MORTAR ANALYSES AND REPLICATION RECOMMENDATIONS

Aiken-Rhett House

Charleston, South Carolina

Prepared for:
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INTRODUCTION

At the request of Historic Charleston Foundation, the architectural conservation firm Jablonski Building Conservation, Inc. analyzed one sample of pointing mortar removed from the brick perimeter wall that borders Elizabeth Street at the Aiken-Rhett House located in Charleston, SC. The mortar sample was provided by April Wood at Historic Charleston Foundation.

The analysis, which conformed to standard wet-chemical techniques, was requested to provide the primary characteristics of the existing pointing mortar used on the exterior brick of the structure. This analysis is critical in the formulation of an appropriate replication mix.

METHOD OF ANALYSIS

Portions of the samples were examined under magnification. Using natural daylight, the binder in the sample was matched to a color standard of the Munsell Color Chart (as per ASTM 1535, "Specifying Color by the Munsell System"). The examination also included separating the sample into three components: the acid-soluble fraction, the "fines" (i.e. pigment, clay or cement residue), and the aggregate or sand fraction. Separation was accomplished via wet-chemical techniques. The acid-soluble fraction was removed by digestion with 3M hydrochloric acid. Levigation and filtration were then used to separate the fines from the aggregate (sand). Percent weights were calculated for further assessment. The color of the fines was matched to the Munsell Soil Color Chart. Predominating colors and shapes of sand grains were noted during examination of the aggregate fractions.

RESULTS OF ANALYSIS

Brick Mortar Sample

In cross-section the matrix of the mortar appears to be light yellowish brown (Munsell 2.5Y 6/3) in color. When broken, the mortar sample crumbled. It was moderately easy to further crush the sample with a mortar and pestle. The sample had a number of voids in the surface and contained large chunks of lime blebs, some as large as 5mm. When the sample was taken, oyster shell was reportedly found in the bedding mortar, but oyster shell was not found in the sample of the pointing mortar provided.

Components of Brick Mortar Sample

Acid soluble fraction – 45.53% of the total sample weight. A 3M solution of hydrochloric acid was added to the crushed portion of the sample, which resulted in an extremely vigorous effervescent reaction that produced heat. Numerous additions of hydrochloric acid were required in order to completely digest the sample.

"**Fines**" – 23.99% of the total sample weight. The "fines" are pale yellow (Munsell 2.5Y 7/3) in color and appear to be clay.

Aggregate – 30.48% of the total sample weight. The majority of the individual grains are white (Munsell 10YR 8/1) in color, but there are also light yellowish brown, brown, and black grains present. The aggregate appears to be clear and cloudy quartz. The majority of the particles are sub-angular, with some sub-rounded particles mixed in. The grains range in size from 1/4mm to 3mm.

CONCLUSIONS

The mortar sample was retrieved from a section of the Charleston gray brick perimeter wall that dates to approximately 1838. This date predates hydraulic cement such as Portland cement, and the analysis supports the fact that there is no cement in the mortar; it is instead a clay, lime, and sand mortar. Although the mortar is from a coastal area that could readily obtain oyster shells, there is no conclusive evidence as to whether the lime for the mortar was produced from the burning of oyster shells or from limestone.

The unusually large amount of "fines" could possibly be explained by the sand in the mortar, which would have come from one of the neighboring rivers: the Cooper River or the Wando River. According to James Funk, the clay for the Charleston gray bricks was dredged from the Wando River.[1] It is thus reasonable to assume that the sand, if it were similarly dredged from the Wando River, may be a clayey sand. As it took numerous additions of hydraulic acid and rinsing to release the clay from the aggregate in the sample during mortar analysis, this is a reasonable explanation for the amount of fines in the mortar.

Another possible explanation for the amount of clay in the sample is that, although it was likely added as part of the aggregate, the clay would continue would provide an elastic quality that would be desirable in a high humidity location such as Charleston, South Carolina. And according to Lorraine Schnabel, clay was a material that was common in eighteenth and nineteenth century building construction.[2] The sample analyzed was in a ratio of approximately 2:1:1.25 (Lime:Clay:Sand). However, with the clay included as part of the aggregate, the resulting lime to aggregate ratio of the sample is 1:1¼.

While 1:1¼ is closer to a reasonable lime to aggregate ratio, it is still an unusually large percentage of lime compared to the typical 1:3 ratio used in most replication lime mortars. However, according to master bricklayer Gerard Lynch, "the majority of historic lime mortars are not commonly found to be 1:3 but typically vary between 1:1½ and 1:2."[3] Although originally the lime to sand ratio would have been mixed in a 1:3 ratio, traditional mortars would have used unslaked quicklime. As the quicklime was slaked, its volume would increase anywhere between 60 and 100% of the original volume depending on the lime, changing the resulting ratio of lime to sand.[4]

[1] James Funk, *Three Rivers Form An Ocean...Vignettes of Life in Charleston, SC* (New York: 1st Books Library, 2003), 192, in Google Books, http://books.google.com (accessed October 6, 2009).

[2] Lorraine Schnabel, "Mortar Analysis Part 1: Mortar-Making Materials," *APT Bulletin* 39, no. 1 (2008): 2, in Jstor, http://www.jstor.org/stable/25433935 (accessed September 18, 2009).

[3] Gerard Lynch, "The Myth In the Mix: The 1:3 Ratio of Lime to Sand," *The Building Conservation Directory* (2007), http://www.buildingconservation.com/articles/mythmix/mythmix.htm (accessed October 6, 2009).

[4] Lynch.

REPLICATION RECOMMENDATIONS

Jablonski Building Conservation, Inc. was requested to match the appearance of the mortar with modern materials. The recommendation below represents an effort to approximate the properties of the historic mortar using modern materials. Consideration was given to matching the color, texture, and strength of the sample. The replication mortar was matched to freshly broken samples. The replication mortar was made with materials available in the New York City area. These materials may require substitution for those available in the Charleston, South Carolina area.

As with the pointing of masonry in any historic structure, the original joint profiles for the masonry and joint widths should be documented before joints are raked and replicated during pointing.

According to *Preservation Brief 2: Repointing Mortar Joints in Historic Masonry Buildings*, "new mortar must be as vapor permeable and as soft or softer than the historic mortar."[5] Therefore, it is our recommendation that the mortar mixes for replication of the pointing mortar at the Aiken-Rhett House be:

Type L

ASTM describes Type L as "a straight lime and sand mortar… [with] low compressive strength and high water retentivity. A wall containing such a mortar would have lower strength, particularly early strength, but greater resistance to cracking and rain penetration."[6] *Preservation Brief 2* describes Type L as a minimally durable mortar suitable for use with soft hand-made brick.[7]

Although Type L mortar is rarely used in modern construction, a Type L mortar is what was originally used at this building as it predates the availability of cement in the United States. It is also the most suitable mortar to be used with the Aiken-Rhett Houses's soft, handmade Charleston gray bricks. Due to early firing methods of these bricks, they are much softer than modern bricks and thus can not be pointed with harder mortars that contain cement, because cement mortars do not provide enough flexibility. As the Charleston gray bricks expand and contract with temperature changes, and shift due to winds and vibration, a cement mortar is too inflexible to move with the brick and will instead, cause damage to the brick through cracks and spalls. However a traditional lime/sand Type L mortar provides the necessary expansion and contraction to move with the soft Charleston gray bricks.

Typically, a Type L mortar would be in a 1:3 ratio of lime to sand, but we are recommending the use of a lime to sand ratio of 1:2. As the original mortar had an approximate lime to sand ratio of 1:1¼, the 1:2 ratio will be softer than what was originally there, as recommended in *Preservation Brief 2*, but it will be closer to the hardness of the original mortar than a 1:3 mortar mix.

[5] Robert C. Mack and John P. Speweik, *Preservation Brief 2: Repointing Mortar Joints in Historic Masonry Buildings*, Washington, DC: Technical Preservation Services, National Park Service, U.S. Department of the Interior, NPS website, http://www.nps.gov/history/hps/TPS/briefs/brief02.htm.

[6] ASTM Standard C270, 1997, "Standard Specification for Mortar for Unit Masonry," ASTM International, West Conshohocken, PA, 1997, DOI: 10.1520/C0270-07A, www.astm.org.

[7] Mack, *Preservation Brief 2: Repointing Mortar Joints in Historic Masonry Buildings.*

Because Type L mortar is a straight lime/sand mix, the curing process should be carefully monitored as the extremely porous surface of the Charleston gray brick will absorb the moisture out of the mortar, causing it to cure too quickly and result in chalking, poor adhesion, and poor durability. The process described in *Preservation Brief 2: Repointing Mortar Joints in Historic Masonry Buildings* should be followed to prevent the mortar from failing:

> Periodic wetting of the repointed area after the mortar joints are thumb-print hard and have been finish tooled may significantly accelerate the carbonation process. When feasible, misting using a hand sprayer with a fine nozzle can be simple to do for a day or two after repointing. Local conditions will dictate the frequency of wetting, but initially it may be as often as every hour and gradually reduced to every three or four hours. Walls should be covered with burlap for the first three days after repointing. (Plastic may be used, but it should be tented out and not placed directly against the wall.) This helps keep the walls damp and protects them from direct sunlight. Once carbonation of the lime has begun, it will continue for many years and the lime will gain strength as it reverts back to calcium carbonate within the wall.[8]

All mortar joints should be fully raked to a depth of ¾ inches to 1 inch, and the units should be pointed to the same depth. Below are recommendations for three different mortar options: 1) a mortar mix using Rainbow Dry Colors; 2) a mortar mix using Kremer Pigments; and 3) a custom pre-mix to match the original mortar. The pre-mix mortar utilizes Natural Hydraulic Lime (NHL) 3.5W that conforms to the European Standard EN 459.

Recommended Mortar Mix 1

1 part Virginia Lime Works Natural Hydraulic Lime (NHL) Gray

2 parts aggregate to be composed of:
2 parts Imperia Brothers "Mason's Sand"

1/32 part pigment to be composed of:
1/64 part Raw Sienna Pigment (Rainbow)
1/64 part Burnt Umber Pigment (Rainbow)

NOTE: All parts should be measured by volume (not by weight). Dry ingredients should be well blended before the addition of water. The enclosed sample is made from the above-recommended mixes. Note that the enclosed sample has been etched on one side to simulate the effect that natural weathering (erosion of binder, exposure of aggregate) will have on the appearance of the pointing over the next few years.

[8] Mack, *Preservation Brief 2: Repointing Mortar Joints in Historic Masonry Buildings.*

Recommended Mortar Mix 2

1 part Virginia Lime Works Natural Hydraulic Lime (NHL) Gray

2 parts aggregate to be composed of:
2 parts Imperia Brothers "Mason's Sand"

1/32 part #40320 Dark Ochre, Italian, PY 43 (Kremer)

NOTE: All parts should be measured by volume (not by weight). Dry ingredients should be well blended before the addition of water. The enclosed samples is made from the above-recommended mixes. Note that the enclosed sample has been etched on one side to simulate the effect that natural weathering (erosion of binder, exposure of aggregate) will have on the appearance of the pointing over the next few years.

Recommended Mortar Mix 3: Custom Pre-Mix Mortar
Sand and lime blend only. No cement is allowed.

