THE PRESERVATION OF HISTORIC MASONRY

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Masonry. For millennia, man has taken building units, whether man made (brick) or natural (stone) and has stuck them together using mortar to construct everything from simple dwellings to ornate cathedrals. And for nearly as long, man has preferred maintenance and repaired these buildings for their continued use. The following will delve into the materials used for constructing these buildings, the way these structures were put together, the changing dynamics as they age, what we have done wrong, what we've done right, what we're still learning, and the maintenance and preservation practices that will ensure their longevity.

A BRIEF HISTORY OF MASONRY

The history of masonry begins thousands of years ago when sun baked clay bricks were stacked upon one another using a bed (or cushion) of wet clay to support and level the brick. The earliest of these units, found at Jericho on the banks of the River Jordan, date back to 8300 BC and were no more than rough units of mud that resembled loaves of bread. Over the next 1700 years these units evolved to a more uniform shape, although rudimentary by today's standards.

The first known illustrations of manufacturing brick using a mold (a square handled, open-bottomed instrument in which mud was thrown in) can be found in the tomb of the Egyptian king Rekh-mi-Re from approximately 1450 BC, although it is thought that this technology may pre-date these images by 4000 years. Regardless, the Egyptians took building technologies to new levels, by incorporating these more uniform building unit into the construction of sophisticated arches and vaults, and utilizing building stone for lintels and beams.

Firing mud brick to form stronger more durable materials dates to around 3000 BC, although the manufacturing of pottery can be traced back much further. Although not much is known regarding the lack of evolution between clay firing for pottery and clay firing for building materials, there are few examples of fired construction units in this 4000 year span, with the exception of a fired brick drain in Maddhur (5000BC).

As brick technology progresses so do architectural technologies and the use of various materials to make mortars. The Egyptians employed clay and gypsum mortars (which performed suitably in such arid climates), as well as lime and bituminous mortars. The first known use of lime for building purposes was around 4000 BC when it was used to plaster the pyramids. Both the Greeks and Romans improved on mortar technology, culminating in the addition of pozzolana to form artificially hydraulic mortars and concretes. This pozzolana (a sandy volcanic ash found around Vesuvius and named after the town in which they were commonly found, Pozzuoli), enabled the Romans to advance into the fields of watertight and stronger masonry, with coatings for aqueducts and cisterns, and concretes for roads and architectural uses.

Although architectural design evolves significantly over the next 1000 years, mortar and brick technology does not change significantly until the late Georgian era. Although the introduction of Medieval, Renaissance, and Baroque architecture brings with it new styles and visions, they are primarily building with the same construction technologies (brick, stone, and mortar). Various raw materials were utilized during this time, including hydraulic limestone which yielded hydraulic limes and natural cements. Examples are as the famous 19th Century natural cements from New York; and septarian nodules which yielded the English made Roman cements. In addition, James Frost, a British cement manufacturer pioneered the wet grinding processes that would later be utilized in the manufacture of Portland cement. Two years later, in 1824, a 46 year old English bricklayer by the name of Joseph Aspdin, received British Patent BP5022 entitled “An Improvement in the Mode of Producing an Artificial Stone.” It is in this patent that the term “Portland cement” (so named for its resemblance to the oolitic limestone of Portland, England) is first used and a material is created that will greatly shape the construction of buildings for nearly 200 years.

In 1866 David O. Saylor established the Coplay Cement Company in Pennsylvania to exploit the naturally occurring hydraulic limestone/cement rock that extends from New York to Tennessee. He was granted a US patent 119,413 for the US based manufacture of Portland cement in September of 1871 and by the early 1900’s the production of Portland cement surpasses that of natural cement. The introduction of the long rotary kilns that have become the hallmark of Portland cement construction were invented by none other than Thomas Edison in 1899 in an effort to utilize waste materials from his ore-mining business.

STRUCTURAL PRINCIPLES OF HISTORIC MASONRY

There is one word that can summarize the difference between historic brick and stone masonry and conventional modern brick and stone masonry: thickness. Traditional historic brick and stone masonry were at least eight inches thick, although there are certainly exceptions to the rule, and it is not rare to find historic masonry walls numerous feet thick. With the advent of modern mortars and masonry units, we find brick walls that are far thinner (often only four inches or one brick thick). This thinner approach to masonry, although cost effective, is not without its problems. Moisture migration, which could traditionally be dealt with in thick walls made of brick bedded in a soft and permeable mortar today require drainage mats, weep holes, and cavities. Loads which were distributed throughout the mass of the wall now must be supported by steel shelf angles. Traditional and historic construction is not without limitations, but there is some weight to the argument that “we don’t build them like we used to.”

IDENTIFYING THE PROBLEMS

Time should be taken to evaluate the problems in the historic structure. More importantly, the causes of these problems must be identified in the context of their use.

