Lime Blog
February 10, 2023
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The conservation and masonry teams are busy making lime putty at the James Brice House. Lime putty is a binder used to make traditional mortar, plaster, and limewash, all of which are needed for the Brice House's restoration. Lime putty (non-hydraulic lime) was used for thousands of years as a binder before hydrated lime powder (hydraulic lime) gradually replaced it in the mid-eighteenth century, followed by Portland cement beginning in the nineteenth century.[1]

Prior materials analysis revealed that local oyster shells provided the lime source for the putty used during the building's construction. Shell lime is commonly found in Colonial-era buildings throughout the Tidewater Region of the United States.[2] In addition to their abundance and availability, oyster shells made beautiful lime putty. By the mid-seventeenth century, "Oyster shell" even became a standard and building specification synonymous with high quality.[3] The conservation and masonry teams' decision to make lime putty, following traditional methods, is not only important because in-kind materials are necessary for restoration work, but also because the incompatibility of some modern and traditional materials can lead to the destruction of existing historic fabric (Image 1).

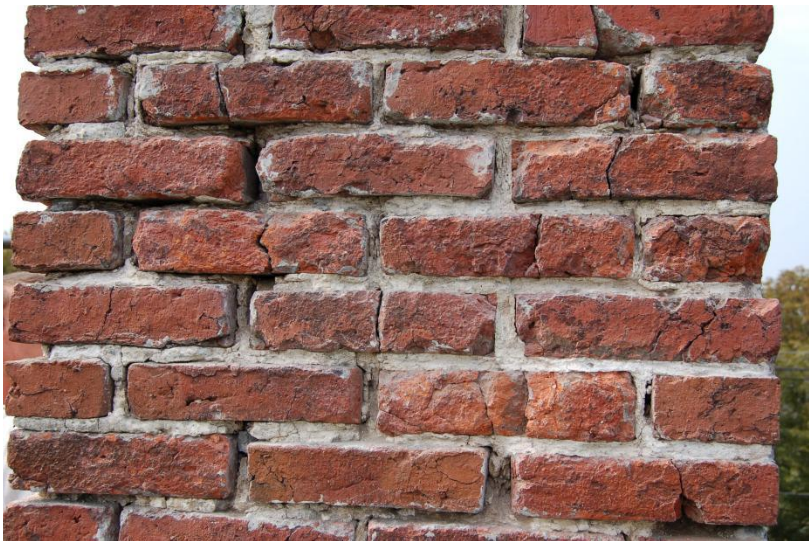

Image 1: Damaged historic brick repointed with an incompatible, non-traditional mortar (Portland cement). Portland cement is less permeable than lime mortars; it alters the way that moisture moves through and escapes from a masonry wall, thus destroying the traditional brick. (Source: Fabio Bardini).[4]

Hydraulic vs. Non-Hydraulic Lime

Hydraulic and non-hydraulic limes (lime putty) are differentiated by their ability, or lack thereof, to set underwater. For both, the process begins with burning (calcifying) a material that contains lime, such as limestone, marble or shells, in a kiln to create a powdered material called quicklime (unslaked lime). Next, the quicklime is slaked (quenched) with water.[5]

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[1] Kerstin Elert, et al., "Lime Mortars for the Conservation of Historic Buildings," Studies in Conservation 47, no. 1 (2002): 63.
[2] Hargis Jr., William J. and Dexter S. Haven, "Chesapeake Oyster Reefs, Their Importance, Destruction and Guidelines for Restoring Them," (1999), VIMS Books and Book Chapters, 331.; Worth Bailey, "Lime Preparation at Jamestown in the Seventeenth Century," The William and Mary Quarterly 18, no. 1 (January 1938): 1.
[3] Bailey, 1.
[4] Fabio Bardini, "Brick damaged by Portland cement mortar," Florentine Renaissance Masonry, 2012, https://www.florentinemasonry.com/photo-galleries/masonry-restoration-and/damaged-brick.html.
[5] Patrick Webb, "Hydrated Lime vs. Hydraulic Lime," updated May 31, 2020, https://www.traditionalbuilding.com/opinions/hydrated-vs-hydraulic-lime.

Unlike non-hydraulic limes, hydraulic quicklime is made from limestone that contains impurities (clay, magnesium and calcium carbonates).[6] These impurities alter the way hydraulic quicklime reacts to water. After burning, the quicklime is misted with water to "hydrate" the powder and reduce its caustic (corrosive) properties. Hydraulic lime remains in powdered form until it is ready for use and mixed with water, which causes the material to set.

