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Drayton Hall: a Case Study, Mortar Analysis and Replication

Frances Henderson Ford1 and Kate A. Stojsavljevic2

1 Clemson University/ College of Charleston, USA, fordf@cofc.edu
2 Keast & Hood Co., USA, kstojsavljevic@keasthood.com

Abstract Drayton Hall, located on the banks of the Ashley River just outside of Charleston, South Carolina, is one of the finest examples of Georgian Palladian architecture in North America. Originally constructed 1738 - 1742, the three-story Flemish bond masonry structure has managed to survive the American Revolution, the American Civil War, its ensuing economic depression, and a severe earthquake in 1886 remarkably intact. Evidence of such perseverance is visible, however, as the building’s exterior exhibits at least seven distinct mortar campaigns over its lifespan. Since 1974, Drayton Hall has been owned and protected by the National Trust for Historic Preservation. This NGO has struggled to preserve and maintain the house within the restrictions of a limited budget. A recent collaboration between Drayton Hall and students and faculty of the Advanced Conservation Lab course; a part of the Clemson University/College of Charleston’s Graduate Program for Historic Preservation provided the opportunity to analyze the mortar from the second campaign (ca. 1810) and formulate an easily reproducible replacement mortar.

1 Introduction

While traditional mortar analysis using dilute hydrochloric acid has been an established method to determine the composite makeup of mortars, stuccos and renders, and is commonly taught in historic preservation graduate programs in the US and Europe, it is not however the best method to analyze mixtures made with calcium carbonate aggregates such as shell, coral, limestone or marble. The need for adaptation of this method became evident when 1738 era Drayton Hall; an American National Trust for Historic Preservation site asked graduate students from the Clemson University/College of Charleston Historic Preservation program to investigate the masonry walls of the house. Specifically, they wanted to develop
an easily reproducible tuck pointing mortar using readily available materials for an upcoming repair project. The group was able to develop a more sensitive acid digestion process for the Drayton Hall mortar, which helped preserve the aggregate and identify the original formula. Using this information they could then adjust it for use with readily available materials, not sacrificing, strength, porosity or visual appearance.

2 House History

Drayton Hall is considered one of the finest surviving examples of Georgian Palladian architecture in North America. It has exceptionally complex and rich handcrafted detail for a building completed in the first half of the 18th century in the southern colonies. As one of the most prominent and important citizens of Colonial South Carolina, John Drayton’s house was built intentionally to reflect his wealth and status. Commissioned between 1738 and 1742, the two-story Flemish bond brick dwelling, raised over an English basement, would have been more at home in the English country side than the low country of South Carolina. It is significant that Drayton Hall remained in the Drayton family for over 240 years. This remarkable record of continuous ownership allowed the house to remain virtually unaltered in subsequent years, as it exists today without the invasive additions of plumbing, electrical and mechanical systems. Thus, the integrity of the original building fabric is relatively sound. Notably, Drayton Hall is also the only plantation house along the Ashley River to have not only survived numerous storms, hurricanes and one 7.2 magnitude earthquake, but also both the American Revolution and the Civil War [1].

While the house managed to survive the Civil War, the ensuing economic depression afterwards created an impoverished class in the once wealthy plantation aristocracy. The Drayton’s in some ways were no different than their neighbors; who not only lost their fortunes but had also lost their grand plantation
mansions. Although the Drayton’s managed to retain ownership of Drayton Hall, it still fell into decline. During the late 1870’s Charles Henry Drayton was able to restore some of the family’s wealth when deposits of phosphate were found on the property and subsequently mined. A powerful earthquake rocked the house in 1886 and using profits from the phosphate operation, Drayton had the means to renovate Drayton Hall and repair damages to the building. Charles greatly respected the integrity of the house and made sound repairs and slight alterations which were considered fashionable in the era.