- An example: A chimney needs to be repointed. Why? Because the mortar is failing. Why is the mortar failing? Because it has more exposure to the elements due to its location and the amount of exposed surface area (exterior, interior, and top faces open). What was the historic context of its use? As a method of venting heated flue gases or smoke from the building interior (boiler, fireplace, stove, furnace) to the exterior of the building. What is the modern context of its use? It is attached to an interior decorative feature that will see rare to occasional use.

- Another example: A cellar wall needs to be repointed. Why? Because the mortar is failing. Why is the mortar failing? Because, below grade, the work is exposed to more retained moisture because of its contact with the ground. Perhaps the grade of the ground has changed and there is no longer positive drainage. What is the historic context of the basement's use? A storage place for food, drink, tools, etc. What is the modern context of its use? A den, rec room, media, room or other livable space (and somebody poured a concrete floor!)

In both of these examples we find an element of a historic structure that is not going to be used in the same way it was used historically. The historic use of the chimney, which many only have one wythe of brick and would be damaged by the elements, ensures that any moisture or exposure is met with a continued temperate area surrounding it. This is due to its constant use for cooking, heating, etc. The modern context provides a much different situation and may need to be addressed. The historic use of the cellar is that of storage, a non-livable space. The adaptation of this space may provide new concerns that will need to be addressed (high humidity) that will not be solved by masonry restoration alone.

Another consideration is realizing that what we examine today is often the result of decades and even centuries of wear and tear, exposure, and deterioration that can be coupled with earlier campaigns of repair and/or restoration.

- An example: An exterior brick wall needs to be repointed. Why? Because the mortar is failing. Why is the mortar failing? Because it is nearly two centuries old. What are we looking at? Soft brick laid with aged and deteriorating lime mortar that has a noticeable red hue on the surface which does not appear to be atmospheric pollution.
- An example: An exterior brick wall needs to be repointed. Why? Because the mortar is failing. Why is the mortar failing? Because it is nearly two centuries old. What are we looking at? Good quality brick laid in a Flemish bond pattern with dark to black glazed "headers", with aged and deteriorating lime mortar that has a noticeable yellow hue on the surface which does not appear to be atmospheric pollution.
- Another example: An exterior stone wall needs to be repointed. Why? Because the mortar is failing. Why is the mortar failing? Because it is nearly two centuries old. What are we looking at? Dark orange interior mortar, light buff exterior mortar and traces of limewash on the stone.

In these examples we find the possibility for the remains of original exterior treatments that may have been used to decorate or protect the masonry. In the first example the reddish hue may be evidence of a colorwash which was traditionally used to “clean” the brickwork by providing a thin but opaque homogenous “stain”. This finish, common in brickwork, would formalize the rough irregular brickwork. This colorwash would provide a degree of watershedding to the masonry, which would be necessary for these soft and permeable brick and mortar and may be coupled with hand painted joints to lend the appearance of mortar joints. In situations where the historic masonry units were of durable quality, as illustrated in the second example, but the mortar may be more susceptible to damage and deterioration the mortar joints may have been “oiled” or brushed with linseed oil, to provide a level of defense to the effects of weather. The third example is a prime illustration of the various levels of protection that we find in masonry. If a source of lime was not readily available, stonework was often bedded in a clay mortar (this practices dates up to the mid 1800s). This mortar, although functionally sound as a bedding material, is not as durable against the elements as a lime mortar. Therefore, what lime was available was utilized as an exterior pointing mortar to provide protection to the clay. Often you see a limewash applied to the stonework to provide an additional level of protection to the masonry.

INVESTIGATION TECHNIQUES

The most basic investigation technique that can be employed to historic structures is a visual inspection. If a wall is retaining moisture and there are no gutters or downspouts, then the source of trouble can be pinpointed. But, what if a wall is retaining moisture and the slope of the ground has changed? What if there is no longer natural positive drainage away from the site or boxwoods that after 200 years of growth tower over the structure, the source of trouble can be easily pinpointed. If a wall is experiencing rising damp and a dense impervious mortar has been used in a later repointing campaign, then the source of trouble can be pinpointed. Never underestimate a visual inspection of the entire structure in establishing a starting point for a restoration or preservation project. There are also other investigations techniques that can be employed to establish information regarding historic construction and its preservation.

- Borescopic Investigation: A borescope is a device consisting of a flexible tube with an eyepiece on one end, a lens on the other and relay in between. This process can be used to see certain areas that might be unaccesible by other means. The tube is inserted into a cavity (where there is loss of mortar) and a visual inspection can take place.
- Infrared Photothermography: Infrared Photothermography is a method of measuring the various levels of infrared radiation from the surface of an object. The result is an image that maps and quantifies thermal differentials. The interpretation of these thermograms can provide insight into anomalies and failures unseen

by the naked eye, such as delamination of render and stucco, voiding or disruption to the interior of masonry walls, moisture, cracking, and more. Due to the wide variety of defects that can be found with Infrared Photothermography, visual inspection and occasionally invasive investigation may be warranted.

