was strained as unslaked particles remain within the mortar 200 years later.

The lime putty used at Nathaniel Russell was likely stored for several years before being used. 19th century literature from this time notes that the best lime putty is stored in a sand pit covered with water for 10 to 12 years. The high quality lime putty was likely mixed with aggregate and potentially additional broken or partially calcined oyster shells to create the high calcium lime pointing mortar

Recommendations

seen on the building. The decorative tuck-pointing seen on Nathaniel Russell is a sophisticated treatment for brickwork that evolved in the 17th century in order to emulate fine rubbed and gauged brickwork while using cheaper bricks. Although tuck pointing was a time-consuming and expensive treatment, it was cheaper than building with gauged brick.

Replication Bedding Mortar

The following mix is recommended as a historically appropriate mortar that would replicate the existing historic mortar.

1 part lime putty
1 part of 75% finely crushed oyster shells with 25% well graded fine quartz aggregate

Note: If the lime is treated as the equivalent of a dry hydrate, the estimated binder to aggregate ratios are 1 : 0.5) Slight changes to the ratio may necessary in order to achieve the desired workability.

For increased workability and durability, the following mix is recommended for testing in place of the pure lime-sand-shell mortar. NHL mortars have been proven to be compatible when applied adjacent to sound historic lime mortars. *Portland cement mortars should never be used in contact with historic lime mortars.* While the NHL 2 pointing mortar has a greater compressive strength than the historic lime mortar, the modulus of elasticity and permeability of this restoration mortar is similar to that of the historic mix.

Recommended Potential Replication Pointing Mortar

2 parts NHL 2
1 part finely graded quartz sand (0.8mm to 0.075mm in diamter)

Recommendations for Replication Mortar Materials

2 Parts NHL (St.Astier NHL 2)
Both available at Hughes Lumber, 82 Mary St. Charleston SC (843.577.6671)
1 Part Aggregate
0.25 Sand (0.8mm to 0.075mm in size).
"Masonry Sand" at Palmetto Sand, 556 Wire Road. Dorchester, SC (843-563-5014)
0.75 Parts Crushed Oyster Shell
Finely crushed "Bocci Mix" (Finely Crushed) Available at Carolina Suppliers & Materials, Inc, 2115 Monrovia Street. Charleston SC (843-723-6588)
OR
Mycosupply (http://www.mycosupply.com)

Cured samples should be compared to the original to ensure an aesthetic match. All parts for each specified mortar mix should be mixed by volume and not by weight. Dry ingredients should be well mixed prior to the addition of a water.

Conclusions

Material analysis has indicated the historic bedding mortar dates to the early 19th century and is approximately a 1 part lime to 2 parts aggregate-shell mix. For increased workability, a 1 part NHL 3.5 to 2 parts aggregate is recommended in place of the pure lime-sand-shell mortar. NHL mortars have been proven to be compatible when applied adjacent to sound historic lime mortars. Analysis of the decorative tuck pointing mortar indicates that it is similar to a 1 part lime putty : 1 part crushed oyster shell and fine sand mix. Due to the loss of knowledge over the last 200 years, this mix is often challenge for modern masons. In order to improve the workability and durability of the restoration mortar, it is recommended that a NHL 2 based pointing mortar be tested alongside the lime-shell restoration mix.

Wet-chemical techniques were successful in obtaining a rough estimation of the percentage of lime used in the original mortars and proved useful for determining an appropriate sand for the replication mortar mixes. Petrographic analysis successfully identified the individual mortar components and assisted in determining a relative age for the coating. Further lab analysis is required to determine the exact formulation of the original mortars. X-ray diffractometry (XRD) and atomic absorption spectroscopy are additional analytical technique that can assist in answering very specific questions regarding the mortars' mineral components.

References

ASTM C136-84a *Standard Method for Sieve Analysis of Fine and Coarse Aggregates*

ASTM C144-99 *Standard Specification for Aggregate for Masonry Mortar*

ASTM C856 *Standard Practice for Petrographic Examination of Hardened Concrete*

ASTM C1324 *Standard Test Method for Examination and Analysis of Hardened Masonry Mortar*

Henry, Alison., and Stewart, John. *Mortars, Renders, & Plasters* (Practical Building Conservation). English Heritage, 2012.

Moore, James and Stewart, John. "Chemical Techniques of Historic Mortar Analysis", *Bulletin of the Association of Preservation Technology*. Vol. 14, No. 1. Association for Preservation Technology, 1982. pp 11-16.

Neve, Richard. *The City and Country Purchaser, and Builder's Dictionary, or the Complete Builder's Guide*. London. The Getty Research Institute, 1703.

Poole, Alan and Sims, Ian. *Concrete Petrography: A Handbook of Investigative Techniques*, Second Edition. 2015

Teutonico, Jeanne Marie. *A Laboratory Manual for Architectural Conservators.* Rome: ICCROM, 1988.