On the converse, non-hydraulic limes do not set when combined with water and require air to dry, a process called carbonation (Image 2). Non-hydraulic lime is actually combined with an excess amount of water during the slaking process to form lime putty that can sit for weeks, months or years before it is used.[7] Hydraulic lime eventually gained popularity over non-hydraulic lime because of its powdered form; it can be stored in bags and easily transported to building sites. Hydraulic lime also has a faster curing time, which makes it appealing for modern work, but lacks the qualities that made non-hydraulic lime putty the preferred material for thousands of years. Non-hydraulic limes have a smaller particle size that results in lime putties being more stable and consistent, easier to handle and apply, and more durable after they cure.[8]

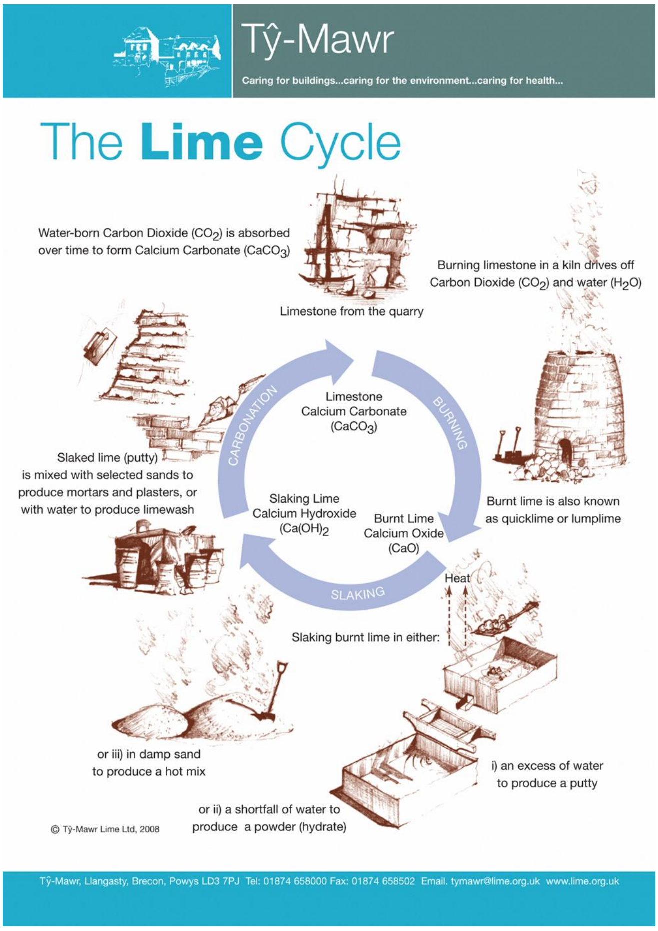

Image 2: The life cycle of lime (Source: Ty-Mar).[9]

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[6] Ashurst, John and Nicola Ashurst, Practical Building Conservation, Mortars, Plasters and Renders (London: Gower Technical Press, 1988), 7.
[7] Eric F. Hansen, Carlos Rodriguez-Navarro, and Koenraad Van Balen, "Lime Putties and Mortar: Insights into Fundamental Properties," Studies in Conservation 53, no 1, (2008), 11.
[8] Roz Artis-Young, "Innovations in Limewash," Building Conservation, 2008, https://www.buildingconservation.com/articles/innovations/innovations.htm.
[9] "Lime and its Production, " Ty Mar, April 11, 2016, https://www.lime.org.uk/community/the-lime-cycle/lime-and-its-production.html.

Traditional (Pre-Industrial) Kilns and Slaking Lime

Historically, kilns were often constructed at or close to building sites. Traditional kilns ranged from temporary (single use) to permanent structures, either flare or draw kilns (Image 3).[10] Both flare and draw kilns have the same basic form. Typically, a vertical shaft (chimney), sunk into a hillside or bank of earth, intersected with a horizontal passage at the bottom. Here, the furnace (hearth) and draw/stoke-hole were located.[11]

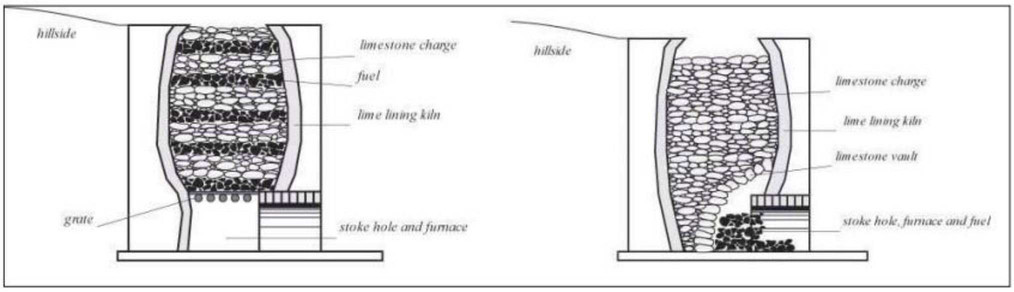
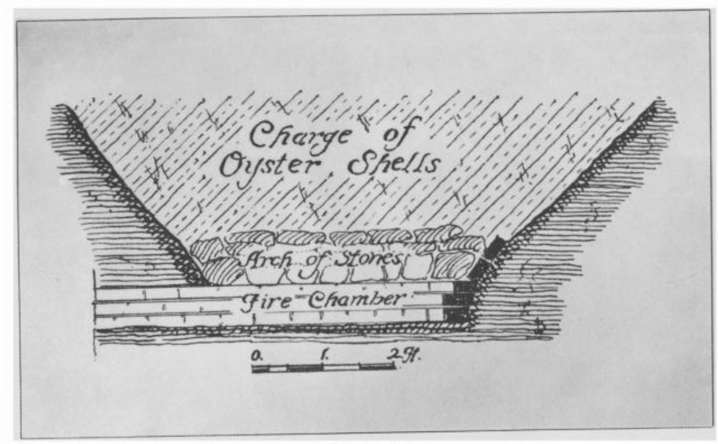
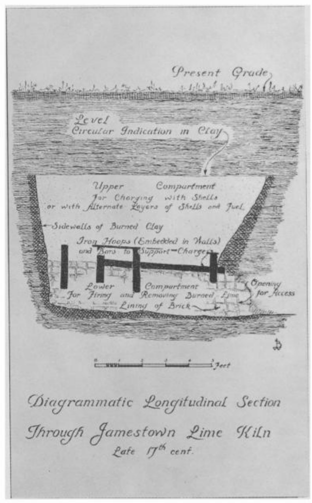


