Assessment of Chimneys and Roof Structure

at

Stenton Mansion

Philadelphia, PA

Prepared by
Materials Conservation
March 2020

MATERIALS
CONSERVATION

Project Overview:

In February of 2020, Materials Conservation was contracted to conduct a survey and analysis of Stenton's chimneys and accessible roof structure, to be executed during the imminent re-roofing project on the mansion. MC employees conducted this investigation on February 26th and 27th, during which two mortar samples were taken from the chimneys for gravimetric analysis, four RILEM tests were conducted on two brick joints and two brick faces, wood samples were extracted from the roof structure for species identification, several historic nails were extracted & collected for analysis, marriage marks incised in the roof framing were recorded where exposed, and the general condition of the chimneys, roof structure, and dormers were noted. Due to availablility of scaffolding and exposed roofing, only the northwest and southwest sides' roof framing were accessible.This physical investigation was supplemented by archival research at the Athenaeum in Philadelphia, the Philadelphia Historical Commission, and the Winterthur archives in Delaware.

Site Orientation:

For the purposes of this report, cardinal direction orientations of elevations have been assigned for clarity.

Figure 1 - Site orientation map with cardinal direction assignments. Source: Google Maps, accessed March 19, 2020

A Brief History Relevant to Chimneys:

G. Edwin Brumbaugh was an architect whose practice emphasized restoration in the early to mid 1900's, and he became involved with several projects at Stenton Mansion, likely due to his wife's involvment in the Colonial Dames organization. Among these projects was the introduction of modern heating systems to both the wing and main house, which had major ramifications on the chimneys in both instances. A heating system was introduced to the wing in 1957-58 after a coal stove with a waterback that had been previously used in the caretaker's portion of the wing broke and could not be repaired. This project was conducted by a joint effort between engineer Charles S. Leopold, Kinkaid Burner Corp., and J.S. Cornell & Son Builders, the entirety of which was supervised by Brumbaugh.

Heat had been contemplated for the main house at this time as well, however the cost proved to be too great to be completed in tandem with the heat installation in the wing. A year later, however, the heating project at the main house was executed by the same project team. Documents in the Brumbaugh collection at Winterthur outline the planning process for this project, and a letter from Charles S. Leopold in January 4, 1957 mentions this,

> "We suggest that the result can be accomplished by installing a gas-fired boilder in the basement below the original north kitchen, in the quarters now occupied by the caretaker. From this point extend hot water piping to the attic of Stenton House. In the attic there would be installed two fan and coil units which would deliver warmed air down the present fireplace flues. The portion of the flue above the point at which the air ducts would be connected would be sealed to the outdoors. The warm air from the flues would reach all areas of the house without in any way affecting the appearance. Recirculation would be via the open stairwell, thence to the attic."

In January of 1958, Brumbaugh makes an interesting observation, "At some time in the past, the upper part of both chimneys seems to have been rebuilt in its entirety. There are flue linings installed in the upper part of both chimneys, and we do not know how far down they extend. As far as it is possible to determine by an examination of the top of the chimney, there appears to be little or no masonry between the separate flue linings."

In July of 1958, Brumbaugh sketched a condition assessment of the exterior faces of the two chimneys on the main house. This assessment noted several cracks, loose mortar throughout, exposed brick faces, and noted that the top portion of the chimneys were pulling away from the center. In a letter dated October 20, 1958 from Brumbaugh to the Chairman, he notes, "Kindly note that it was necessary to remove both chimneys to below the roof, and entirely rebuild them. This was discussed with you, as Chairman of the Comittee, when the conditions were uncovered, and your approval attained." This demolition and subsequent reconstruction appears to have been in reaction to the conditions found during his assessment. Below the roof line, the Cornell workers cut through the third floor plaster ceiling to provide access for the heating contractor, reinforced the 3rd floor ceiling from collar beams, and cut into the lower portion of the chimneys to insert the air ducts for the heating units. After the units were installed, the 3rd floor ceiling was replastered.