The early part of the 20th century marked a 70 year period of limited occupancy at Drayton Hall. Although Drayton Hall remained in the family, the house was mainly used for annual family gatherings or as a country retreat for a few weeks each year [2]. By the early 1970’s the building was entirely vacant and consequently deteriorating [1]. The large house was an iconic representation of the families past importance, but at the same time a burden to repair and maintain. In the 1970’s the family began to explore options for the long term preservation of the buildings and its site. With the help of the Historic Charleston Foundation, the Drayton’s generously agreed to let the National Trust for Historic Preservation, an American NGO, take on the role of owner and caretaker for the property. They were acutely aware of the vast needs of the property, but also had a selfless and scholarly sense of how important the site was to the low country of South Carolina and the nation.

When the National Trust (from this point forward referred to as the Trust) assumed ownership of the property in 1974, they were able to begin to survey and study the buildings and grounds. A Historic Structures Report was commissioned resulting in a set of recommendations which lead to the necessary stabilizing repair work. Care was taken to not over-restore or alter the buildings fabric or design. It was the intent of the project team and the Trust to maintain the site and dwelling as it was when the Drayton family transferred it to them. This property would be interpreted as an empty building with no furniture, fixtures or added decorative elements on the walls, floors or ceilings. Drayton Hall pays tribute to the workmanship and craft of the building. It is therefore extremely important to maintain the building through sound craftsmanship, quality materials, compatible techniques and formulas in the trowel trades as well as the latest preservation and conservation science methodology. Overall, the site offers visitors a unique glimpse into South Carolina history, while today simultaneously portraying contemporary issues facing historic sites and their scenic settings.

3  Project background

The impetus for this project came during a grant proposal meeting concerning long term maintenance of Drayton Hall, present were then director of preservation Matt Webster and Richard Marks, a local restoration contractor and adjunct
professor in the Clemson/College of Charleston graduate program in Historic Preservation. It was apparent to Webster and Marks that the track record for maintenance and repairs at Drayton Hall was largely uncertain. Although the property had remained in the hands of the Trust for the past 30 years, changes over the years in staff, hired outside consultants and advisors had lead to repairs and interventions that were well intentioned but not always successful and rarely well documented. It was clear that an academic approach to several key maintenance problems might shed the best light on the issue.

One factor that had bothered Matt Webs ter since his arrival at Drayton Hall was the lack of documentation of the exterior pointing mortar. There were obviously several early campaigns of mortar that predated the Trust’s ownership. Also of concern were several campaigns of tuck pointing by the Trust that were not holding up well and exact data on the mix and application was scant. He hoped that the students could provide initial documentary research into past repair work, a timeline for the mortar campaigns and conduct an exterior building condition survey. Webster hoped for an easily reproducible formula that any hired mason could replicate on site over time.

A conditions assessment was the first task. The brickwork was surveyed on all four sides of the building’s exterior and some open areas in the house interior. A photographic record was taken and notations were made on HABS drawings provided by the Trust. The brick sizes, bonding patterns, mortar joint size and tooling was also noted. Care was taken to develop a clear evolution of the walling from original bedding and pointing to subsequent re-pointing, repairs and alterations. Samples were taken from every type of mortar identified on the building. Patterns emerged in the mortar mixtures that seemed to coincide with known periods of work by the family or later campaigns by the Trust.

The initial student findings were interesting; seven different mortar campaigns were documented. Documentary research from the historic structures report, finished in 1988, found that Drayton Hall had both a brick kiln, for the production of brick and an egg shaped reverbaratory furnace on site for lime production [2]. The earliest pointing joint from the time of construction was tooled or scribed. The second campaign, during the time period of Charles Drayton, c. 1810 is characterized by a struck joint. It was this time period of significance which was chosen by the director of preservation for analysis and replication.
The students spent weeks on site conducting the exterior building survey, identifying the areas of intact second generation mortar joints and removing mortar from all pointing campaigns for analysis. The second part of the project would be to head back to the conservation lab to examine the mortar samples and determine the correct lime/aggregate formula ratios through gravimetric analysis, acid digestion and compression cube tests keeping the ultimate goal in mind of creating as accurate as possible match to the second mortar campaign but using modern materials and creating an easily duplicated formula.