- Radar: Radar can be employed as a non-destructive investigation technique that will have minimum to no impact on the historic structure. An electromagnetic pulse is sent through the masonry. As this pulse is reflected back to the receiver, a visual image can be made that may show any anomalies or defects that may warrant further investigation.

MATERIALS ANALYSIS

The most important thing to remember when preparing for a mortar analysis or any type of mortar replication is that the material that is sampled is indicative (and preferably original) of the mortar you want to repair. As simple as this may seem, it is common to see later repointing samples submitted (often Portland cement based) mistaken for original material. Before undertaking a mortar analysis it is helpful to know what results you want to know from the analysis report. Is there a necessity to identify and quantify the components of the original mortar mix design? Is verification needed as to the types of historic materials (such as lime, natural cements, sand) that were employed? If the answer is no, and the only need for the project is a good, durable, and compatible replacement mortar, a mortar analysis may be unnecessary. If the answer is yes, there are options that provide varying degrees of quantitative information depending on the needs of the project.

- Simple Wet Chemical Analysis: This simple and basic method of analysis utilizes diluted acid (often 4 parts of water to 1 part hydrochloric acid) to dissolve any carbonate material from the mortar. The remnants of the sample are then agitated and rinsed providing quantitative information on the aggregates and clay from the sample. Because all carbonate minerals are dissolved, care should be exercised as the results may not allow for any oystershell, limestone aggregate, or other carbonate based materials that may be lost during digestion. The information provided from the simple wet chemical analysis is the sample's approximate original mix design, the color of the aggregates and fines within the sample, and the gradation of the aggregate used.
- Petrography: Petrographic examination offers a highly magnified view of a mortar sample. Often the sample is impregnated with dye, sectioned, and polished to provide a visual image of the makeup of the minerals of the mortar.
- X-Ray Diffraction: When a beam of x-rays under certain controlled conditions scans a crystalline material it produces a diffraction pattern that is characteristic and unique for this

material. In a mixture of crystalline materials, each component generates its characteristic diffraction response and a complex picture may emerge identifying the various mineral components of the mortar.

- Scanning Electron Microscopy: SEM is often utilized for delicate and fragile samples where an in-depth visual examination is necessary.

UNDERSTANDING HISTORIC MORTARS

There are many ways of approaching the preservation of historic masonry. In its most basic form, masonry preservation is extending life or maintaining what you have for the future. This can be achieved by any number of preservation philosophies and mentalities as long as any repointing and repairing of the masonry are done with materials that are compatible. Inappropriate materials or incompatible materials may shorten the life of, or cause irreversible damage to, historic masonry. Compatibility is often achieved by looking at the following criteria:

Vapor permeability and porosity: The vapor permeability and porosity of any replacement material used in conjunction with historic structures is an important consideration. As mentioned previously, the primary difference between historic masonry and conventional masonry is thickness and it is because of this thickness, coupled with the historic materials used in historic construction, that moisture is accommodated. In historic brick masonry, moisture, through direct contact with weather or infiltration from the ground, is absorbed through the brick and migrates out via the path of least resistance (the soft mortar joint). When that vapor permeability is blocked by impervious Ordinary Portland cement (OPC or "Portland cement') based mortars, moisture is retained, rather than evaporating from the mortar joint. This retention can cause the lime in the existing historic mortar to deteriorate, greatly damaging the integrity of the original mortar. Also, moisture retained within the masonry units can potentially freeze and thaw during weather cycles, causing cracking, spalling, and other forms of irreversible damage to the masonry units, and of course, speed up the deterioration of the original mortar.

Flexibility: Historic masonry will move. Whether it is the gradual settling over hundreds of years or the minute expansion and contraction of the masonry going through warming and cooling cycles, historic masonry buildings move. Traditionally this movement was accommodated by a soft bedding mortar (be it lime, hydraulic lime, clay, or natural cement) that provided a cushion for the masonry units. The mortar, be it of high compressive strength or low, could accommodate much of this movement. On the other hand, the use of a rigid Portland cement-based mortar may hamper this accommodation causing failure of the mortar, masonry units, and in many cases, both. When lime or other traditional mortars with a high percentage of free (or soluble) lime were, if the mortar developed small cracks or fissures due to the gradual movement such as settling or thermal expansion and contraction, this free lime works to the materials advantage. As atmospheric moisture enters into the crack, this soluble material goes into solution, and migrates to the crack where it is deposited and sets. This action is often described as the autogeneous or "self" healing property of lime.