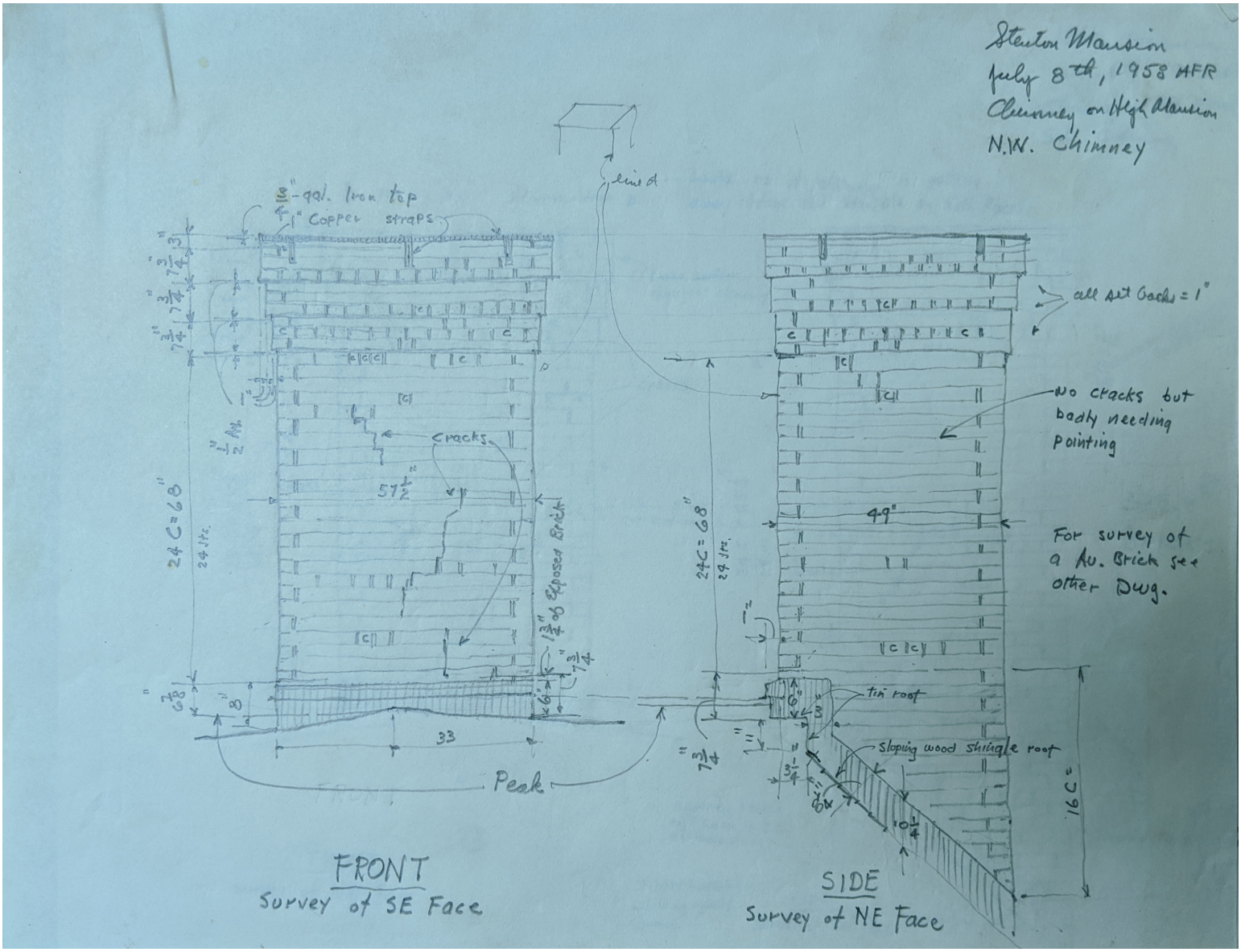


Figure 2 - Condition assessment sketch of 2 faces of the northwest (wing side) chimney, July 8, 1958. Source: G.E. Brumbaugh Paper Collection at Winterthur Library