4 Laboratory Analysis

In order to reproduce Drayton Hall’s, c. 1810 second campaign mortar, analysis of pointing and bedding mortar samples was performed using a combination of several different methods. The various methodologies employed for this project included a magnified visual analysis, acid digestion, particle separation through sieves, and compression cube testing of the new replica samples.

Each sample was first inspected visually to look for similarities or anomalies, and then photographed on site before being removed. Care was taken to only remove loose or damaged samples. After samples were taken on site, they were catalogued into the time line matrix to help place them in context. Next, a basic visual analysis was performed in the lab for each mortar sample under magnification with an American Optical Micro Star stereo zoom microscope using a 40x lens. Representative parts of each sample were postured in resin cubes, then cut and polished flat to reveal the mortar in cross section. Observations were recorded in regard to aggregate particles, binder and the visual ratio of the composition, enabling a better understanding of the mortar composition before a more destructive analysis was performed. Most samples were observed to have pieces of quartz, sharp angular red aggregate and long angular gray and white aggregate. The binder matrix was predominately a whitish yellow substance which profusely coated the gray/white aggregate. This aggregate was potentially identified as oyster or clam shells which would have been manually crushed to become aggregate for the tuck mortar. Samples from beading mortar did not have
the shell, only quartz and sand particles were visible. It would be desirable to reproduce a mortar with this shell aggregate in order to achieve the appropriate color, texture, and strength of the replica pointing mortar.

After completion of this visual analysis and a few tests using 31.45% hydrochloric acid, it was observed that most of the sample was digested, leaving little or no aggregate. It was felt at this point that the shell was present in large enough quantities to be essential to the final replication mortar. It was determined that standard acid digestion procedures would have to be altered to best uncover the original mortar mixture. Attempts were made with some samples to gently crush the mortar and clean the aggregate of its lime binder. This proved difficult without some re-agent to dissolve the lime. Finally, an attempt was made to stir the sample in a beaker which held a mild vinegar solution (5% acidity). The entire procedure was monitored under magnification to determine the level of attack by the vinegar on the aggregate. When the aggregate was suitably clean, the vinegar was filtered and the aggregate rinsed with water. The shell aggregate could then be weighed free of most of its lime binder.

After recording the initial visual analysis, students sought to find the appropriate mortar aggregate ratio of the existing Drayton Hall mortar samples. This ratio compares the volume of aggregate (sand/shell/brick dust, etc.) to that of the cementitious materials (lime and/or cement). The students used the following procedure to determine the proportions of the three principle components of Drayton Hall’s historic mortar [1. The binder (essentially calcium carbonate, or CaCO3), which is soluble in acid. 2. The fines (finely textured impurities such as clays or brick dust) 3. The aggregate (sand/quartz/shell)].

The Drayton Hall mortar samples were ground by hand using a mortar and pestle. While grinding of the samples did not specifically yield the original particle sizes, it was useful in determining the percentage of each constituent part through visual inspection and weighing each sieve. The resulting particles were then separated through a series of sieves (Sieve models used were USA Standard Test Sieve ASTM E-11 specification made by Gibson, Co. Inc. The following sizes were used: #10 (2mm), #20 (850 µm), #40 (425 µm), #60 (250 µm), #100...
(150 µm), and #200 (75 µm)) and brick dust, sand/quartz and shell were visible. After each sieve was visually inspected, weighed and recorded, a light wash of mild acetic acid (5%) was used to dissolve the lime binder coating around each particle. Each washed aggregate sample was then allowed to dry and an approximate constituent percentage was visually determined. The remaining aggregate samples were also weighed again. The sieve analysis concluded that the approximate aggregate percentages of the c. 1810 second campaign mortar are 80% sand/quartz, 10% brick dust and 10% shell.

Bedding mortar samples were also analyzed. Early visual inspection found aggregate consisting of only sand and quartz so a more traditional method of mortar analysis was chosen for these mortar samples. After acid digestion, and gravimetric analysis, a comparison between the sample constituent sand and present-day river sand found near Drayton Hall yielded identical consistency, color, and texture.