Compressive strength: The compressive strength of replacement mortars for historic masonry has been used as a starting point for decades. It is common knowledge that rigid impervious mortars with high compressive strengths can be disastrous for historic masonry. However, the vapor permeability, flexibility, and more importantly durability and resistance to weather are far more valuable benchmarks when dealing with historic masonry. Often in an effort to increase the strength or set of lime mortars a small portion of Portland cement is added to "toughen up the mix". The results of the Smeaton Project (Teutonico, McCaig, Burns, Ashurst, 1993) tell a different story. From their published finding; "The broad objective of the Smeaton Project is to contribute to the understanding of the characteristics and behavior of lime-based mortars for the repair and conservation of historic buildings. This article presents the first phase results of a joint research program of ICCROM, English Heritage, and Bournemouth University". The Smeaton Project set out to test a wide variety of mortars for use in historic preservation. Their conclusions state that: "The addition of small quantities of cement to lime: sand mortars has a negative effect on the strength and durability of the mortars."

Other factors: Other factors such as color, texture, composition should be considered but more as a compliment to those criteria listed above. A wide variety of compressive strengths, rates of elasticity, degrees of vapor permeability, levels of capillarity, resistance to sulfates, and dependence on carbonation versus hydraulicity are available in the traditional mortar materials that were used historically.

HISTORIC MASORNY MORTAR MATERIALS

Overview

In its most basic form mortar, like most compounds, is comprised of two components. The binder (lime, hydraulic lime, or natural cement) is the glue that holds the material together. The aggregates, commonly sand or sand with fines, serve as filler that gives the mortar strength and body.

Aggregates

Sands for traditional mortar should be well graded, sharp, and clean, but it is important to understand WHY well graded sands are best for building and repair work. If sands are comprised of particles that are overwhelmingly coarse or fine they will be less workable and harsher to "the trowel." When this happens, it is common to compensate by adding more water. This can lead to shrinkage, cracking, and potential "bleeding" or staining, particularly in brickwork. A good sand gradient will appear in a bell curve. On the microscopic level, these coarse, medium, and fine particles will form a tighter matrix within each other, which should require a lesser amount of lime in addition to a lesser amount of water. The sharpness of the sand is important too. Imagine the particles of sand as a tiny puzzle and you want to get the grains as close as possible. In rounded sands the particles will not fit together as well as sharper sands. Suitable mortar sand is clean and free of clay and/or silt. Silt or clay in your sand can make your mortar "thirsty." The purpose of adding water to the mortar is to properly hydrate the lime to bring it to a plastic state. If water is being soaked into the particles of clay then there will be a tendency to add water to compensate. This can expand your mix, which can lead to shrinkage cracking. It can also lead to a reduction in compressive and flexural strength which your mortar brittle and friable. It also reduces vapor permeability, which accommodates water vapor in and out of your building. While measuring sand, it is important to have a consistent method of measuring. Ensure that the sand that is being used for mortar or plaster is not too damp or too dry. The difference between wet sand versus dry sand can lead to a margin of error of 40% when measuring by volume. The industry standard is to use a "damp, loose sand" when making mortars. Measuring sand by weight is often the best method; however using gauging buckets are the accepted norm for job site use. These can be common buckets that have been pre-measured for a certain amount, such as a 5 gallon bucket or a pail that has been marked and cut off at, for example, three and a half gallons. Using a "shovelful" as a measuring device should not be used when site mixing traditional mortars.

Binders

There are four principal types of masonry binders that were used historically in pre-Portland Cement mortars: Air (Non-Hydraulic) Limes, Water Limes (Hydraulic) Limes, Clay & Natural Cements. There is no "right binder" that should be considered a cure all for every application. These materials, when used correctly, can be applied to a great many, and in some cases, overwhelming amount of historic projects. However, an understanding of the properties and limitations of each material will help ensure proper matching for the right application. It is important to mention that although there is a host of materials available today for the restoration of historic masonry, during the time of construction, and particularly before the age of transportation, the materials that were often used were what were available locally. The masons and builders of our architectural treasures had the capacity to know their materials and how to make their materials work for the situation in which they found themselves.

Lime: Unarguably the most common binder for mortars in historic masonry over time has been lime. Chemically, lime has been made from calcium carbonate, which can come in many different sources, such as limestone, oystershell, marble, and coral. Limestone can contain minimal to large amounts of magnesium carbonate and those with higher levels are known as "dolomitic" limes. The raw limestone may also be infiltrated with silicates and aluminates which will provide hydraulic qualities to the lime and will be discussed later.

The limestone is placed in a kiln and burned at temperatures (over 1650° F) sufficient to drive off the carbon dioxide and moisture from the stone, producing a material known as quicklime or calcium oxide. The process is known as "calcining," although many refer to it as "lime burning." Many different fuels can be employed for this process. Wood and coal were common traditional fuels that were utilized historically, while many limes are produced by utilizing gas heat. It is common for conventional limes that are utilized for use with Portland cement to make conventional building mortars to be burned at much higher temperatures to help speed up the decomposition of the limestone. However, this solid burned quicklime may have a more formal chemical structure than that of quicklime made by calcining the stone at lower temperatures. It may be slower to hydrate and may cause serious problems, such as delayed hydration and lack of carbonation or setting in some situations. Traditionally, the burning of limestone with wood, which produces slight pressure in the kiln that can be conducive to lime burning, provides sufficient temperatures to calcine the stone while rarely achieving the higher temperatures possible by burning with coal or gas.