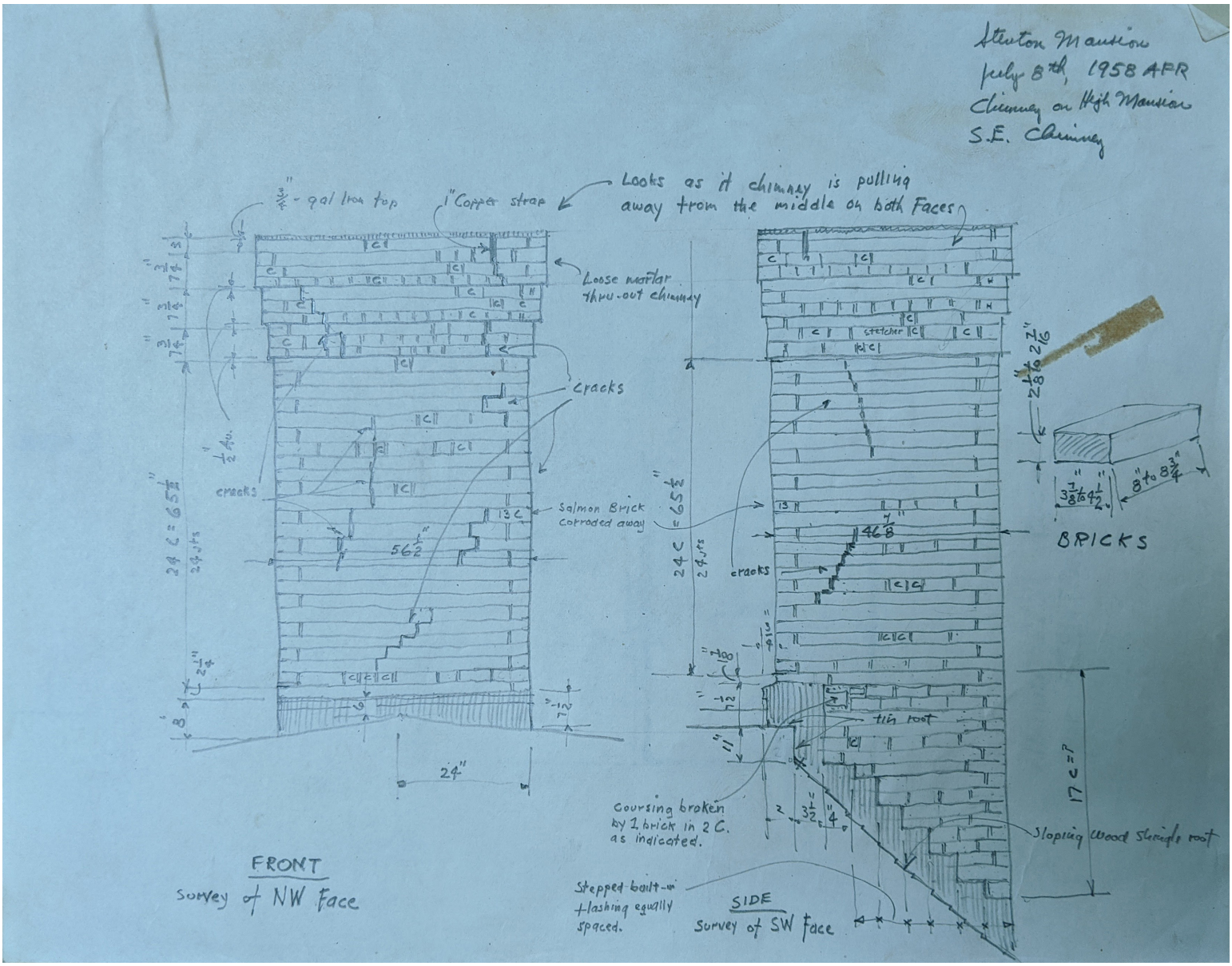


Figure 3 - Condition assessment sketch of 2 faces of the southeast (garden side) chimney, July 8, 1958. Source: G.E. Brumbaugh Paper Collection at Winterthur Library