Virginia Lime Works MG-1069 custom colored Mix&GO 2/1

NOTE: Mix&GO 2/1 is a lime mortar that contains lime (NHL 3.5W), a blend of natural sands, and synthetic iron oxide pigments that have been custom matched to the original mortar. Mix&GO 2/1 is equal to a 1:2 (lime:sand) mortar mix. Only water should be added to the Mix&GO 2/1 pre-mix.

NOTE: The enclosed sample is made from the above-recommended mixes. Note that the enclosed sample has been etched on one side to simulate the effect that natural weathering (erosion of binder, exposure of aggregate) will have on the appearance of the pointing over the next few years.

NOTE: The "MG-1069" number is the number of the custom color that is on file with Virginia Lime Works. This number must be used when ordering.

RECOMMENDED MATERIALS AND SUPPLIERS

As an accurate replication mix is difficult to formulate, the type and quantity of materials used are essential to ensure on-site reproduction. Materials recommended in this report or their equal may be used. If materials are substituted, resulting appearance of mortar may vary. Samples of all the replication materials and components of the original mortar are enclosed for matching to materials available in the Charleston, SC area. Aggregate samples have been enclosed to facilitate substitutions with locally available sands.

Sands Used by JBCI to Replicate Original Aggregate:

Imperia Brothers

"Mason's Sand" – described as a tan mason's sand with particles ranging from fine to coarse.

Available from: Imperia Bros., Inc., 57 Canal Road, Pelham Manor, NY 10803-2792, (914) 738-0900 or substitute equal

Recommended Lime:

Virginia Lime Works

NHL 3.5 Gray – Natural Hydraulic Lime

Available from All South Supply, Inc., 200 Olympic Street, Charlotte, NC 28273, (704) 588-5861.

Recommended Pigments:

Rainbow Dry Colors

"Raw Sienna"

"Burnt Umber"

Available from Empire Blended Products, Inc., 250 Hickory Lane, Bayville, NJ 08721, (732)269-4949 , or substitute equal

Kremer Pigments

"40320 Dark Ochre, Italian, PY 43"

Available from Kremer Pigments, 247 West 29th Street, New York, NY 10001 (800-995-5501), or substitute equal

Recommended Commercial Mortar Mix:

Virginia Lime Works

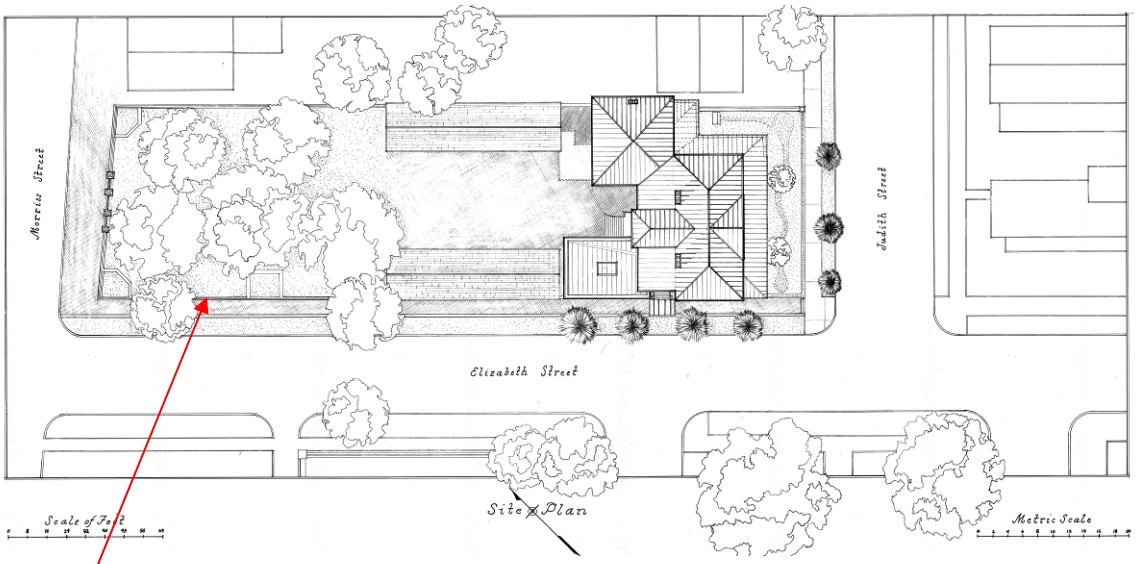
MG-1069 Mix & Go 2/1 – custom colored pre-mix masonry mortar, made with NHL 3.5 White

Available from All South Supply, Inc., 200 Olympic Street, Charlotte, NC 28273, (704) 588-5861.

Appendix A
Mortar Sample Location

Aiken-Rhett House

MORTAR SAMPLE LOCATION



Sample Location[9]

Sample Location[10]

[9] Reginald Lee Gibson, *Site Plan, Robinson-Aiken House*, 1985, Historic American Buildings Survey, The Library of Congress, Washington, D.C., http://memory.loc.gov (accessed September 18, 2009).

[10] *West Courtyard Fence*, Historic American Buildings Survey, The Library of Congress, Washington, D.C., http://memory.loc.gov (accessed September 18, 2009).

Appendix B
Preservation Brief 2

Aiken-Rhett House

2 Preservation Briefs
Technical Preservation Services
National Park Service
U.S. Department of the Interior

Repointing Mortar Joints in Historic Masonry Buildings

Robert C. Mack, FAIA, and John P. Speweik

A NOTE TO OUR USERS: The web versions of the **Preservation Briefs** differ somewhat from the printed versions. Many illustrations are new, captions are simplified, illustrations are typically in color rather than black and white, and some complex charts have been omitted.

Masonry--brick, stone, terra-cotta, and concrete block--is found on nearly every historic building. Structures with all-masonry exteriors come to mind immediately, but most other buildings at least have masonry foundations or chimneys. Although generally considered "permanent," masonry is subject to deterioration, especially at the mortar joints. Repointing, also known simply as "pointing"or--somewhat inaccurately--"tuck pointing"*, is the process of removing deteriorated mortar from the joints of a masonry wall and replacing it with new mortar. Properly done, repointing restores the visual and physical integrity of the masonry. Improperly done, repointing not only detracts from the appearance of the building, but may also cause physical damage to the masonry units themselves.

The purpose of this Brief is to provide general guidance on appropriate materials and methods for repointing historic masonry buildings and it is intended to benefit building owners, architects, and contractors. The Brief should serve as a guide to prepare specifications for repointing historic masonry buildings. It should also help develop sensitivity to the particular needs of historic masonry, and to assist historic building owners in working cooperatively with architects, architectural conservators and historic preservation consultants, and contractors. Although specifically intended for historic buildings, the guidance is appropriate for other masonry buildings as well. This publication updates *Preservation Briefs 2: Repointing Mortar Joints in Historic Brick Buildings* to include all types of historic unit masonry. The scope of the earlier Brief has also been expanded to acknowledge that the many buildings constructed in the first half of the 20th century are now historic and eligible for listing in the National Register of Historic Places, and that they may have been originally constructed with portland cement mortar.

**Tuckpointing technically describes a primarily decorative application of a raised mortar joint or lime putty joint on top of flush mortar joints.*

Historical Background

Mortar consisting primarily of lime and sand has been used as an integral part of masonry structures for thousands of years. Up until about the mid-19th century, lime or quicklime (sometimes called lump lime) was delivered to construction sites, where it had to be slaked, or combined with water. Mixing with water caused it to boil and resulted in a wet lime putty that was left to mature in a pit or wooden box for several weeks, up to a year. Traditional mortar was made from lime putty, or slaked lime, combined with local sand, generally in a ratio of 1 part lime putty to 3 parts sand by volume. Often other ingredients, such as crushed marine shells (another source of lime), brick dust, clay, natural cements, pigments, and even animal hair were also added to mortar, but the basic formulation for lime putty and sand mortar remained unchanged for centuries until the advent of portland cement or its forerunner, Roman cement, a natural, hydraulic cement.

Portland cement was patented in Great Britain in 1824. It was named after the stone from Portland in Dorset which it resembled when hard. This is a fast-curing, hydraulic cement which hardens under water. Portland cement was first manufactured in the United States in 1872, although it was imported before this date. But it was not in common use throughout the country until the early 20th century. Up until the turn of the century portland cement was considered primarily an additive, or "minor ingredient" to help accelerate mortar set time. By the 1930s, however, most masons used a mix of equal parts portland cement and lime putty. Thus, the mortar found in masonry structures built between 1873 and 1930 can range from pure lime and sand mixes to a wide variety of lime, portland cement, and sand combinations.

In the 1930s more new mortar products intended to hasten and simplify masons' work were introduced in the U.S. These included **masonry cement**, a premixed, bagged mortar which is a combination of portland cement and ground limestone, and **hydrated lime**, machine-slaked lime that eliminated the necessity of slaking quicklime into putty at the site.

Identifying the Problem Before Repointing

The decision to repoint is most often related to some obvious sign of deterioration, such as disintegrating mortar, cracks in mortar joints, loose bricks or stones, damp walls, or damaged plasterwork. It is, however, erroneous to assume that repointing alone will solve deficiencies that result from other problems. The root cause of the deterioration--leaking roofs or gutters, differential settlement of the building, capillary action causing rising damp, or extreme weather exposure--should always be dealt with prior to beginning work. Without appropriate repairs to eliminate the source of the problem, mortar deterioration will continue and any repointing will have been a waste of time and money.

Masons practice using lime putty mortar to

Use of Consultants. Because there are so many possible causes for deterioration in historic buildings, it may be desirable to retain a consultant, such as a historic architect or architectural conservator, to analyze the building. In addition to determining the most appropriate solutions to the problems, a consultant can prepare specifications which

reflect the particular requirements of each job and can provide oversight of the work in progress. Referrals to preservation consultants frequently can be obtained from State Historic Preservation Offices, the American Institute for Conservation of Historic and Artistic Works (AIC), the Association for Preservation Technology (APT), and local chapters of the American Institute of Architects (AIA).

repair historic marble. Photo: NPS files.

Finding an Appropriate Mortar Match

Preliminary research is necessary to ensure that the proposed repointing work is both physically and visually appropriate to the building. Analysis of unweathered portions of the historic mortar to which the new mortar will be matched can suggest appropriate mixes for the repointing mortar so that it will not damage the building because it is excessively strong or vapor impermeable. Examination and analysis of the masonry units--brick, stone or terra cotta--and the techniques used in the original construction will assist in maintaining the building's historic appearance. A simple, non- technical, evaluation of the masonry units and mortar can provide information concerning the relative strength and permeability of each--critical factors in selecting the repointing mortar--while a visual analysis of the historic mortar can provide the information necessary for developing the new mortar mix and application techniques.

This late 19th century granite has recently been repointed with the joint profile and mortar color carefully matched to the original. Photo: NPS files.

Although not crucial to a successful repointing project, for projects involving properties of special historic significance, a mortar analysis by a qualified laboratory can be useful by providing information on the original ingredients. However, there are limitations with such an analysis, and replacement mortar specifications should not be based solely on laboratory analysis. Analysis requires interpretation, and there are important factors which affect the condition and performance of the mortar that cannot be established through laboratory analysis. These may include: the original water content, rate of curing, weather conditions during original construction, the method of mixing and placing the mortar, and the cleanliness and condition of the sand. *The most useful information that can come out of laboratory analysis is the identification of sand by gradation and color.* This allows the color and the texture of the mortar to be matched with some accuracy because sand is the largest ingredient by volume.