Once the quicklime has been taken from the kiln, it must be hydrated or slaked, which is the action of combining moisture with the quicklime. When quicklime and water are combined an exothermic reaction takes place as the quicklime begins to swell and crumble away, producing a calcium hydroxide. If slaking is done with a minimum amount of water (steam or air), the quicklime breaks down to a powder, or a hydrated lime. If slaking is done with an excess of water, the material can be worked down to form milk of lime. This milk of lime, over time, will settle out and lime putty will be formed. Also, when lime is made into lime putty, the material continues to slake, and the particles break down, dissolve, and then precipitate, causing the particle sizes to become finer and richer. Lime putties that are run directly from quicklime are considered better when applications require superior plasticity and carbonation. Also, as it is in a wet state there is a greatly reduced risk of the material carbonating while being stored. It can be argued that if one adds water to hydrated lime it forms lime putty, but this is both true and misleading. Since the material has previously been slaked, as in a “hydrated lime,” when one adds water it forms a lime paste, and although the particles of lime may absorb moisture and fatten, the continual process of dissolution and precipitation does not occur. Basically this is just an extension of hydrated lime, unlike true lime putties that are made by slaking quicklime with an excess of water.

On the same subject of slaking, it should be noted that the Romans had legislation stating that lime used for buildings must be aged for a period of at least three years. It should be noted that this was due to the fact that the lime that they were burning was dolomitic. The magnesium carbonate found in dolomitic limes converts to magnesium oxide at a lower temperature than calcium carbonate converts to calcium oxide; therefore, there was often the possibility that the magnesium oxide was over burnt and would need a longer period to allow for hydration. This is why it was so important to allow the lime as much time as possible to slake. In modern production, dolomitic limes are slaked by an autoclave (under pressure) process, which ensures the proper hydration of magnesium oxide.

Although slaking lime separately from mixing to make lime putty mortar is a process that is much discussed in historic preservation, it is only one way of hydrating lime to make mortar. The “hot mix” method of making lime mortar is a process that appears to have been used predominately for historic building construction. Taking the quicklime (also known as lump lime) fresh from the kiln and adding the sand and lime directly seems to provide a mortar that tends to have more durability than that of “cold mixed” lime putty and sand. Also, the evidence of lime inclusions (small particles of lime distributed throughout the mortar) is indicative of a hot mixed mortar, whereas lime “smears” or “streaks” often can be attributed to improper mixing of lime putty mortars. By using hot lime mortars for construction, the construction process could begin much earlier allowing the masons to get to work immediately while reserving and slaking lime in advance for plasterwork. Due to the potential for “air slaking” which may cause pitting and popping, hot lime mortars should not be used for plasterwork.

After the mortar has been mixed with the prescribed aggregates and water is used in building or repointing, the mortar must set and cure. This process is known as carbonation. As the mortar dries (over the course of a few days to a week) the mortar will set and develop its final color. However, carbonic acid, atmospheric moisture laden with carbon dioxide, is absorbed into the mortar slowly over extended periods of time. This gives the mortar its final set, resulting in a mortar that has in many ways reverted back to its raw state of calcium carbonate. In some instances the mortar may stay wet indefinitely, as was evidenced by the discovery of uncured mortar deep in the walls at the Castillo de San Marcos, in St. Augustine FL, built nearly 400 years ago! These limes are known as air limes or non-hydraulic limes. They depend wholly on the absorption of carbon dioxide in order to set and gain strength. The presence of reactive silicates or aluminates in the raw mineralogy of the limestone will result in the production of a water lime or hydraulic lime.

Hydraulic Limes, by definition, are limes that begin to set or get hard, when they come in contact with water. The European Norm classifies Natural Hydraulic Limes as “limes produced by burning of more or less argillaceous or siliceous limestones with reduction to powder by slaking with or without grinding. All NHL have the property of setting and hardening under water. Atmospheric carbon dioxide contributes to the hardening process.” (EN459.1:2001.3.10.1) Historically hydraulic limes, like most masonry binders, were made on-site by the builders, and previous to more sophisticated industrial processes were commonly used without much fanfare in hot mixes for building construction. However, the exploitation of known sources of this material resulted in hydraulic lime factories springing up throughout the United States after the Civil War. The lime works at Riverton, Virginia in the northern Shenandoah Valley, produced hydraulic limes from the 1860s until their closing in 2000.