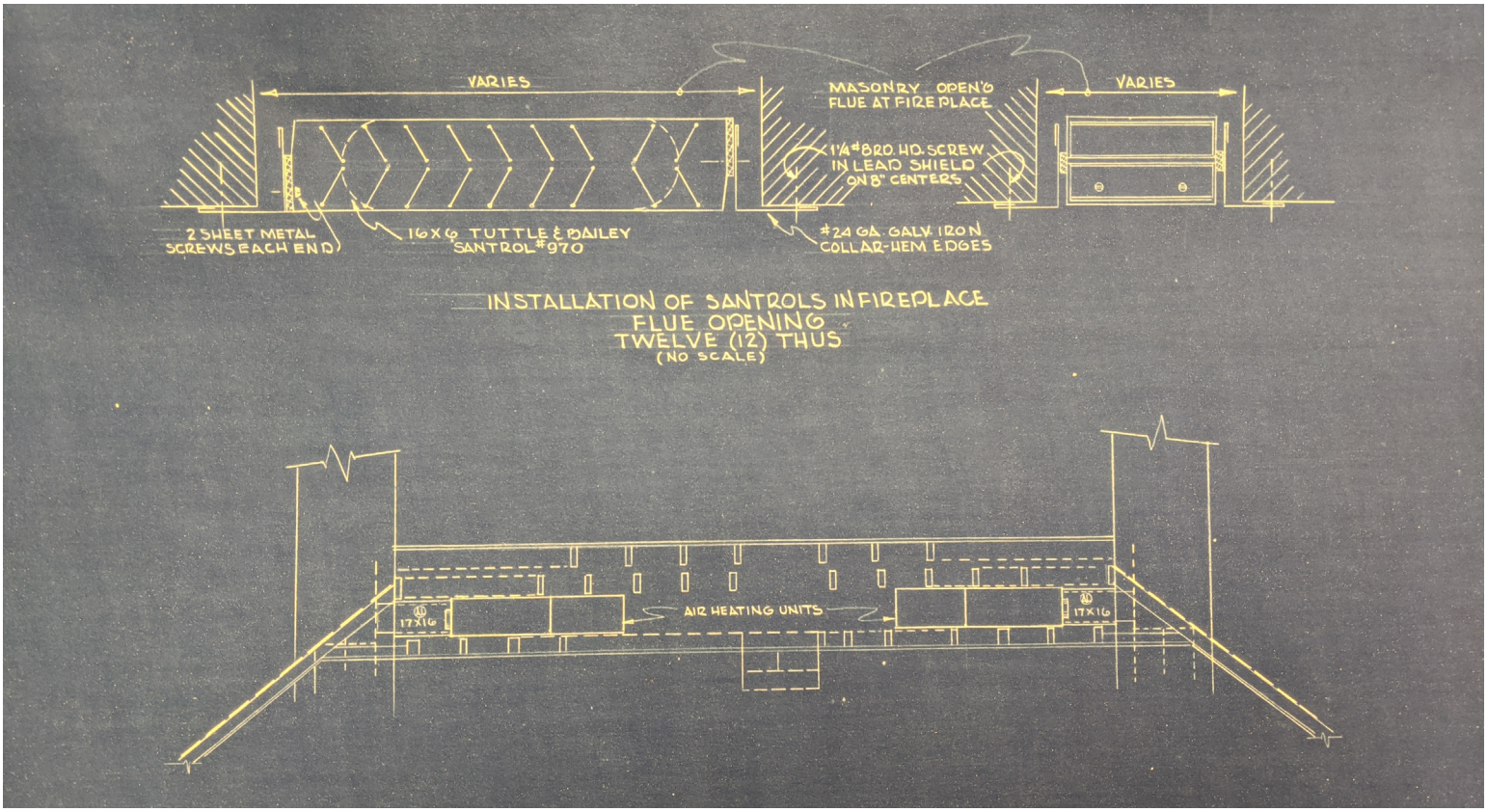


Figure 4 - Section through attic showing heating units and air ducts into chimneys.
Source: G.E. Brumbaugh Paper Collection at Winterthur Library