In creating a repointing mortar that is compatible with the masonry units, the objective is to achieve one that matches the historic mortar as closely as possible, so that the new material can coexist with the old in a sympathetic, supportive and, if necessary, sacrificial capacity. The exact physical and chemical properties of the historic mortar are not of major significance as long as the new mortar conforms to the following criteria:

- The new mortar must match the historic mortar in **color, texture and tooling.** (If a laboratory analysis is undertaken, it may be possible to match the binder components and their proportions with the historic mortar, if those materials are available.)
- The **sand must match the sand** in the historic mortar. (The color and texture of the new mortar will usually fall into place if the sand is matched successfully.)
- The new mortar must have **greater vapor permeability** and be **softer** (measured in compressive strength) than the masonry units.
- The new mortar must be **as vapor permeable** and **as soft or softer** (measured in compressive strength) than the historic mortar. (Softness or hardness is not

necessarily an indication of permeability; old, hard lime mortars can still retain high permeability.)

This mortar is the proper consistency for repointing historic brick. Photo: John P. Speweik.

Mortar Analysis

Methods for analyzing mortars can be divided into two broad categories: **wet chemical** and **instrumental.** Many laboratories that analyze historic mortars use a simple **wet-chemical** method called acid digestion, whereby a sample of the mortar is crushed and then mixed with a dilute acid. The acid dissolves all the carbonate-containing minerals not only in the binder, but also in the aggregate (such as oyster shells, coral sands, or other carbonate-based materials), as well as any other acid-soluble materials. The sand and fine-grained acid-insoluble material is left behind. There are several variations on the simple acid digestion test. One involves collecting the carbon dioxide gas given off as the carbonate is digested by the acid; based on the gas volume the carbnate content of the mortar can be accurately determined (Jedrzejewska, 1960). Simple acid digestion methods are rapid, inexpensive, and easy to perform, but the information they provide about the original composition of a mortar is limited to the color and texture of the sand. The gas collection method provides more information about the binder than a simple acid digestion test.

Instrumental analysis methods that have been used to evaluate mortars include polarized light or thin-section microscopy, scanning electron microscopy, atomic absorption spectroscopy, X-ray diffraction, and differential thermal analysis. All instrumental methods require not only expensive, specialized equipment, but also highly-trained experienced analysts. However, instrumental methods can provide much more information about a mortar. Thin-section microscopy is probably the most commonly used instrumental method. Examination of thin slices of a mortar in transmitted light is often used to supplement acid digestion methods, particularly to look for carbonate-based aggregate. For example, the new ASTM test method, ASTM C 1324-96 "Test Method for Examination and Analysis of Hardened Mortars" which was designed specifically for the analysis of modern lime-cement and masonry cement mortars, combines a complex series of wet chemical analyses with thin-section microscopy.

The drawback of most mortar analysis methods is that mortar samples of known composition have not been analyzed in order to evaluate the method. Historic mortars were not prepared to narrowly defined specifications from materials of uniform quality; they contain a wide array of locally derived materials combined at the discretion of the mason. While a particular method might be able to accurately determine the original proportions of a lime-cement-sand mortar prepared from modern materials, the usefulness of that method for evaluating historic mortars is questionable unless it has been tested against mortars prepared from materials more commonly used in the past. **Lorraine Schnabel.**

Properties of Mortar

Mortars for repointing should be softer or more permeable than the masonry units and no harder or more impermeable than the historic mortar to prevent damage to the masonry units. It is a common error to assume that hardness or high strength is a measure of appropriateness, particularly for lime-based historic mortars. Stresses within

a wall caused by expansion, contraction, moisture migration, or settlement must be accommodated in some manner; in a masonry wall, these stresses should be relieved by the mortar rather than by the masonry units. A mortar that is stronger in compressive strength than the masonry units will not "give," thus causing stresses to be relieved through the masonry units--resulting in permanent damage to the masonry, such as cracking and spalling, that cannot be repaired easily.

This early 19th century building is being repointed with lime mortar. Photo: Travis McDonald.

While stresses can also break the bond between the mortar and the masonry units, permitting water to penetrate the resulting hairline cracks, this is easier to correct in the joint through repointing than if the break occurs in the masonry units.

Permeability, or rate of vapor transmission, is also critical. High lime mortars are more permeable than denser cement mortars. Historically, mortar acted as a bedding material--not unlike an expansion joint--rather than a "glue" for the masonry units, and moisture was able to migrate through the mortar joints rather than the masonry units. When moisture evaporates from the masonry it deposits any soluble salts either on the surface as *efflorescence* or below the surface as *subflorescence.* While salts deposited on the surface of masonry units are usually relatively harmless, salt crystallization within a masonry unit creates pressure that can cause parts ofthe outer surface to spall off or delaminate. If the mortar does not permitmoisture or moisture vapor to migrate out of the wall and evaporate, theresult will be damage to the masonry units.

Components of Mortar

Sand. Sand is the largest component of mortar and the material that gives mortar its distinctive color, texture and cohesiveness. Sand must be free of impurities, such as salts or clay. The three key characteristics of sand are: particle shape, gradation and void ratios.

When viewed under a magnifying glass or low-power microscope, particles of sand generally have either rounded edges, such as found in beach and river sand, or sharp, angular edges, found in crushed or manufactured sand. For repointing mortar, rounded or natural sand is preferred for two reasons. It is usually similar to the sand in the historic mortar and provides a better visual match. It also has better working qualities or plasticity and can thus be forced into the joint more easily, forming a good contact with the remaining historic mortar and the surface of the adjacent masonry units. Although manufactured sand is frequently more readily available, it is usually possible to locate a supply of rounded sand.

The gradation of the sand (particle size distribution) plays a very important role in the durability and cohesive properties of a mortar. Mortar must have a certain percentage of large to small particle sizes in order to deliver the optimum performance. Acceptable guidelines on particle size distribution may be found in ASTM C 144 (American Society for Testing and Materials). However, in actuality, since neither historic nor modern sands are always in compliance with ASTM C 144, matching the same particle appearance and gradation usually requires sieving the sand.

A scoop of sand contains many small voids between the individual grains. A mortar that performs well fills all these small voids with binder (cement/lime combination or mix) in a balanced manner. Well-graded sand generally has a 30 per cent void ratio by volume. Thus, 30 per cent binder by volume generally should be used, unless the historic mortar had a different binder: aggregate ratio. This represents the 1:3 binder to sand ratios

often seen in mortar specifications.

For repointing, sand generally should conform to ASTM C 144 to assure proper gradation and freedom from impurities; some variation may be necessary to match the original size and gradation. Sand color and texture also should match the original as closely as possible to provide the proper color match without other additives.

Lime. Mortar formulations prior to the late-19th century used lime as the primary binding material. Lime is derived from heating limestone at high temperatures which burns off the carbon dioxide, and turns the limestone into quicklime. There are three types of limestone--calcium, magnesium, and dolomitic--differentiated by the different levels of magnesium carbonate they contain which impart specific qualities to mortar. Historically, calcium lime was used for mortar rather than the dolomitic lime (calcium magnesium carbonate) most often used today. But it is also important to keep in mind the fact that the historic limes, and other components of mortar, varied a great deal because they were natural, as opposed to modern lime which is manufactured and, therefore, standardized. Because some of the kinds of lime, as well as other components of mortar, that were used historically are no longer readily available, even when a conscious effort is made to replicate a "historic" mix, this may not be achievable due to the differences between modern and historic materials.

Caulking was inappropriately used here in place of mortar on the top of the wall. As a result, it has not been durable. Photo: NPS files.

Lime, itself, when mixed with water into a paste is very plastic and creamy. It will remain workable and soft indefinitely, if stored in a sealed container. Lime (calcium hydroxide) hardens by carbonation absorbing carbon dioxide primarily from the air, converting itself to calcium carbonate. Once a lime and sand mortar is mixed and placed in a wall, it begins the process of carbonation. If lime mortar is left to dry too rapidly, carbonation of the mortar will be reduced, resulting in poor adhesion and poor durability. In addition, lime mortar is slightly water soluble and thus is able to re-seal any hairline cracks that may develop during the life of the mortar. Lime mortar is soft, porous, and changes little in volume during temperature fluctuations thus making it a good choice for historic buildings. *Because of these qualities, high calcium lime mortar may be considered for many repointing projects, not just those involving historic buildings.*

For repointing, lime should conform to ASTM C 207, Type S, or Type SA, Hydrated Lime for Masonry Purposes. This machine-slaked lime is designed to assure high plasticity and water retention. The use of quicklime which must be slaked and soaked by hand may have advantages over hydrated lime in some restoration projects if time and money allow.

Lime putty. Lime putty is slaked lime that has a putty or paste-like consistency. It should conform to ASTM C 5. Mortar can be mixed using lime putty according to ASTM C 270 property or proportion specification.

Portland cement. More recent, 20th-century mortar has used portland cement as a primary binding material. A straight portland cement and sand mortar is extremely hard, resists the movement of water, shrinks upon setting, and undergoes relatively large thermal movements. When mixed with water, portland cement forms a harsh, stiff paste that is quite unworkable, becoming hard very quickly. (Unlike lime, portland cement will harden regardless of weather conditions and does not require wetting and drying cycles.) Some portland cement assists the workability and plasticity of the mortar without adversely affecting the finished project; it also provides early strength to the mortar and speeds setting. Thus, it may be appropriate to add some portland cement to an essentially lime-based mortar even when repointing relatively soft 18th or 19th

century brick under some circumstances when a slightly harder mortar is required. The more portland cement that is added to a mortar formulation the harder it becomes--and the faster the initial set.

For repointing, portland cement should conform to ASTM C 150. White, non- staining portland cement may provide a better color match for some historic mortars than the more commonly available grey portland cement. But, it should not be assumed, however, that white portland cement is always appropriate for all historic buildings, since the original mortar may have been mixed with grey cement. The cement should not have more than 0.60 per cent alkali to help avoid efflorescence.

Masonry cement. Masonry cement is a preblended mortar mix commonly found at hardware and home repair stores. It is designed to produce mortars with a compressive strength of 750 psi or higher when mixed with sand and water at the job site. It may contain hydrated lime, but it always contains a large amount of portland cement, as well as ground limestone and other workability agents, including air-entraining agents. Because masonry cements are not required to contain hydrated lime, and generally do not contain lime, they produce high strength mortars that can damage historic masonry. *For this reason, they generally are not recommended for use on historic masonry buildings.*

Lime mortar (pre-blended). Hydrated lime mortars, and pre-blended lime putty mortars with or without a matched sand are commercially available. Custom mortars are also available with color. In most instances, pre-blended lime mortars containing sand may not provide an exact match; however, if the project calls for total repointing, a pre-blended lime mortar may be worth considering as long as the mortar is compatible in strength with the masonry. If the project involves only selected, "spot" repointing, then it may be better to carry out a mortar analysis which can provide a custom pre-blended lime mortar with a matching sand. In either case, if a preblended lime mortar is to be used, it should contain Type S or SA hydrated lime conforming to ASTM C 207.