Image 3: Cross sections of a traditional draw kiln (left) and flare kiln (right). (Source: Historic England).[12]

Flare kilns were built with an internal arch that prevented the limestone or shells from coming in contact with the fuel while they burned (Image 4). This separation yielded a more pure, high-quality quicklime. However, only a single charge of limestone or shells could be loaded and burned at a time, making flare kilns more expensive to run. Alternatively, draw kilns were continuously fed with alternating layers of limestone and fuel at the top of the shaft. As they burned, these materials fell through a metal grate located above the furnace (Image 5). Draw kilns were run for weeks or months as a time, producing large quantities of quicklime, but the quicklime and ash ended up mixed together.[13]



Drawing No. 2



Drawing No. 1

Image 4 (left): Cross section of a late-seventeenth-century flare kiln used to burn oyster shells, excavated at Jamestown, Virginia. (Source: Worth Bailey).[14]
Image 5 (right): Cross section of a late-seventeenth-century draw kiln excavated at Jamestown, Virginia. (Source: Worth Bailey).[15]

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[10] Ruth Siddal, "Kiln Architecture and Technology," accessed February 9, 2023, https://www.ucl.ac.uk/~ucfbrxs/limes/Kilns.htm.
[11] Bailey, 3.; Muirus O'Sullivan and Liam Downey, "Lime Kilns," Archaeology Ireland 19, no. 2 (Summer 2005): 19.; Nicky Smith, "Pre-industrial Lime Kilns," Historic England, 2018, https://historicengland.org.uk/images-books/publications/iha-preindustrial-lime-kilns/heag222-pre-industrial-lime-kilns, 2.
[12] "Pre-industrial Lime Kilns," 3.
[13] Downey, 19.
[14] Bailey, 25.
[15] Bailey, 21.

Hydraulic quicklime was then removed from the kiln and ready for slaking with water, forming lime putty.[16] Adding quicklime to water causes a highly exothermic reaction, during which heat is released in the form of vapor bubbles and steam.[17] The powder could be slaked in a basin and then the putty moved into vats for storage or it was transferred directly to a slaking pit in the ground and mixed with damp sand (Image 2). In both instances, the putty was often covered with a layer of sand, soil, or turf to prevent moisture loss and left to mature.[18] Following construction, kilns located on building sites were left in place and abandoned, disassembled and moved, or infilled.

Image 6 (left): The electric kiln we use to burn oyster shells (Source: Chris Mills).
Image 7 (right): Our supply of local oyster shells. (Source: Chris Mills).

Our Process

Currently, we are burning oyster shells on site in an electric kiln, recognizable to anyone who has taken a pottery class before 9 (Image 5, 6). The oyster shells retain their shape after they burn (calcify) (Image 8). A "shortfall of water" is slowly added to the shells to hydrate the lime, producing a quicklime powder (Image 2, Image 9). This powder is sifted to remove any impurities. The powder is settles to the bottom of the container and is left under a layer of water to mature into lime putty (Image 10). No slaking pits will be dug behind the house, but storing our lime putty in tightly sealed containers will work just as well. The masons are combining lime putty with sand to make mortar and the conservators will use the putty for plaster and limewash. Plaster is made by mixing lime putty, aggregate, and fibers, typically animal hair, and limewashes are made by combining lime putty with additional water. Limewashes can be left unaltered. However, we will be making both unpigmented and pigmented limewashes to replicate finishes at the Brice House.

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[16] Bailey, 9.; Siddal, "Kiln Architecture."
[17] Hansen et al,, 12.
[18] Siddal, "Kiln Architecture."; Ashurst, 2.; Hansen et al,, 11.

Image 8 (top): Oyster shells after they are removed from the kiln. (Source: Chris Mills)
Image 9 (right): Slowly adding water to the burned shells to produce hydrated quicklime powder. (Source: Chris Mills)
Image 10 (left): The quicklime powder in a container of water left to mature into lime putty. (Source Chris Mils)