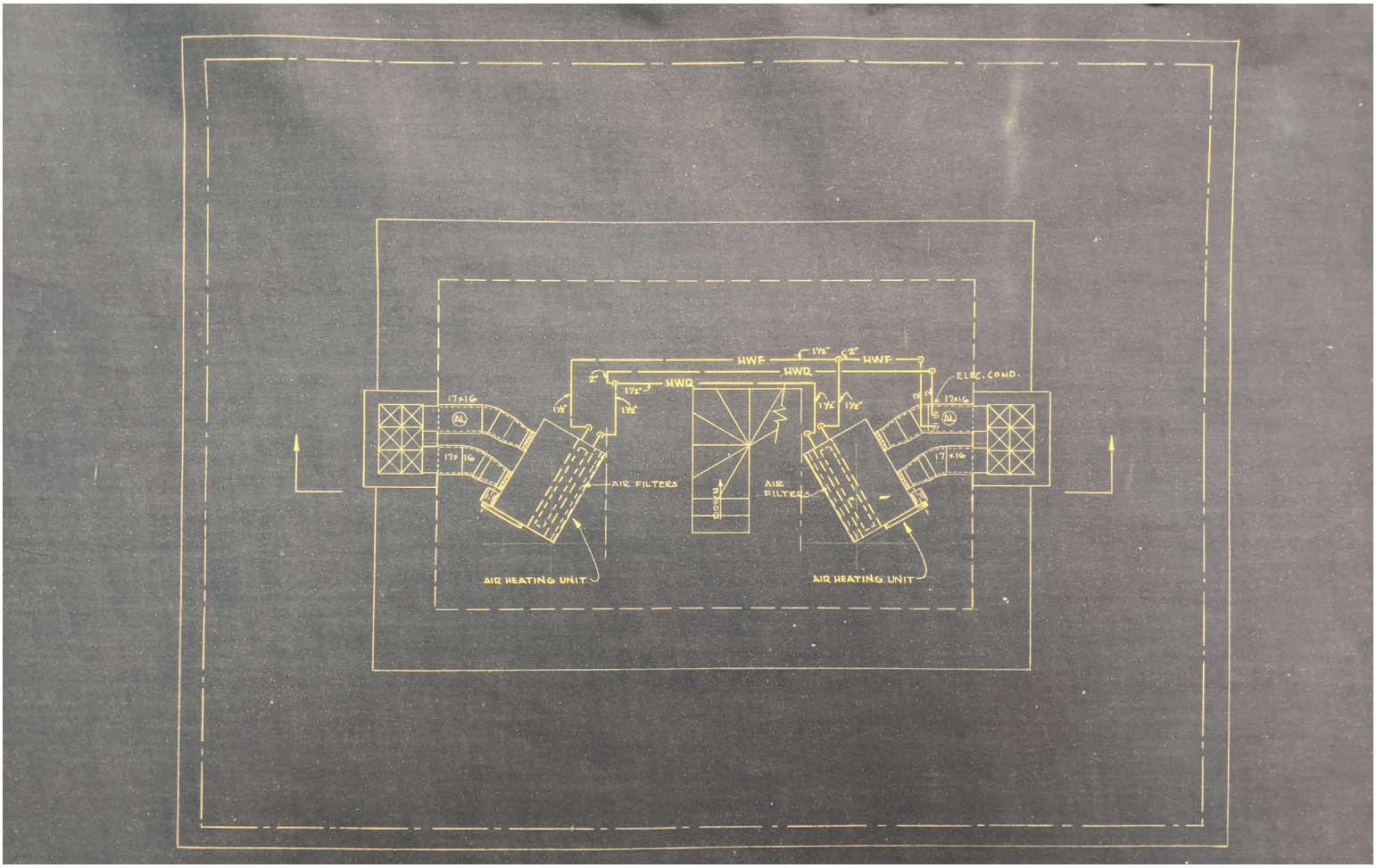


Figure 5 - Plan of attic showing heating units and air ducts into chimneys.
Source: G.E. Brumbaugh Paper Collection at Winterthur Library