Water. Water should be potable--clean and free from acids, alkalis, or other dissolved organic materials.

Other Components

Historic components. In addition to the color of the sand, the texture of the mortar is of critical importance in duplicating historic mortar. Most mortars dating from the mid-19th century on--with some exceptions--have a fairly homogeneous texture and color. Some earlier mortars are not as uniformly textured and may contain lumps of partially burned lime or "dirty lime", shell (which often provided a source of lime, particularly in coastal areas), natural cements, pieces of clay, lampblack or other pigments, or even animal hair. The visual characteristics of these mortars can be duplicated through the use of similar materials in the repointing mortar.

Replicating such unique or individual mortars will require writing new specifications for each project. If possible, suggested sources for special materials should be included. For example, crushed oyster shells can be obtained in a variety of sizes from poultry supply dealers.

Pigments. Some historic mortars, particularly in the late 19th century, were tinted to match or contrast with the brick or stone. Red pigments, sometimes in the form of brick dust, as well as brown, and black pigments were commonly used. Modern pigments are available which can be added to the mortar at the job site, but they should not exceed 10 per cent by weight of the portland cement in the mix, and carbon black should be limited to 2 per cent. Only synthetic mineral oxides, which are alkali-proof and sun-fast, should be used to prevent bleaching and fading.

Modern components. Admixtures are used to create specific characteristics in mortar, and whether they should be used will depend upon the individual project. *Air entraining agents*, for example, help the mortar to resist freeze-thaw damage in northern climates. *Accelerators* are used to reduce mortar freezing prior to setting while *retarders* help to extend the mortar life in hot climates. Selection of admixtures should be made by the architect or architectural conservator as part of the specifications, not something routinely added by the masons.

Generally, modern chemical additives are unnecessary and may, in fact, have detrimental effects in historic masonry projects. The use of antifreeze compounds is not recommended. They are not very effective with high lime mortars and may introduce salts, which may cause efflorescence later. A better practice is to warm the sand and water, and to protect the completed work from freezing. No definitive study has determined whether air-entraining additives should be used to resist frost action and enhance plasticity, but in areas of extreme exposure requiring high-strength mortars with lower permeability, air-entrainment of 10-16 percent may be desirable (see formula for "severe weather exposure" in **Mortar Type and Mix**). Bonding agents are not a substitute for proper joint preparation, and they should generally be avoided. If the joint is properly prepared, there will be a good bond between the new mortar and the adjacent surfaces. In addition, a bonding agent is difficult to remove if smeared on a masonry surface.

Mortar Type and Mix

Mortars for repointing projects, especially those involving historic buildings, typically are custom mixed in order to ensure the proper physical and visual qualities. These materials can be combined in varying proportions to create a mortar with the desired performance and durability. The actual specification of a particular mortar type should take into consideration all of the factors affecting the life of the building including: current site conditions, present condition of the masonry, function of the new mortar, degree of weather exposure, and skill of the mason. Thus, no two repointing projects are exactly the same. Modern materials specified for use in repointing mortar should conform to specifications of the American Society for Testing and Materials (ASTM) or comparable federal specifications, and the resulting mortar should conform to ASTM C 270, Mortar for Unit Masonry.

Here, a hammer and chisel are being correctly used to prepare a joint for repointing. Photo: John P. Speweik.

Specifying the proportions for the repointing mortar for a specific job is not as difficult as it might seem. Five mortar types, each with a corresponding recommended mix, have been established by ASTM to distinguish high strength mortar from soft flexible mortars. The ASTM designated them in decreasing order of approximate general strength as Type M (2,500 psi), Type S (1,800 psi), Type N (750 psi), Type O (350 psi) and Type K (75 psi). (The letters identifying the types are from the words MASON WORK using every other letter.) Type K has the highest lime content of the mixes that contain portland cement, although it is seldom used today, except for some historic preservation projects. The designation "L" in the accompanying chart identifies a straight lime and sand mix. Specifying the appropriate ASTM mortar by proportion of ingredients, will ensure the desired physical properties. Unless specified otherwise, measurements or proportions for mortar mixes are always given in the following order: cement-lime-sand. Thus, a Type K mix, for example, would be referred to as 1-3-10, or 1 part cement to 3 parts lime to 10 parts sand. Other requirements to create the desired visual qualities should be included in the specifications.

The strength of a mortar can vary. If mixed with higher amounts of portland cement, a harder mortar is obtained. The more lime that is added, the softer and more plastic the

mortar becomes, increasing its workability. A mortar strong in compressive strength might be desirable for a hard stone (such as granite) pier holding up a bridge deck, whereas a softer, more permeable lime mortar would be preferable for a historic wall of soft brick. Masonry deterioration caused by salt deposition results when the mortar is less permeable than the masonry unit. A strong mortar is still more permeable than hard, dense stone. However, in a wall constructed of soft bricks where the masonry unit itself has a relatively high permeability or vapor transmission rate, a soft, high lime mortar is necessary to retain sufficient permeability.

Budgeting and Scheduling

Repointing is both expensive and time consuming due to the extent of handwork and special materials required. It is preferable to repoint only those areas that require work rather than an entire wall, as is often specified. But, if 25 to 50 per cent or more of a wall needs to be repointed, repointing the entire wall may be more cost effective than spot repointing. Total repointing may also be more sensible when access is difficult, requiring the erection of expensive scaffolding (unless the majority of the mortar is sound and unlikely to require replacement in the foreseeable future). Each project requires judgement based on a variety of factors. Recognizing this at the outset will help to prevent many jobs from becoming prohibitively expensive.

When repairing this stone wall, the mason matched the raised profile of the original tuckpointing. Photo: NPS files.

In scheduling, seasonal aspects need to be considered first. Generally speaking, wall temperatures between 40 and 95 degrees F (8 and 38 degrees C) will prevent freezing or excessive evaporation of the water in the mortar. Ideally, repointing should be done in shade, away from strong sunlight in order to slow the drying process, especially during hot weather. If necessary, shade can be provided for large-scale projects with appropriate modifications to scaffolding.

The relationship of repointing to other work proposed on the building must also be recognized. For example, if paint removal or cleaning is anticipated, and if the mortar joints are basically sound and need only selective repointing, it is generally better to postpone repointing until after completion of these activities. However, if the mortar has eroded badly, allowing moisture to penetrate deeply into the wall, repointing should be accomplished before cleaning. Related work, such as structural or roof repairs, should be scheduled so that they do not interfere with repointing and so that all work can take maximum advantage of erected scaffolding.

Building managers also must recognize the difficulties that a repointing project can create. The process is time consuming, and scaffolding may need to remain in place for an extended period of time. The joint preparation process can be quite noisy and can generate large quantities of dust which must be controlled, especially at air intakes to protect human health, and also where it might damage operating machinery. Entrances may be blocked from time to time making access difficult for both building tenants and visitors. Clearly, building managers will need to coordinate the repointing work with other events at the site.

A mechanical grinder

Contractor Selection

The ideal way to select a contractor is to ask knowledgeable owners of recently repointed historic buildings for recommendations. Qualified contractors then can provide lists of

improperly used to cut out the horizontal joint and incompatible repointing have seriously damaged the 19th century brick. Photo: NPS files.

other repointing projects for inspection. More commonly, however, the contractor for a repointing project is selected through a competitive bidding process over which the client or consultant has only limited control. In this situation it is important to ensure that the specifications stipulate that masons must have a minimum of five years' experience with repointing historic masonry buildings to be eligible to bid on the project. Contracts are awarded to the lowest responsible bidder, and bidders who have performed poorly on other projects usually can be eliminated from consideration on this basis, even if they have the lowest prices.

The contract documents should call for unit prices as well as a base bid. Unit pricing forces the contractor to determine in advance what the cost addition or reduction will be for work which varies from the scope of the base bid. If, for example, the contractor has fifty linear feet less of stone repointing than indicated on the contract documents but thirty linear feet more of brick repointing, it will be easy to determine the final price for the work. Note that each type of work--brick repointing, stone repointing, or similar items--will have its own unit price. The unit price also should reflect quantities; one linear foot of pointing in five different spots will be more expensive than five contiguous linear feet.

Execution of the Work

Test Panels. These panels are prepared by the contractor using the same techniques that will be used on the remainder of the project. Several panel locations--preferably not on the front or other highly visible location of the building--may be necessary to include all types of masonry, joint styles, mortar colors, and other problems likely to be encountered on the job. If cleaning tests, for example, are also to be undertaken, they should be carried out in the same location. Usually a 3 foot by 3 foot area is sufficient for brickwork, while a somewhat larger area may be required for stonework. These panels establish an acceptable standard of work and serve as a benchmark for evaluating and accepting subsequent work on the building.

Unskilled repointing has negatively impacted the character of this late-19th century building. Photo: NPS files.

Joint Preparation. Old mortar should be removed to a minimum depth of 2 to 2-1/2 times the width of the joint to ensure an adequate bond and to prevent mortar "popouts." For most brick joints, this will require removal of the mortar to a depth of approximately ½ to 1 inch; for stone masonry with wide joints, mortar may need to be removed to a depth of several inches. Any loose or disintegrated mortar beyond this minimum depth also should be removed.

Although some damage may be inevitable, careful joint preparation can help limit damage to masonry units. The traditional manner of removing old mortar is through the use of hand chisels and mash hammers. Though labor-intensive, in most instances this method poses the least threat for damage to historic masonry units and produces the best final product.

The most common method of removing mortar, however, is through the use of power saws or grinders. The use of power tools by unskilled masons can be disastrous for historic masonry, particularly soft brick. Using power saws on walls with thin joints, such as most brick walls, almost always will result in damage to the masonry units by breaking the edges and by overcutting on the head, or vertical joints.

However, small pneumatically-powered chisels generally can be used safely and effectively to remove mortar on historic buildings as long as the masons maintain appropriate control over the equipment. Under certain circumstances, thin diamond-

bladed grinders may be used to cut out *horizontal* joints only on hard portland cement mortar common to most early-20th century masonry buildings. Usually, automatic tools most successfully remove old mortar without damaging the masonry units when they are used in combination with hand tools in preparation for repointing. Where horizontal joints are uniform and fairly wide, it may be possible to use a power masonry saw to assist the removal of mortar, such as by cutting along the middle of the joint; final mortar removal from the sides of the joints still should be done with a hand chisel and hammer. Caulking cutters with diamond blades can sometimes be used successfully to cut out joints without damaging the masonry. Caulking cutters are slow; they do not rotate, but vibrate at very high speeds, thus minimizing the possibility of damage to masonry units. Although mechanical tools may be safely used in limited circumstances to cut out horizontal joints in preparation for repointing, they should never be used on vertical joints because of the danger of slipping and cutting into the brick above or below the vertical joint. Using power tools to remove mortar without damaging the surrounding masonry units also necessitates highly skilled masons experienced in working on historic masonry buildings. Contractors should demonstrate proficiency with power tools before their use is approved.

Using any of these power tools may also be more acceptable on hard stone, such as quartzite or granite, than on terra cotta with its glass-like glaze, or on soft brick or stone. The test panel should determine the acceptability of power tools. If power tools are to be permitted, the contractor should establish a quality control program to account for worker fatigue and similar variables.