APPENDIX

Table 1: Mortar analysis data sheet (NatRus.WBM)

MEADORS CONSERVATION **MORTAR ANALYSIS**				
Project/Site:		Nathaniel Russel House		
Location:	Charleston, SC	Date Sampled:		8/11/2016
		Date Analyzed		8/30/2016
DESCRIPTION OF SAMPLE				
Type/Location:	North Wall Bedding Mortar	Sample:	NatRus.WBM	
Surface Appearance	Sample is biege to tan in hand sample. Sample easily broken by hand and disaggregates. Brick, clay, and shells are present.			
Cross Section:		Petrographic		
Color:	10YR 8/3 Very Pale Brov	Texture:	Sandy	
Hardness:	~3	Gross Wgt		21.6
GRINDING				
Watch glass #1 (g):	62.12	Wg + Sample (g):	83.84	
Wg + Smpl dry (g):	83.84	Beaker:	216.52	
Bkr + Smpl (g):	238.12			
FILTERING				
Filter paper (g):	1.64	Wg #2 (g):	62.12	
Wg + Smpl + fltr dry (g):	65.12	Bkr+ Smpl dry (g):	222.76	
Fines	Color		Dark beige to gray	
	Wgt:		1.36	
	Wgt %:		6.30	
	Organic Matter		N/A	
	Composition		Clays	
Acid Soluble Fraction:	Wgt:		13.18	
	Wgt %:		61.02	
	Desc:		Very effervescent	
	Filtrate Color:		Dark Yellow	
Aggregate	Color			
	Wgt:		7.06	
	Wgt %:		32.69	
	Grain Shape:		subangular to subrounded	
	Mineralogy:		Quartz sand	
	SIEVE ANALYSIS			
	Screen	Mass (g)	% Retained	
	8	1.08		84.70
	16	0.28		80.74
	30	0.24		77.34
	50	0.36		72.24
	100	3.28		25.78
	200	1.68		1.98
	pan	0.08		0.85
ASSESSMENT				
Mortar Type:		Clay Lime Mortar		
Fines:	Clays			
Acid Soluble Fraction:	Lime (Shells)			
Aggregate	Quartz sand and shells			

Table 2: Aggregate sieve analysis raw data (NatRus.WBM)

Sieve Number	Screen Size	M_c (g)	M_2 (sample + cont.) (g)	M_r (M_2 - M_c) (g)	%M_r (M_r / M_s)*100%	%M_{rt} Σ %M_r (on or above)	%M_{pt} 100% - M_{rt}%
8	2360	1.6	2.68	1.08	15.30	15.30	84.70
16	1180	1.58	1.86	0.28	3.97	19.26	80.74
30	595	1.62	1.86	0.24	3.40	22.66	77.34
50	297	1.58	1.94	0.36	5.10	27.76	72.24
100	149	1.5	4.78	3.28	46.46	74.22	25.78
200	74	1.58	3.26	1.68	23.80	98.02	1.98
Pan	70	1.58	1.66	0.08	1.13	99.15	0.85

Table 3: Mortar analysis data sheet (NatRus.PM)

MEADORS CONSERVATION MORTAR ANALYSIS			
Project/Site:		Nathaniel Russel House	
Location:	Charleston, SC	Date Sampled:	8/11/2016
		Date Analyzed	8/30/2016
DESCRIPTION OF SAMPLE			
Type/Location:	Exterior Pointing Mortar	Sample:	NatRus.PM
Surface Appearance	Sample is white to grey in hand sample and is very indurate. A tuck pointed joint profile is visible. Evidence of historic bedding mortar on backside.		
Cross Section:		Petrogrpahic Cross Section	
Color:	10YR 9/1 to 8.5/1 "White"	Texture:	Rough
Hardness:	~5 (mohs)	Gross Wgt	6.76
GRINDING			
Watch glass #1 (g):	62.46	Wg + Sample (g):	69.25
Wg + Smpl dry (g):	69.25	Beaker:	215.5
Bkr + Smpl (g):	222.26		
FILTERING			
Filter paper (g):	1.62	Wg #2 (g):	62.46
Wg + Smpl + fltr dry (g):	64.46	Bkr+ Smpl dry (g):	215.92
Fines	Color		Beige
	Wgt:		0.38
	Wgt %:		5.62
	Organic Matter		Clays/Clinker
	Composition		Clays from Shells
Acid Soluble Fraction:	Wgt:		5.96
	Wgt %:		88.17
	Desc:		Soluble Lime and Shells
	Filtrate Color:		Yellow
Aggregate	Color		
	Wgt:		0.42
	Wgt %:		6.21
	Grain Shape:		Subangular to subrounded
	Mineralogy:		Quartz aggregate with additional shells as aggregate
	SIEVE ANALYSIS		
	Screen	Mass (g)	% Retained
	8	0.02	95.24
	16	0.04	85.71
	30	0.04	76.19
	50	0.08	57.14
	100	0.18	14.29
	200	0.06	0.00
	pan	0	0.00
ASSESSMENT			
Mortar Type:	Finely ground shell and fine sand pointing mortar		
Fines:	Clays		
Acid Soluble Fraction:	Lime and Small Shells		
Aggregate	Shells and Fine Sand		

Table 4: Aggregate sieve analysis raw data (NatRus.PM)

Sieve Number	Screen Size	M_c (g)	M_2 (sample + cont.) (g)	M_r (M_2 - M_c) (g)	$\%M_r$ (M_r / M_s)*100%	$\%M_{rt}$ $\Sigma \%M_r$ (on or above)	$\%M_{pt}$ 100% - M_{rt}%
8	2360	1.6	1.62	0.02	4.76	4.76	95.24
16	1180	1.58	1.62	0.04	9.52	14.29	85.71
30	595	1.58	1.62	0.04	9.52	23.81	76.19
50	297	1.62	1.7	0.08	19.05	42.86	57.14
100	149	1.52	1.7	0.18	42.86	85.71	14.29
200	74	1.58	1.64	0.06	14.29	100.00	0.00
Pan	70	1.58	1.58	0	0.00	100.00	0.00