Hydraulic Limestone comes from two sources: those with a clay content (argillaceous) or those with a silica content (siliceous). Hydraulic Limes are made in a similar fashion to non-hydraulic limes. The limestone comes from the earth and is fired in a kiln. During this calcining process moisture and carbon dioxide are released from the stone. The stone in the kiln must reach a temperature of 1560°F to convert from limestone to quicklime. During the burning of hydraulic limestone the silicates in the limestone convert from an inert material to reactive form. These are the components that will cause the lime to set when they come in contact with water.

The hydraulic components found in hydraulic limes are known as “belite” or di-calcium silicates. At higher temperatures the reactive silicates would form “alite” or tri-calcium silicates. Tri-calcium silicates are often found in Ordinary Portland Cement (OPC) and are highly reactive, resulting in a material with high compressive strengths and extremely fast sets. The di-calcium silicates that are found in Natural Hydraulic Limes result in a faster early set than that of air limes, moderate to low compressive strengths, and higher flexibility, all of which are important when using as a mortar or plaster in a historic structure.

Slaking (or hydration) is the process of taking the quicklime and adding water to it, to bring it to a usable form for mortars or plasters. The quicklime is taken and moisture is added to it. If a minimum addition of water is added the quicklime will break down and become a hydrate. If an excess of water is added the material will break down into a “lime putty” or paste. When working with hydraulic limes, only a minimum of water can be used because if an excess is used it will trigger the reactive components that were formed during the burning process. This is why hydraulic limes are supplied as a dry powder or “hydrate.”

Natural cement: Natural cements are produced by burning limestone that has such strong hydraulic properties that the hydration of the resulting burnt stone is impossible as there is no “lime” left. This eminently hydraulic limestone was utilized historically from as far north as Connecticut to as far south as North Carolina and Tennessee, and nearly every state in between. The cement stone is quarried where it is burned in a kiln, much like lime, to drive off carbon dioxide and moisture. The resulting calcined stone is then ground to a powder where it is mixed on-site. Natural cement has been utilized in American building construction since the late 18th century with commercialized production beginning in the early to mid-1800s. This cement, not to be confused with artificial cements (such as the modern cement), quickly rose to prominence. Many engineered projects, such as bridges, canals, forts, and railroad tunnels were built of this material. Natural cement production was superseded by the production of Portland Cements at the turn of the 20th century along, with other traditional materials.

Clay: As mentioned in the section regarding masonry’s history, clay has been used for building mortar for the longest period of time; however, as industrial production processes became more common, it was the first to fall from vogue. Clay mortars are primarily found as a bedding material for stone work in colonial masonry in the United States in areas where there were minimal deposits of limestone to exploit or no availability of large quantities of shell. The clay would have been made wet and pliable, and in many cases, mixed with sand. As the mortar was taken to the wall for use, quicklime (calcium oxide, burnt limestone) was added. The presence of quicklime in clay mortars has often been described as that of a stabilizer, but under practical application the addition of quicklime and subsequent heat generation as the lime hydrates provides a drying quality to the mortar, allowing work to proceed at a reasonable pace. Clay mortars on the east coast faded from prominence during the antebellum period as the transport of construction materials became more prevalent. The use of clay mortars and plasters for other applications, such as adobe construction and restoration in the dry arid regions of the American Southwest, has been and remains quite popular.

DEVELOPING A SOLUTION

When dealing with historic masonry preservation there can be so many variables to be taken into consideration that each project may require a different approach. In the example projects from above, many different approaches can be taken without being considered wrong or inappropriate.

Example: An exterior brick wall needs to be repointed. Why? Because the mortar is failing. Why is the mortar failing? Because it is nearly two centuries old. What are we looking at? Soft brick laid with aged and deteriorating lime mortar that has a noticeable red hue on the surface that does not appear to be atmospheric pollution. Upon further analysis, the original mortar seems to be comprised of 2.5 parts river sand and 1 part non-hydraulic high calcium hot lime mortar.

In this case, there is evidence of an applied colorwash, a mixture of pigment, potash alum, glue, and water that was commonly applied to historic masonry. This masonry stain provides a uniform color and a slight degree of water shedding to the wall. In this case there are three options available.

First: Restore the masonry using all traditional materials and techniques. Using a non-hydraulic high calcium hot lime mortar, which may have a high degree of capillarity and a low degree of frost resistance, may be problematic, but the evidence of the colorwash indicates that the original construction details have taken this into consideration and had been dealt with accordingly. Therefore, utilizing a colorwash over any new repointing work will allow the masonry to function properly (or if the structure was limewashed, rendered, or the masonry oiled, recreate the same finishes).

Second: Restore the masonry using compatible materials that accommodate various situations that may currently be evident. Perhaps the appearance of colorwash is not desired on the project. Perhaps the appearance of the original construction details is not evident in the period of significance to which the structure is being restored. Perhaps the owner has a personal preference. In many cases, the incorporation of compatible materials with proven performance characteristics is suitable. In this case, the utilization of a hydraulic lime without colorwash may be an appropriate approach.