Mortar should be removed cleanly from the masonry units, leaving square corners at the back of the cut. Before filling, the joints should be rinsed with a jet of water to remove all loose particles and dust. At the time of filling, the joints should be damp, but with no standing water present. For masonry walls--limestone, sandstone and common brick--that are extremely absorbent, it is recommended that a continual mist of water be applied for a few hours before repointing begins.

Mortar Preparation. Mortar components should be measured and mixed carefully to assure the uniformity of visual and physical characteristics. Dry ingredients are measured by volume and thoroughly mixed before the addition of any water. Sand must be added in a damp, loose condition to avoid over sanding. Repointing mortar is typically pre-hydrated by adding water so it will just hold together, thus allowing it to stand for a period of time before the final water is added. Half the water should be added, followed by mixing for approximately 5 minutes. The remaining water should then be added in small portions until a mortar of the desired consistency is reached. The total volume of water necessary may vary from batch to batch, depending on weather conditions. It is important to keep the water to a minimum for two reasons: first, a drier mortar is cleaner to work with, and it can be compacted tightly into the joints; second, with no excess water to evaporate, the mortar cures without shrinkage cracks. Mortar should be used within approximately 30 minutes of final mixing, and "retempering," or adding more water, should not be permitted.

Using Lime Putty to Make Mortar. Mortar made with lime putty and sand, sometimes referred to as roughage or course stuff, should be measured by volume, and may require slightly different proportions from those used with hydrated lime. No additional water is usually needed to achieve a workable consistency because enough water is already contained in the putty. Sand is proportioned first, followed by the lime putty, then mixed for five minutes or until all the sand is thoroughly coated with the lime putty. But mixing, in the familiar sense of turning over with a hoe, sometimes may not be sufficient if the best possible performance is to be obtained from a lime putty mortar. Although the old practice of chopping, beating and ramming the mortar has largely been forgotten, recent field work has confirmed that lime putty and sand rammed and beaten with a wooden mallet or ax handle, interspersed by chopping with a hoe, can significantly improve workability and performance. The intensity of this action increases the overall lime/sand contact and removes any surplus water by compacting the other ingredients. It may also be advantageous for larger projects to use a mortar pan mill for

mixing. Mortar pan mills which have a long tradition in Europe produce a superior lime putty mortar not attainable with today's modern paddle and drum type mixers.

For larger repointing projects the lime putty and sand can be mixed together ahead of time and stored indefinitely, on or off site, which eliminates the need for piles of sand on the job site. This mixture, which resembles damp brown sugar, must be protected from the air in sealed containers with a wet piece of burlap over the top or sealed in a large plastic bag to prevent evaporation and premature carbonation. The lime putty and sand mixture can be recombined into a workable plastic state months later with no additional water.

If portland cement is specified in a lime putty and sand mortar--Type O (1:2:9) or Type K (1:3:11)--the portland cement should first be mixed into a slurry paste before adding it to the lime putty and sand. Not only will this ensure that the portland cement is evenly distributed throughout the mixture, but if dry portland cement is added to wet ingredients it tends to "ball up," jeopardizing dispersion. (Usually water must be added to the lime putty and sand anyway once the portland cement is introduced.) Any color pigments should be added at this stage and mixed for a full five minutes. The mortar should be used within 30 minutes to 1½ hours and it should not be retempered. Once portland cement has been added the mortar can no longer be stored.

Filling the Joint. Where existing mortar has been removed to a depth of greater than 1 inch, these deeper areas should be filled first, compacting the new mortar in several layers. The back of the entire joint should be filled successively by applying approximately 1/4 inch of mortar, packing it well into the back corners. This application may extend along the wall for several feet. As soon as the mortar has reached thumb-print hardness, another 1/4 inch layer of mortar--approximately the same thickness--may be applied. Several layers will be needed to fill the joint flush with the outer surface of the masonry. It is important to allow each layer time to harden before the next layer is applied; most of the mortar shrinkage occurs during the hardening process and layering thus minimizes overall shrinkage.

When the final layer of mortar is thumb-print hard, the joint should be tooled to match the historic joint. Proper timing of the tooling is important for uniform color and appearance. If tooled when too soft, the color will be lighter than expected, and hairline cracks may occur; if tooled when too hard, there may be dark streaks called "tool burning," and good closure of the mortar against the masonry units will not be achieved.

If the old bricks or stones have worn, rounded edges, it is best to recess the final mortar slightly from the face of the masonry. This treatment will help avoid a joint which is visually wider than the actual joint; it also will avoid creation of a large, thin featheredge which is easily damaged, thus admitting water. After tooling, excess mortar can be removed from the edge of the joint by brushing with a natural bristle or nylon brush. Metal bristle brushes should never be used on historic masonry.

Curing Conditions. The preliminary hardening of high-lime content mortars--those mortars that contain more lime by volume than portland cement, i.e., Type O (1:2:9), Type K (1:3:11), and straight lime/sand, Type "L" (0:1:3)--takes place fairly rapidly as water in the mix is lost to the porous surface of the masonry and through evaporation. A high lime mortar (especially Type "L") left to dry out too rapidly can result in chalking, poor adhesion, and poor durability. Periodic wetting of the repointed area after the mortar joints are thumb-print hard and have been finish tooled may significantly accelerate the carbonation process. When feasible, misting using a hand sprayer with a fine nozzle can be simple to do for a day or two after repointing. Local conditions will dictate the frequency of wetting, but initially it may be as often as every hour and gradually reduced to every three or four hours. Walls should be covered with burlap for the first three days after repointing. (Plastic may be used, but it should be tented out and not placed directly against the wall.) This helps keep the walls damp and protects them from direct sunlight. Once carbonation of the lime has begun, it will continue for many years and the lime will gain strength as it reverts back to calcium carbonate

within the wall.

This 18th century pediment and surrounding wall exhibit distinctively different mortar joints. Photo: NPS files.

***Aging* the Mortar.** Even with the best efforts at matching the existing mortar color, texture, and materials, there will usually be a visible difference between the old and new work, partly because the new mortar has been matched to the unweathered portions of the historic mortar. Another reason for a slight mismatch may be that the sand is more exposed in old mortar due to the slight erosion of the lime or cement. Although spot repointing is generally preferable and some color difference should be acceptable, if the difference between old and new mortar is too extreme, it may be advisable in some instances to repoint an entire area of a wall, or an entire feature such as a bay, to minimize the difference between the old and the new mortar. If the mortars have been properly matched, usually the best way to deal with surface color differences is to let the mortars age naturally. Other treatments to overcome these differences, including cleaning the non-repointed areas or staining the new mortar, should be carefully tested prior to implementation.

Staining the new mortar to achieve a better color match is generally not recommended, but it may be appropriate in some instances. Although staining may provide an initial match, the old and new mortars may weather at different rates, leading to visual differences after a few seasons. In addition, the mixtures used to stain the mortar may be harmful to the masonry; for example, they may introduce salts into the masonry which can lead to efflorescence.

Cleaning the Repointed Masonry. If repointing work is carefully executed, there will be little need for cleaning other than to remove the small amount of mortar from the edge of the joint following tooling. This can be done with a stiff natural bristle or nylon brush after the mortar has dried, but before it is initially set (1-2 hours). Mortar that has hardened can usually be removed with a wooden paddle or, if necessary, a chisel.

Further cleaning is best accomplished with plain water and natural bristle or nylon brushes. If chemicals must be used, they should be selected with extreme caution. Improper cleaning can lead to deterioration of the masonry units, deterioration of the mortar, mortar smear, and efflorescence. New mortar joints are especially susceptible to damage because they do not become fully cured for several months. Chemical cleaners, particularly acids, should never be used on dry masonry. The masonry should always be completely soaked once with water before chemicals are applied. After cleaning, the walls should be flushed again with plain water to remove all traces of the chemicals.

Several precautions should be taken if a freshly repointed masonry wall is to be cleaned. First, the mortar should be fully hardened before cleaning. Thirty days is usually sufficient, depending on weather and exposure; as mentioned previously, the mortar will continue to cure even after it has hardened. Test panels should be prepared to evaluate the effects of different cleaning methods. Generally, on newly repointed masonry walls, only very low pressure (100 psi) water washing supplemented by stiff natural bristle or nylon brushes should be used, except on glazed or polished surfaces, where only soft cloths should be used.**

New construction "bloom" or efflorescence occasionally appears within the first few months of repointing and usually disappears through the normal process of weathering. If the efflorescence is not removed by natural processes, the safest way to remove it is by dry brushing with stiff natural or nylon bristle brushes followed by wet brushing. Hydrochloric (muriatic) acid, is generally ineffective, and it should not be used to remove efflorescence. It may liberate additional salts, which, in turn, can lead to more efflorescence.

Surface Grouting is sometimes suggested as an alternative to repointing brick buildings, in particular. This process involves the application of a thin coat of cement-based grout to the mortar joints and the mortar/brick interface. To be effective, the grout must extend slightly onto the face of the masonry units, thus widening the joint visually. The change in the joint appearance can alter the historic character of the structure to an unacceptable degree. In addition, although masking of the bricks is intended to keep the grout off the remainder of the face of the bricks, some level of residue, called "veiling," will inevitably remain. Surface grouting cannot substitute for the more extensive work of repointing, and it is not a recommended treatment for historic masonry.

***Additional information on masonry cleaning is presented in Preservation Briefs 1: Assessing Cleaning and Water-Repellent Treatments for Historic Masonry Buildings, Robert C. Mack, FAIA, and Anne Grimmer, Washington, D.C.: Technical Preservation Services, National Park Service, U.S. Department of the Interior, 2000; and Keeping it Clean: Removing Exterior Dirt, Paint, Stains & Graffiti from Historic Masonry Buildings, Anne E. Grimmer, Washington, D.C.: Technical Preservation Services, National Park Service, U.S. Department of the Interior, 1988.*

Visually Examining the Mortar and the Masonry Units

A simple *in situ* comparison will help determine the hardness and condition of the mortar and the masonry units. Begin by scraping the mortar with a screwdriver, and gradually tapping harder with a cold chisel and mason's hammer. Masonry units can be tested in the same way beginning, even more gently, by scraping with a fingernail. This relative analysis which is derived from the 10-point hardness scale used to describe minerals, provides a good starting point for selection of an appropriate mortar. It is described more fully in "The Russack System for Brick & Mortar Description" referenced in **Selected Reading** at the end of this Brief.

Mortar samples should be chosen carefully, and picked from a variety of locations on the building to find unweathered mortar, if possible. Portions of the building may have been repointed in the past while other areas may be subject to conditions causing unusual deterioration. There may be several colors of mortar dating from different construction periods or sand used from different sources during the initial construction. Any of these situations can give false readings to the visual or physical characteristics required for the new mortar. Variations should be noted which may require developing more than one mix.

1) Remove with a chisel and hammer three or four unweathered samples of the mortar to be matched from several locations on the building. (Set the largest sample aside--this will be used later for comparison with the repointing mortar). Removing a full representation of samples will allow selection of a "mean" or average mortar sample.