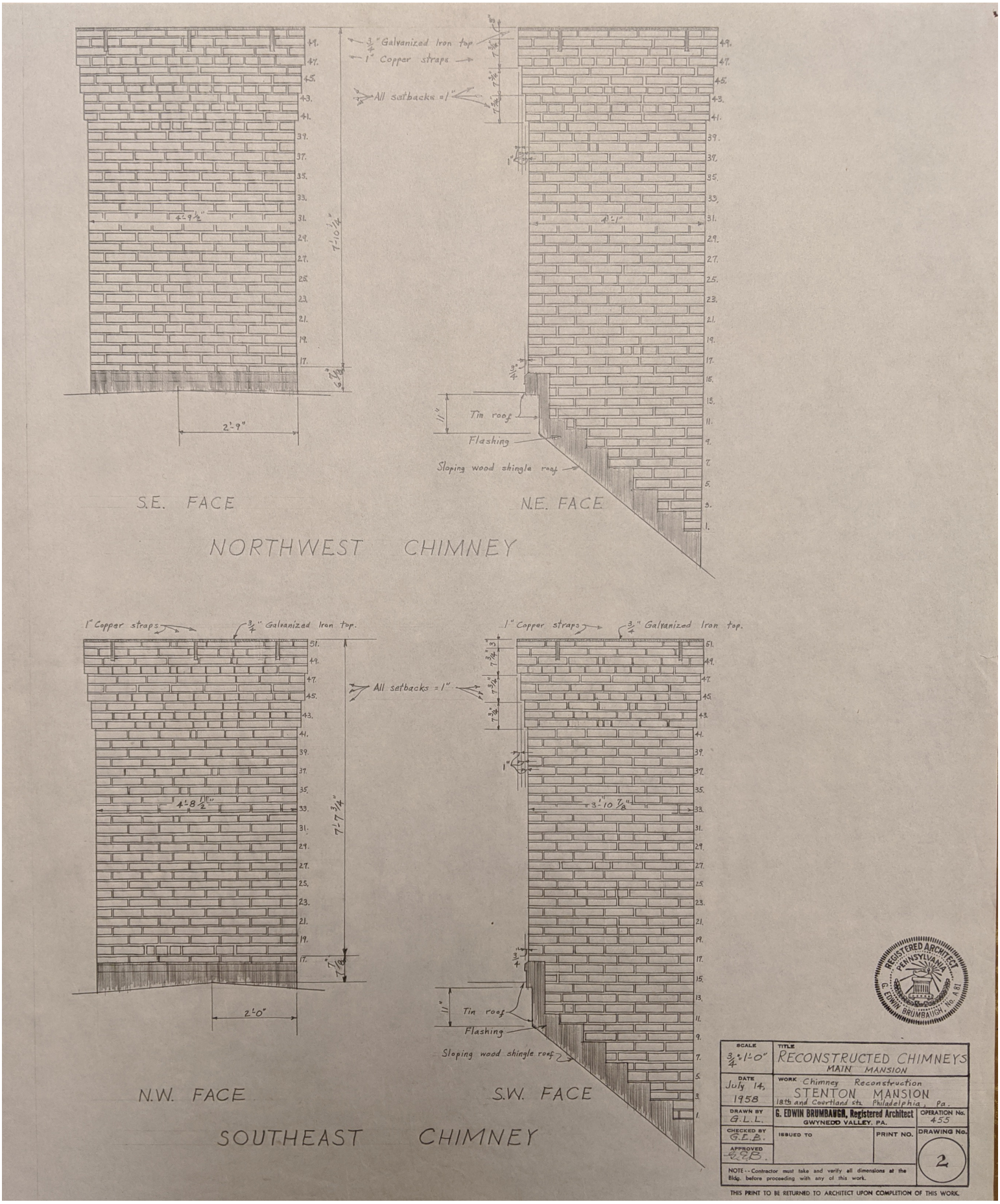


Figure 6 - Drawings of chimneys post-reconstruction, July 14, 1958.
Source: G.E. Brumbaugh Paper Collection at Winterthur Library

RILEM Testing:

The following provides the methodology and results of an in-situ water absorption test, known as a RILEM test. It was conducted on February 26th and 27th by Materials Conservation Co. LLC on both chimneys on the main house. The RILEM Test *(Reunion Internationale des Laboratoires D'Essais et de Recherches sur les Materiaux et les Constructions)* is used to quantify the absorption rate of wind-driven rain and moisture penetration. It is a diagnostic tool to identify possible points of water entry and potential existence & effectiveness of water repellants applied during previous interventions. Two tests were conducted on mortar joints on February 26th, and two tests conducted on the faces of brick on February 27th.