Third: Restore the masonry using traditional materials in effort to promote extended use. This approach, although commonly used, may be problematic. In this case, the soft and porous non-hydraulic high calcium hot lime mortar was designed to work in conjunction with the exterior colorwash for many years after the mortar’s placement. Ignoring this fact and proceeding with a partial approach to the detailing may mean a greatly decreased life cycle of the mortar or possible failure and loss of work.

Before any work commences, it is recommended to take your time and look at your project. Issues such as positive drainage, faulty gutters, or failing roof systems must be addressed. If these issues are not addressed, repointing may do little if anything to help your project, causing a waste of time, energy, and money.

PREPARATION & EXECUTION

Examine and identify areas needing to be repointed. It is important to remember that the removal of sound original mortar and the loss of this historic fabric are irreversible. Only failing or deteriorating mortar should be removed. The argument "this mortar is too old" is never valid unless mortar failure is occurring. Occasionally and only when large areas of repointing are required or other extenuating circumstances are present, should the cutting out and replacing of good quality historic material be exercised.

Temperature & Climate

Traditionally historic buildings were constructed during the traditional building season (from mid-Spring to early Autumn), as the slower set and curing of traditional mortars made year round construction nearly impossible. Whilst restoring historic masonry and utilizing traditional materials available, working time may be limited to this same time frame. As a general rule it is best to limit work on historic masonry to when the temperature is between 40 and 95 degrees Fahrenheit, both during the application and for at least several days and potentially even weeks after work is completed. As a good rule of thumb, if the mason is comfortable then the wall is comfortable. On hot days where accelerated drying may be an issue make sure the wall is well protected by shade cloths, or tarps, keeping attention to the absorption rate of the substrate. Mist as necessary to slow the drying for the first day or so but still allow the material to slowly dry out and cure. Protect all work from harsh drying winds or direct sunlight, which could cause "flash curing," and from driving rain and frost which could cause mortar failure. Continue to wet the damp burlap periodically as needed. One good method of protecting the wall and promote good carbonation is not to drape the walls or surface directly, but to have a gap of at least six inches from the surface to the damp cloth or burlap. This provides a good moist condition to slow the drying process, enhance curing, and maintains good air circulation for carbonation. Also, care should be taken to protect work from direct sunlight which may cause accelerated drying, as well as driving wind and rain which may over saturate fresh mortar. If work commences or continues during late fall, winter, and early spring where cold or freezing temperatures are a concern, work can be protected by building enclosures or encasing and heating scaffolding to protect the mortar during its curing.

Craftsmen, Contractors, and Mockups

When selecting a contractor for your project, a discussion on what you want to see happen on your project and how they envision approaching your project can help prepare you for the work to take place. It is highly advisable to ask for a list of the contractor's completed projects and photographs of both the finished projects and work in progress (to show site practices). It is understandable to pursue a bid process to select a contractor, and award the work to the lowest price. However, in many cases, low bids do not necessarily provide the desired level of detail or attention required for the preservation of our architectural heritage. Keep in mind that whatever work is performed on the structure becomes part of this building's history. Contractors who are sympathetic to this ideal may provide a higher standard of quality but may ultimately carry a higher price tag. There is a trend of spending money for the preservation of historic money without spending money on the actual preservation of the masonry. Consultants, testing, analysis, and other preliminary services often leaves less money available for the actual physical work that becomes part of the building fabric. All of these factors should be weighed equally when budgeting for the work. Mockups or test panels are used to provide the owner an opportunity to see and approve the techniques, materials, and skills that will be utilized on the project. These panels can show the various joint profiles, mortar types and colors, or exterior coatings and finishes that will be used on the project. These panels can be utilized to provide a reference for the preservation work to be performed. Most mockup panels are installed on the actual walls themselves (although they may also be installed separately) and are often a few feet square in area.

Removing Mortar and Preparing to Repoint

Any existing defective mortar or pointing should be removed to a depth of at least one and a half times the width of the joint, (remove all friable material) but not less than ¾" to receive the new mortar. Prepared joints should be as clean as possible with existing mortar cleaned from the edges of the brick to ensure proper bonding between masonry unit (i.e., brick or stone) and the mortar. The back of the joint should be square to receive the mortar and mortar joints should not be shallow or feather edged. Firm contact between historic fabric and replacement material without voids within the wall is vital. If mortar removal may result in lack of stability of the masonry units, shims may be employed to hold the units in place until the mortar can be replaced. Existing historic lime-based mortar should be removed by hand. Use only hand or pneumatic stone carving chisels that are no wider than one half the widths of the existing masonry joints. Take great care to not widen the existing masonry joints by damaging masonry units or spawl and chip the surrounding masonry edges in the process of mortar removal.