2) Mash the remaining samples with a wooden mallet, or hammer if necessary, until they are separated into their constituent parts. There should be a good handful of the material.

3) Examine the powdered portion--the lime and/or cement matrix of the mortar. Most particularly, note the color. There is a tendency to think of historic mortars as having white binders, but grey portland cement was available by the last quarter of the 19th century, and traditional limes were also sometimes grey. Thus, in some instances, the natural color of the historic binder may be grey, rather than white. The mortar may also have been tinted to create a colored mortar, and this color should be identified at this point.

4) Carefully blow away the powdery material (the lime and/or cement matrix which bound the mortar together).

5) With a low power (10 power) magnifying glass, examine the remaining sand and other materials such as lumps of lime or shell.

6) Note and record the wide range of color as well as the varying sizes of the individual grains of sand, impurities, or other materials.

Other Factors to Consider

Color. Regardless of the color of the binder or colored additives, the sand is the primary material that gives mortar its color. A surprising variety of colors of sand may be found in a single sample of historic mortar, and the different sizes of the grains of sand or other materials, such as incompletely ground lime or cement, play an important role in the texture of the repointing mortar. Therefore, when specifying sand for repointing mortar, it may be necessary to obtain sand from several sources and to combine or screen them in order to approximate the range of sand colors and grain sizes in the historic mortar sample.

Pointing Style. Close examination of the historic masonry wall and the techniques used in the original construction will assist in maintaining the visual qualities of the building. Pointing styles and the methods of producing them should be examined. It is important to look at both the horizontal and the vertical joints to determine the order in which they were tooled and whether they were the same style. Some late-19th and early-20th century buildings, for example, have horizontal joints that were raked back while the vertical joints were finished flush and stained to match the bricks, thus creating the illusion of horizontal bands. Pointing styles may also differ from one facade to another; front walls often received greater attention to mortar detailing than side and rear walls. **Tuckpointing** is not true repointing but the application of a raised joint or lime putty joint on top of flush mortar joints. **Penciling** is a purely decorative, painted surface treatment over a mortar joint, often in a contrasting color.

Masonry Units. The masonry units should also be examined so that any replacement units will match the historic masonry. Within a wall there may be a wide range of colors, textures, and sizes, particularly with hand-made brick or rough-cut, locally-quarried stone. Replacement units should blend in with the full range of masonry units rather than a single brick or stone.

Matching Color and Texture of the Repointing Mortar

New mortar should match the unweathered interior portions of the historic mortar. The simplest way to check the match is to make a small sample of the proposed mix and allow it to cure at a temperature of approximately 70 degrees F for about a week, or it can be baked in an oven to speed up the curing; this sample is then broken open and the surface is compared with the surface of the largest "saved" sample of historic mortar.

If a proper color match cannot be achieved through the use of natural sand or colored aggregates like crushed marble or brick dust, it may be necessary to use a modern mortar pigment.

During the early stages of the project, it should be determined how closely the new mortar should match the historic mortar. Will "quite close" be sufficient, or is "exactly" expected? The specifications should state this clearly so that the contractor has a reasonable idea how much time and expense will be required to develop an acceptable match.

The same judgment will be necessary in matching replacement terra cotta, stone or brick. If there is a known source for replacements, this should be included in the specifications. If a source cannot be determined prior to the bidding process, the specifications should include an estimated price for the replacement materials with the

final price based on the actual cost to the contractor.

Mortar Types (Measured by volume)			
Designation	Cement	Hydrated Lime or Lime Putty	Sand
M	1	1/4	3 - 3 3/4
S	1	1/2	4 - 4 1/2
N	1	1	5 - 6
O	1	2	8 - 9
K	1	3	10 - 12
"L"	0	1	2 1/4 - 3

Suggested Mortar Types for Different Exposures			
	Exposure		
Masonry Material	Sheltered	Moderate	Severe
Very durable: granite, hard-cored brick, etc.	O	N	S
Moderately durable: limestone, durable stone, molded brick	K	O	N
Minimally durable: soft hand-made brick	"L"	K	O

Summary

For the Owner/Administrator. The owner or administrator of a historic building should remember that repointing is likely to be a lengthy and expensive process. First, there must be adequate time for evaluation of the building and investigation into the cause of problems. Then, there will be time needed for preparation of the contract documents. The work itself is precise, time-consuming and noisy, and scaffolding may cover the face of the building for some time. Therefore, the owner must carefully plan the work to avoid problems. Schedules for both repointing and other activities will thus require careful coordination to avoid unanticipated conflicts. The owner must avoid the tendency to rush the work or cut corners if the historic building is to retain its visual integrity and the job is to be durable.

For the Architect/Consultant. Because the primary role of the consultant is to ensure the life of the building, a knowledge of historic construction techniques and the special problems found in older buildings is essential. The consultant must assist the owner in planning for logistical problems relating to research and construction. It is the consultant's responsibility to determine the cause of the mortar deterioration and ensure that it is corrected before the masonry is repointed. The consultant must also be prepared to spend more time in project inspections than is customary in modern construction.

For the Masons. Successful repointing depends on the masons themselves. Experienced masons understand the special requirements for work on historic buildings and the added time and expense they require. The entire masonry crew must be willing and able to perform the work in conformance with the specifications, even when the specifications may not be in conformance with standard practice. At the same time, the masons should not hesitate to question the specifications if it appears that the work specified would damage the building.

Conclusion

A good repointing job is meant to last, at least 30 years, and preferably 50- 100 years. Shortcuts and poor craftsmanship result not only in diminishing the historic character of a building, but also in a job that looks bad, and will require future repointing sooner than if the work had been done correctly. The mortar joint in a historic masonry building has often been called a wall's "first line of defense." Good repointing practices guarantee the long life of the mortar joint, the wall, and the historic structure. Although careful maintenance will help preserve the freshly repointed mortar joints, it is important to remember that mortar joints are intended to be sacrificial and will probably require repointing some time in the future. Nevertheless, if the historic mortar joints proved durable for many years, then careful repointing should have an equally long life, ultimately contributing to the preservation of the entire building.

Selected Reading

Ashurst, John & Nicola. *Practical Building Conservation. Vol. 3: Mortars, Plasters and Renders.* New York: Halsted Press, a Division of John Wiley & Sons, Inc., 1988.

Cliver, E. Blaine. "Tests for the Analysis of Mortar Samples." *Bulletin of the Association for Preservation Technology.* Vol. 6, No. 1 (1974), pp. 68-73.

Coney, William B., AIA. *Masonry Repointing of Twentieth-Century Buildings.* Illinois Preservation Series. Number 10. Springfield, IL: Division of Preservation Services, Illinois Historic Preservation Agency, 1989.

Davidson, J.I. "Masonry Mortar." *Canadian Building Digest.* CBD 163. Ottawa, ONT: Division of Building Research, National Research Council of Canada, 1974.

Ferro, Maximillian L., AIA, RIBA. "The Russack System for Brick and Mortar Description: A Field Method for Assessing Masonry Hardness." *Technology and Conservation.* Vol. 5, No. 2 (Summer 1980), pp. 32-35.

Hooker, Kenneth A. "Field Notes on Repointing." *Aberdeen's Magazine of Masonry Construction.* Vol. 4, No. 8 (August 1991), pp. 326-328.

Jedrzejewska, H. "Old Mortars in Poland: A New Method of Investigation." Studies in Conservation. Vol. 5, No. 4 (1960), pp. 132-138.

"Lime's Role in Mortar." Aberdeen's Magazine of Masonry Construction. Vol. 9, No. 8 (August 1996), pp. 364-368.

Phillips, Morgan W. "Brief Notes on the Subjects of Analyzing Paints and Mortars and the Recording of Moulding Profiles: The Trouble with Paint and Mortar Analysis." *Bulletin of the Association for Preservation Technology.* Vol. 10, No. 2 (1978), pp. 77-89.

Preparation and Use of Lime Mortars: An Introduction to the Principles of Using Lime Mortars. Scottish Lime Centre for Historic Scotland. Edinburgh: Historic Scotland, 1995.

Schierhorn, Carolyn. "Ensuring Mortar Color Consistency." *Aberdeen's Magazine of Masonry Construction.* Vol. 9, No. 1 (January 1996), pp. 33-35.

"Should Air-Entrained Mortars Be Used?" *Aberdeen's Magazine of Masonry Construction.* Vol. 7, No. 9 (September 1994), pp. 419-422.

Sickels-Taves, Lauren B. "Creep, Shrinkage, and Mortars in Historic Preservation." *Journal of Testing and Evaluation, JTEVA.* Vol. 23, No. 6 (November 1995), pp. 447-452.

Speweik, John P. *The History of Masonry Mortar in America*, 1720-1995. Arlington, VA: National Lime Association, 1995.

Speweik, John P. "Repointing Right: Why Using Modern Mortar Can Damage a Historic House." *Old-House Journal.* Vol. XXV, No. 4 (July-August 1997), pp. 46-51.

Technical Notes on Brick Construction. Brick Institute of America, Reston, VA.

"Moisture Resistance of Brick Masonry: Maintenance." 7F. February 1986.

"Mortars for Brick Masonry." 8 Revised II. November 1989.

"Standard Specification for Portland Cement-Lime Mortar for Brick Masonry." 8A Revised. September 1988.

"Mortar for Brick Masonry-Selection and Controls." 8B Reissued. September 1988. (July/August 1976).

"Guide Specifications for Brick Masonry, Part V Mortar and Grout." 11E Revised. September 1991.

"Bonds and Patterns in Brickwork." 30 Reissued. September 1988.

Useful Addresses

Brick Institute of America
11490 Commerce Park Drive
Reston, VA 22091

National Lime Association
200 N. Glebe Road, Suite 800
Arlington, VA 22203

Portland Cement Association
5420 Old Orchard Road
Skokie, IL 60077

Acknowledgments

Robert C. Mack, FAIA, is a principal in the firm of MacDonald & Mack, Architects, Ltd., an architectural firm that specializes in historic buildings in Minneapolis, Minnesota. **John P. Speweik, CSI,** Toledo, Ohio, is a 5th-generation stonemason, and principal in U.S. Heritage Group, Inc., Chicago, Illinois, which does custom historic mortar matching. **Anne Grimmer,** Senior Architectural Historian, Heritage Preservation Services Program, National Park Service, was responsible for developing and coordinating the revision of this Preservation Brief, incorporating professional comments, and the technical editing.

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The original version of this brief, *Repointing Mortar Joints in Historic Brick Buildings*, was written by Robert C. Mack in 1976, and was revised and updated in 1980 by Robert C. Mack, de Teel Patterson Tiller, and James S. Askins.

Washington, D.C. October, 1998

Home page logo: Soft mortar for repointing. Photo: John P. Speweik.

This publication has been prepared pursuant to the National Historic Preservation Act of 1966, as amended, which directs the Secretary of the Interior to develop and make available information concerning historic properties. Technical Preservation Services (TPS), Heritage Preservation Services Division, National Park Service prepares standards, guidelines, and other educational materials on responsible historic preservation treatments for a broad public.