Based on the observed sample particle sizes, colors, and approximate aggregate ratios, a test formula for the new replica mortar was determined. The initial test mortar mix consisted of a 3:1 ratio of aggregate to binder, and the aggregate ratio consisted of 4:1 marble dust to crushed oyster shell, with a minute amount of brick dust added for color and texture (historically added to pointing mortar and speculated by many to also act as a pozzolan). Marble dust was used as the main aggregate component; a source of calcium carbonate, readily available and at a low cost (per Drayton Hall’s needs), allowed the formula to require only a small portion of crushed shell for visual texture. Three types of readily available binder; lime putty, hydraulic lime, and a 2:1 lime cement mixture were then created for use with the sample aggregate.

Each test mortar sample was hand-mixed in the laboratory, and samples were placed into 2” cubes for additional compression cube testing. The compression test provides information needed to evaluate mortar performance based on tensile strength, soundness, expansion and setting time. The compression tests themselves were actually performed outside the Clemson laboratory, however, by a private mortar consultant. Sample mortar joints were also created to mimic the style of joint that would be used for the pointing work at Drayton Hall. Each of the sample joints was misted before curing to allow the aggregate texture to stand out. The test cubes and joints cured inside the laboratory and were re-examined after seven days.

5 Results

After the initial sample curing, the first sample mortar was determined to be too light in color to use as an adequate replica pointing mortar; too much marble dust was used in the initial aggregate ratio, resulting in the lighter hue. The second
aggregate ratio was adjusted accordingly to 6:2:1 marble dust to shell to sand. After this second sample cured, the desired color and texture was achieved.

6 Conclusion

Drayton Hall was pointed later that summer by professional restoration masons. The lime was slaked off site and then mixed as it was needed at Drayton Hall using the historic method of beating the lime and aggregate in a tub. The struck joint was also replicated. Since the pointing campaign has concluded, further research using primary documents has been conducted into the information which was actually recorded by Drayton Hall’s second owner, Charles Drayton. His diary’s which cover the periods from 1784-1820 provides a time line of brick and mortar production at the site. In the early days it is noted that both brick and “barrels of lime” are being brought to Drayton Hall for use [3]. On November 5, 1791, Charles states that:

“John Phaley, bricklayer finished my reverbarotory kiln furnace for burning shells to lime. It is shaped as an egg & is 9 ½ feet deep: diameter at the floor, 1 ½ d greatest, 6 ft D at the upper orifice, 4 ft. The furnace took him and my brick-layer Carolina, 10 days to lay the bricks including Carolina one day to deepen the hole into the earth. Two other fellows were at the same time employed in carrying water, tempering and carrying mortar and handling bricks [3].”

Charles then goes on to further describe the furnaces operation:

“…In order to form the furnace truly, a gauge frame, like to the dotted lines Fig. 1, is by a pivot at the bottom and another on top, made to turn round at the will of the work-man: and close to this gauge he lays the bricks. By confining and reverberating the heat and flame, it does not require ½ the fewel (fuel), as when shells are burnt in the open air. It will perfect the burning in 4 or 6 hours. It will contain 60 bushels of shells and 20 of wood. One bushel of burned shells will yield nearly or fully 2 bushels of slacked lime [3].”

Of great interest was the discovery of not just the written description of this furnace and its construction but also sketches in Charles Drayton’s own hand.

This new insight into the actual production of lime on the plantation grounds for use in mortar for repair and new construction at Drayton Hall is a wonderful confirmation of the student findings where oyster shell was found to be such an important mortar ingredient both for strength and visual appearance. The real world concerns of cost, availability of materials and consistent replication posed interesting preservation issues for the students when developing the modern mortar formula. A collaborative project such as this one between graduate students who need real world opportunities and a non-profit site struggling to stay ahead of ongoing maintenance was a win-win situation for both.
7 References

   <http://memory.loc.gov/cgi-bin/query/D?hb> 
3. Drayton Diaries C (1784-1820) Drayton Hall Archives, Charleston, SC