Much attention is given to the use (or prohibition of use) of grinders for mortar removal. As only deteriorating historic mortar should be replaced, the using of grinders may be deemed unnecessary. However, if it is absolutely necessary, horizontal cement joints may be raked out by carefully scoring the center of the mortar joint with an angle grinder to relieve the stress on the joint. Angle grinders should only be used by highly skilled masons and proficiency in this type of removal should be demonstrated before this method of mortar removal is employed. Under no circumstance should grinding be allowed for the removal of head joints, as there is a greater risk of damage to the masonry. The remaining mortar in head and bed joints should be removed to the required depth using hand or pneumatic stone carving chisels. NEVER grind mortar from any surface of the host masonry. Remove debris from joints by brushing joint faces, vacuuming, or blowing with pressurized air. Joints may be rinsed using very low pressure spray assembly with caution. Verify that water will not migrate to other areas and cause damage. Ensure that all surfaces below rinse areas are wet prior to cleaning out joints so as not to cause staining of the masonry fabric.

After the preparation of the mortar joints, the prepared area must be cleaned. Preferably the joints will be vacuumed of dust and debris and then rinsed down with water removing all excesses of mortar and dust from the joints. Care should be taken not to saturate the masonry, but to dampen and clean the joints. The idea is to control the absorption rate in the wall and to promote the slow curing of the mortar that is being replaced. If the host masonry is not thoroughly dampened the brick or stone could pull the moisture too quickly from the mortar which could cause shrinkage cracking, lack of bonding, and loss of strength. Depending on the type of brick or stone wall being pointed and the amount of area cut out and rinsed down, you may have to re-dampen the wall before pointing. Misting with spray bottles or garden sprayers prior to pointing in that area is also a good way to keep control of the wall area being repaired. The mortar should be as dry as is practicable to point with but moist enough to achieve any joint details required. This allows maximum compaction in the joint, which reduces shrinkage cracking and reduces the tendency to smear on the masonry surface.

Pointing

After removal of the defective mortar and dampening of wall, the wall is ready to start pointing. A good mortar for pointing should be fairly dry, which will allow for good compaction of the new mortar to the old mortar. Fill out all major voids or relaying of brick or stone, leaving the finish joint back about 1 ½ times the width of the joint, this is usually about ¾ to1 ½ of an inch back from the face of the masonry (ensure that all friable material has been removed). Then point in lifts of between ½" or ¾"at a time to replace the mortar. The employ of grout bags for placing mortar is not advised as often the addition of excess water to provide proper flow may cause shrinkage and cracking, and the use of such a fluid mix may prevent proper compaction of replacement mortar to the historic fabric. Maintaining an even amount of pointing helps to keep the consistency of replacement mortar the same and curing of the wall should come about in an equal and even fashion. The tooling of the finish joints should be determined and specified. Keep in mind that is often beneficial to tool new work to match the original existing joints on the structures whereas the original joint profile could be lost forever. Some tooling may be different from one location on a building to another, being either face work or backup work. The joint details from front facades to side or rear elevations may change, so be aware of existing evidence for making the proper determination of which technique should be used. One method that can be used in pointing is to slightly reveal or trim back the mortar from the face edge of the brick or stone to detailing that unit. Keep the joint contained on the inside and do not let it come out to the outside of the brick. In keeping the joint contained it makes a much more attractive wall, and when viewed the wall should blend together where existing joints have weathered and already are somewhat revealed.

Once the work is completed the mortar must absorb carbon dioxide to set. Make sure that the mortar cures out naturally over the course of a few days. Make sure that the work is protected from harsh sunlight, drying winds, and driving rains for at least a week to ensure this natural curing. When dealing in frost conditions, work should cease at least a month before the first hard frost, although this time frame may change due to site conditions.

When cleaning repointed work, the best option is low pressurized water (around 100 psi) and scrubbing with stiff natural bristles or nylon brushes. If detergents are used, please check manufacturer's guidelines to ensure acceptable results.

CONCLUSION

The preservation of historic masonry is not a task to be taken lightly. For decades we have seen historic structures suffer irreversible harm at the hands of persons charged with their care. Stewards of building preservation should be willing to advocate for appropriate repair regardless of cost, time, energy, and effort as their work will be part of the history, good or bad, of the structure. There are three points that should always be kept in mind by the conscientious preservation professional. First, preservation is akin to maintenance, and occasionally we must rise to the occasion and do what needs to be done. Just as wood work needs to be repainted, mortar joints occasionally need to be refreshed from years of life. Second, whatever avenue you pursue in historic preservation should cause no harm to the structure. Unfortunately we've learned the hard way the damage that can be caused by inappropriate or ill informed repairs and our architectural heritage has suffered because of it. Finally, repointing the right way should give you decades, if not close to a century, of continued life. Do it right the first time and save yourself unnecessary heartache and strife.