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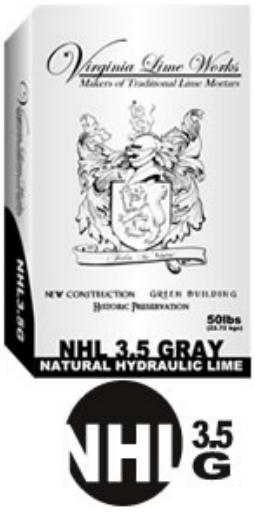
Appendix C
Product Data Sheets

Aiken-Rhett House



NHL 3.5 Gray

Virginia Lime Works NHL 3.5 Gray is a Natural Hydraulic Lime for Historic Preservation, New Construction and Ecologically Friendly Building. Of the four Natural Hydraulic Limes available through Virginia Lime Works NHL 3.5 Gray offers moderate compressive strengths, high vapor permeability, high sulfate resistance, a balance between hydraulic set and carbonation, and a soft gray color.

Where to Use

Perfect for general purpose work, NHL 3.5 Gray can be used in laying, bedding, or repointing brick and stone masonry, external renders/stuccos and internal plasters, grouts, and limewater consolidation.

TECHNICAL INFORMATION

Components

NHL 3.5 Gray is made by burning a unique French limestone that is infiltrated with silica and alumina and conforms to the European Standard EN:459. This product contains no cement, latex, or acrylic admixtures. NHL 3.5 Gray is supplied in 50 lb black/white paper sacks and in pallets of 49 bags.

Compressive Strengths (Approximate Pounds per Square Inch)

NHL 3.5G	7 Days	14 Days	28 Days	56 Days	91 Days	182 Days	365 Days	730 Days
1:1	87.02	253.82	406.11	565.65	659.92	812.21	964.50	1109.54
1:1 ½	72.52	244.81	369.85	514.88	609.16	746.94	877.48	1016.71
1:2	49.31	156.64	263.97	371.30	445.26	552.60	659.92	767.25
1:2 ½	34.81	94.27	168.24	242.21	292.98	366.96	440.91	515.88
1:3	29.01	76.87	145.04	214.66	262.52	330.69	400.30	468.47
1:4	21.76	50.76	79.77	145.04	174.05	224.81	282.82	330.69
1:6	14.50	29.01	50.76	72.52	94.27	145.04	188.55	221.91

Expansion (mm)	0.3	Fineness to 90µ	5.9
Blaine Value (cm^2/g)	10033	Fineness to 200µ	1.0
Bulk Density (kg/dm^3)	0.754	Free Water (%)	0.33
Setting Times (min)	156	Real Density (g/cm^3)	2.60
SO_3 (%)	2.18	Penetration (mm)	14.7
		Free Lime (%)	20.9

Preparation

On the day prior to working control absorption by thoroughly dampening substrate by fine mist spray (depending on conditions this may entail dampening for additional time). Ensure there is no standing water or over-saturation before application. If the substrate is retaining moisture it may be attributed to

various conditions which would need to be corrected before work begins. Issues such as detailing, positive drainage, etc. should be dealt with before any work commences.

Mixing Directions

Mix 1 portion of NHL 3.5G with determined portions of sharp, clean, and well-graded sand and water. Blend thoroughly and add water slowly to achieve a workable mix. Take care when adding water whereas too much water will expand your mix and cause potential problems such as shrinkage cracks and frost damage.

For Mechanical Mixing in a standard paddle mixer: Add lime and water together to make a paste, add sand slowly and then additional water to desired consistency.

Application

Please see individual guidelines available from Virginia Lime Works for your specific application

After-Care

Protect work from drying winds, frost, direct sun, and rain for at least 7 days although some conditions may deem it necessary to cure for longer periods of time. Allow the mortar to cure slowly during this time by protecting with burlap, plastic, and fine mist spray if necessary. If working in freezing conditions, care must be taken that the mortar does not freeze during its curing (which may entail protection for extended periods of time).

Coverages and Consumption (per bag)

Mix Design	Yield (cubic feet)	Bricklaying 4" bed- ⅜" thick	Stonework 4" bed- ⅜" thick	Repointing Brick ½" joint – ¾" thick	Repointing Stone ½" joint – ¾" thick
1 part NHL: 2 parts sand	Approx. 2.4 ft^3	122 brick	148 linear ft	270 ft^2	792 linear ft
1 part NHL: 2.5 parts sand	Approx. 3.0 ft^3	157 brick	185 linear ft	335 ft^2	990 linear ft
Mix Design	**Plaster/Stucco** ¼" thick	**Plaster/Stucco** ⅜" thick	**Plaster/Stucco** ½" thick	**Plaster/Stucco** ¾" thick	**Plaster/Stucco** 1" thick
1 part NHL: 2 parts sand	70 ft^2	56 ft^2	42 ft^2	28 ft^2	14 ft^2
1 part NHL: 2.5 parts sand	90 ft^2	72 ft^2	54 ft^2	36 ft^2	18 ft^2

Clean Up

Ensure that all work is properly protected prior to cleaning. Maintain clean surfaces on the face, sills, ledges, and projections of masonry on a daily basis. Tools can be cleaned using conventional methods and properly protect any unused product from moisture and freezing. Opened bags of NHL3.5G can be stored in sealed pails for up to 6 months from date of purchase.

Protect eyes, nose, and skin. Work in well ventilated areas.

Store unopened containers away from direct sunlight and moisture, between 40°F-85°F. NHL3.5G can be stored for approximately 9 months from date of receipt.

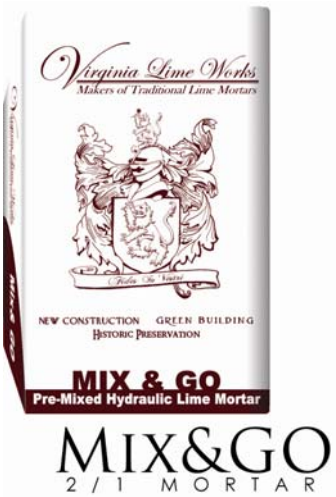
Not for internal consumption. Keep out of the reach of children and animals.

Alternate products

NHL3.5W, Mix&GO Pre-Mixed Natural Hydraulic Lime Products

Additional References

NHL3.5G Material Safety Data Sheet, Guide to Natural Hydraulic Limes.



Mix&GO 2/1 Masonry Mortar

This Mix&GO is the perfect choice when a highly workable, easy to use product is needed, particularly in brickwork. Our Standard Mix&GO 2/1 Mortar is made with NHL 3.5W, however can be made with the Natural Hydraulic Lime of your choice. This durable 100% Natural Mortar product is perfect for almost any masonry application. No sourcing sands, no dealing with color, just add water "Mix&GO". Available Custom Colored and in our range of 40 standard colors.
Mix&GO 2/1 Mortar is MADE IN THE USA.

Where to Use

This Mix&GO is designed to work in the following applications. Laying Brick, Stone, & Masonry Units, Repointing Brick & Stonework. Mix&GO 2/1 Masonry Mortars can be used on interior and exterior masonry.

TECHNICAL INFORMATION

Components

Mix&GO 2/1 is a lime mortar that contains lime, (Natural Hydraulic Lime, conforming to EN:459), a blend of natural sands, and (in colored products), synthetic iron oxide pigments. This product contains no cement, latex, or acrylic admixtures.

Compressive Strengths (Approximate)

Lime	7 Days	14 Days	28 Days	56 Days	91 Days	182 Days	365 Days	730 Days
NHL 3.5	49.31	156.64	263.97	371.30	445.26	552.60	659.92	767.25
NHL 5	14.50	73.97	200.15	326.33	416.26	542.44	670.07	796.25
NHL 2	29.01	36.82	108.78	168.24	210.30	269.77	329.24	388.70

Aggregate Sieve Analysis (Percent Retained)

#2	#4	#8	#16	#25	#50	#100	#200	PAN
0.000	0.000	0.018	4.778	17.825	55.063	19.540	1.700	0.238

Preparation

For Laying or Bedding Masonry: Protect work from harsh direct sunlight, wind and rain, and if necessary freezing temperatures. Protect sills, ledges, windows, doors, and projections from droppings and splatters. Do not use tape or adhesives on any masonry surface. Prevent mortar from staining the face of the masonry and or other surfaces to be left exposed.

For Masonry Repointing: Remove all existing cement mortar by hand. Angle Grinders should not be used at risk of damaging historic masonry. If grinding is deemed necessary only craftspeople demonstrating skill at this task should perform this work. All deteriorated mortar should be raked out to sound mortar, leaving a clean square face at the back of the joint, to which ever depth is greatest (1 inch, 1 ½ times the width of the mortar joints, or until cohesive existing mortar is encountered). Care should be taken not to damage historic masonry surfaces and masonry joints should not be widened. Debris should be removed by hand brushing, vacuuming, or pressurized air. If there is evidence of moisture retention or rising damp it may be necessary to allow the structure to "dry out". If this process is not done, lime leeching may occur, causing failure or the placed mortar and staining of the masonry.

Control Absorption by wetting units or surfaces prior to application. Surfaces and/or units should be cool and damp but not glistening or "holding water" to prevent premature drying of mortar

Mixing Directions

Mix&GO can be mixed either by hand or in a mechanical paddle mixer. Add one bag (65 lbs) of Mix&GO with 1.1 gallons and blend, adding additional water as necessary to achieve workability. Mix for at least 5 minutes. Please note that adding too much water can cause mortar to shrink , crack, and/or change color while curing.

Application

Lay a bed of mortar to sufficiently create full bed (horizontal) joints and "butter" brick ends to form full head (vertical) joints. Do not move or adjust units after the commencement of set, which can cause loss of bond between mortar and masonry units. If adjustments are deemed necessary remove both the masonry unit and the bed, and re-lay using fresh mortar.

For Masonry Repointing: Pack mortar firmly against the previously placed mortar by applying firm pressure to ensure close contact between the two materials. When finishing mortar joints it is often preferable to match the original joint profile.

Reworking: Standard Mix&GO can be reworked for up to 3 hours. If a different Natural Hydraulic Lime is required, reworking times may be different. Please view corresponding Natural Hydraulic Lime Datasheets. If a significant amount of water is need to rework the mortar, the hydraulic set may have started and the material should be discarded.

Curing Time: Mortar work should be protected from sun, wind, and rain for at least 7 days. Mortar work should be protected from freezing temperatures for at least 28 days. In some cases mortar work may need to be protected from freezing temperatures for several months.

Coverages and Consumption (per bag)

Yield (Gallons)	Yield (cubic feet)	Bricklaying 4" bed- ½" thick	Stonework 4" bed- ½" thick	Repointing Brick ½" joint – ¾" thick	Repointing Stone ½" joint – ¾" thick
Approx. 5 gallons	Approx. 0.75 ft^3	30 brick	41.25 linear ft	75 ft^2	220 linear ft

Clean Up

Ensure that all work is properly protected prior to cleaning. Maintain clean surfaces on the face, sills, ledges, and projections of masonry on a daily basis, and with a trowel, strike off minor dabs of adherent mortar from masonry faces. After mortar has achieved thumbprint hardness, lightly brush masonry to remove small mortar burrs from joints and masonry edges. Manual cleaning of masonry can be effective by using water and soft bristled brushes to remove mortar smears. Mortar must be sufficiently cured before light pressurized spray (less than 300 PSI) can be used. Caution should also be exercised due to the fact that over saturation of the masonry could lead to moisture migration. Virginia Lime Works does not recommend cleaning with masonry detergents, however, if such measures deem detergents necessary, contact detergent manufacturer for protocol when cleaning "PURE LIME MORTAR" and test the treatment in small inconspicuous areas to determine its effectiveness and to ensure no damage occurs to the building fabric. Tools can be cleaned using conventional methods and properly protect any unused product from moisture and freezing. Opened bags of Mix&GO can be stored in sealed pails for up to 6 months from date of purchase.

Alternate products

Mix&GO 2.5/1, Natural Hydraulic Lime (to be mixed with sand on-site), Lime Putty Mortar, Hot Lime Mortar.

Additional References

Mix&GO Material Safety Data Sheet, Guide to Traditional Lime Mortar, Guide to Natural Hydraulic Limes, Mortar Classification Chart, Guide to Masonry Repointing.

Appendix D
Material Safety Data Sheets

Aiken-Rhett House

MATERIAL SAFETY DATA SHEET (MSDS)
NATURAL HYDRAULIC LIME (NHL)

Prepared August 31, 2007

Manufacturer:
Virginia Lime Works
P.O. Box 516
Monroe, VA 24574

Emergency Telephone No: 434/929-8113
Information Telephone No: 434/929-8113

SECTION I- PRODUCT IDENTIFICATION

Product Names:
Virginia Lime Works Natural Hydraulic Lime, NHL2, NHL3.5, NHL3.5W, NHL3.5G, NHL5

Also applies to any custom colored material

SECTION II– HAZARDOUS INGREDIENTS/IDENTITY INFORMATION

Components	CAS No.	PEL (OSHA)	TLV (ACGIH)
Hydraulic Calcium Hydroxide (hydraulic hydrated lime)	1305-62-0	15mg/m^3	10mg/m^3

Other substances representing a hazard:
No known substance in this category present.
Substances present at a concentration below the minimum danger threshold:
No known substance in this category present.
Other substances with occupational exposure limits:
No known substance in this category present.

SECTION III- PHYSICAL INFORMATION

Appearance and Odor: White to Gray (depending on product) dry powder. With pigments color will vary; No Odor

Important health, safety and environmental information:

pH of the substance or preparation:	slightly basic.
When a pH measure is possible, it has a value of:	not stated.
Boiling point/boiling range:	not relevant.
Flash point interval:	not relevant.
vapour pressure:	not specified.
Density:	> 1
water solubility:	Dilutable.
Other information:	
melting point/melting range:	not specified.
Self-ignition temperature:	not relevant.
Decomposition point/decomposition range :	not specified.

SECTION IV- FIRE AND EXPLOSION HAZARD DATA

Flammability: Noncombustible and nonexplosive

SECTION V- REACTIVITY DATA

Stability:	Stable
Cautions to avoid:	Hydrofluoric acid dissolves silica to produce the corrosive gas silicon tetrafluoride. Acids react violently to produce heat.
Hazardous polymerization:	Will Not Occur

SECTION VI- HEALTH HAZARD DATA

Route of Entry: Inhalation, Skin, Ingestion

Effects of Overexposure

Inhalation:	Inhalation of the dust may cause coughing, sneezing, irritation and inflammation of the upper respiratory tract. Inhalation of free crystalline silica (SiO_2) may cause silicosis, a dust disease with signs and symptoms of coughing, shortness of breath, wheezing and changes in chest x-ray. Silicosis is typically associated with chronic or long-term exposure to silica; the disease may continue to progress even after exposure is eliminated. Exposure to very high air concentrations of free silica can cause an acute form of silicosis that may occur within one year after exposure begins. This condition may be fatal.
Dermal Exposure:	Not absorbed through the skin. Calcium hydroxide and calcium oxide are caustic and may cause irritation of skin.
Eye Irritation:	May be irritating to the eyes, with burning, itching, or redness.
Carcinogenicity:	The Sixth Annual Report on Carcinogens, 1991, U.S. Department of Health and Human Services, National Toxicology Program states: "There is sufficient evidence of the carcinogenicity of respirable crystalline silica in experimental animals." However, an IARC Working Group has reported limited evidence of carcinogenicity in humans. NIOSH considers respirable silica to be a potential human carcinogen. OSHA and ACGIH have not identified respirable silica as a carcinogen.
Ingestion:	Not considered a likely route of exposure.
Emergency & First Aid:	In case of contact with eyes, immediately flush eyes with large quantities of clean water for at least 15 minutes. Call a physician if irritation persists. Or skin contact, flush with water. If swallowed, do not induce vomiting. If conscious, have victim drink large quantities of water and contact a physician. In the event of exposure by inhalation: In the event of dust formed by mechanical action (sanding, sawing, etc..), this dust may cause irritation by inhalation and contact with eyes. If a large quantity is inhaled, move the patient into the fresh air and keep him/her warm and still. If breathing is irregular or has stopped, effect mouth-to-mouth resuscitation and call a doctor. Do not give the patient anything orally.

SECTION VII- WASTE DISPOSAL & HANDLING

Sweep and place bulk material in containers and remove for disposal or use if not contaminated or wet. Flush spill area with water. This product is not classified as a hazardous waste under RCRA or CERCLA, however it may be a characteristic hazardous waste due to its high pH. The final, cured product is not hazardous. Dispose of in a landfill in accordance with all governmental regulations.

SECTION VIII- PERSONAL PROTECTION

Respiratory Protection:	Special care should be taken to prevent dust from becoming airborne. The use of ventilation systems and wet-methods are recommended. If other methods are not sufficient to reduce the dust concentration below the OSHA permissible exposure lime, use a NIOSH approved respirator with particle filters.
Protective Clothing:	Coveralls and protective gloves are recommended to minimize contact with skin.
Eye Protection:	Safety glasses are recommended to minimize eye contact.

MAKE ALL EMPLOYEES, USERS, AND CUSTOMERS AWARE OF THE HAZARDS ASSOCIATED WITH THIS PRODUCT AND THE REQUIRED OSHA PRECAUTIONS FOR ITS USE

P.O. Box 516
Monroe, VA 24574
www.virginialimeworks.com

434/929-8113
434/929-8114 fax
e-mail: jeff@virginialimeworks.com

MATERIAL SAFETY DATA SHEET (MSDS)
Mix&GO Pre-Mixed Natural Hydraulic Lime Mortar

Prepared August 31, 2007

Manufacturer:
Virginia Lime Works
P.O. Box 516
Monroe, VA 24574

Emergency Telephone No: 434/929-8113
Information Telephone No: 434/929-8113

SECTION I- PRODUCT IDENTIFICATION

Product Types: Virginia Lime Works Natural Hydraulic Lime Pre-Mixed Masonry Products

Product Names:

Virginia Lime Works Mix&GO 2:1 Mortar
Virginia Lime Works Mix&GO 2.5:1 Mortar
Virginia Lime Works Mix&GO 1:1 Mortar (Butterjoint)
Virginia Lime Works Mix&GO BaseCoat
Virginia Lime Works Mix&GO RenderCoat
Virginia Lime Works Mix&GO FinishCoat
Virginia Lime Works Mix&GO FinishCoat Exterior

Also applies to any custom colored or special mixes

SECTION II– HAZARDOUS INGREDIENTS/IDENTITY INFORMATION

Components	CAS No.	PEL (OSHA)	TLV (ACGIH)
Natural Sand* *Composition varies naturally-typically contains quartz (crystalline silica)	None 14808-60-7		
Silica Sand	14808-60-7	10mg/m^3	
Hydraulic Calcium Hydroxide (hydrated hydraulic lime)	1305-62-0	15mg/m^3	10mg/m^3
Calcium Carbonate (calcite)	1317-65-3	15mg/m^3 5mg/m^3*	10mg/m^3 5mg/m^3*
Calcium Oxide (fired limestone)	10034-77-2	5mg/m^3*	2mg/m^3*
Iron Oxide Pigments	01309-37-1	5mg/m^3*	5mg/m^3*

*Respirable fraction

SECTION III- PHYSICAL INFORMATION

Appearance and Odor: White to Gray Powder with coarse particles (sand) in its non-colored state. With pigments color will vary; No Odor

Solubility: Slight

SECTION IV- FIRE AND EXPLOSION HAZARD DATA

Flammability: Noncombustible and nonexplosive

SECTION V- REACTIVITY DATA

Stability:	Stable
Cautions to avoid:	Hydrofluoric acid dissolves silica to produce the corrosive gas silicon tetrafluoride. Acids react violently to produce heat.
Hazardous polymerization:	Will Not Occur

SECTION VI- HEALTH HAZARD DATA

Route of Entry: Inhalation, Skin, Ingestion

Effects of Overexposure

Inhalation:	Inhalation of the dust may cause coughing, sneezing, irritation and inflammation of the upper respiratory tract. Inhalation of free crystalline silica (SiO_2) may cause silicosis, a dust disease with signs and symptoms of coughing, shortness of breath, wheezing and changes in chest x-ray. Silicosis is typically associated with chronic or long-term exposure to silica; the disease may continue to progress even after exposure is eliminated. Exposure to very high air concentrations of free silica can cause an acute form of silicosis that may occur within one year after exposure begins. This condition may be fatal.
Dermal Exposure:	Not absorbed through the skin. Calcium hydroxide and calcium oxide are caustic and may cause irritation of skin.
Eye Irritation:	May be irritating to the eyes, with burning, itching, or redness.
Carcinogenicity:	The Sixth Annual Report on Carcinogens, 1991, U.S. Department of Health and Human Services, National Toxicology Program states: "There is sufficient evidence of the carcinogenicity of respirable crystalline silica in experimental animals." However, an IARC Working Group has reported limited evidence of carcinogenicity in humans. NIOSH considers respirable silica to be a potential human carcinogen. OSHA and ACGIH have not identified respirable silica as a carcinogen.
Ingestion:	Not considered a likely route of exposure.
Emergency & First Aid:	In case of contact with eyes, immediately flush eyes with large quantities of clean water for at least 15 minutes. Call a physician if irritation persists. Or skin contact, flush with water. If swallowed, do not induce vomiting. If conscious, have victim drink large quantities of water and contact a physician.

SECTION VII- WASTE DISPOSAL & HANDLING

Sweep and place bulk material in containers and remove for disposal or usE if not contaminated or wet. Flush spill area with water. This product is not classified as a hazardous waste under RCRA or CERCLA, however it may be a characteristic hazardous waste due to its high pH. The final, cured product is not hazardous. Dispose of in a landfill in accordance with all governmental regulations.

SECTION VIII- PERSONAL PROTECTION

Respiratory Protection:	Special care should be taken to prevent dust from becoming airborne. The use of ventilation systems and wet-methods are recommended. If other methods are not sufficient to reduce the dust concentration below the OSHA permissible exposure lime, use a NIOSH approved respirator with particle filters.
Protective Clothing:	Coveralls and protective gloves are recommended to minimize contact with skin.
Eye Protection:	Safety glasses are recommended to minimize eye contact.

MAKE ALL EMPLOYEES, USERS, AND CUSTOMERS AWARE OF THE HAZARDS ASSOCIATED WITH THIS PRODUCT AND THE REQUIRED OSHA PRECAUTIONS FOR ITS USE

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