A small amount of putty was applied to the brim of the RILEM induction tube and pressed firmly against the masonry to prevent leakage. Water was poured into to the tube until reached 0 gradation mark. Water absorption measurements were taken at elapsed intervals as indicated by the bottom of the meniscus. Findings were recorded and are shown in the chart below.

Figure 7 - Northwest chimney with RILEM test location on a mortar joint called out by red arrow and test location on a brick face called out by a red circle

Figure 8 - Southeast chimney with RILEM test location on a mortar joint called out by red arrow and test location on a brick face called out by a red circle

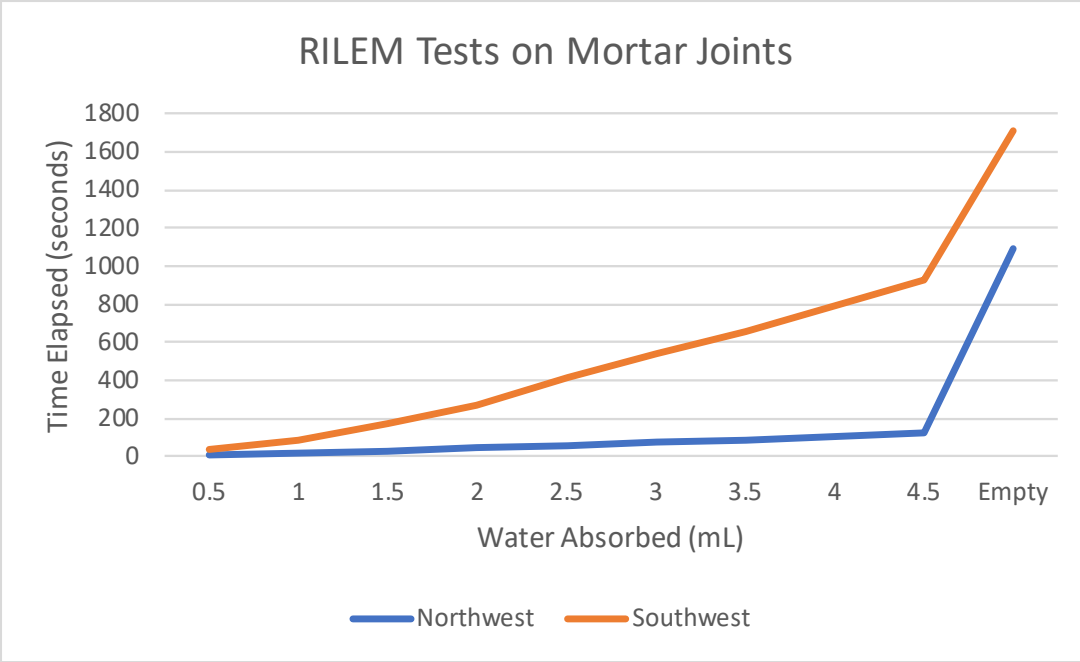


Figure 9 - Chart depicting water absorption vs. time on mortar joints

mL Absorbed	NW (time)	SE (time)
0.5	0:05	0:39
1.0	0:17	1:25
1.5	0:30	2:49
2.0	0:44	4:34
2.5	1:01	6:55
3.0	1:14	9:02
3.5	1:30	10:59
4.0	1:47	13:16
4.5	2:02	15:32
5.0	18:11	28:17

Figure 10 - Data from RILEM tests on mortar joints

RILEM Testing Results:

It is important to note the condition of the mortar joints that these tests were conducted on, the joint on the northwest chimney appeared to not be completely sealed, a small crack along the brick face was present. The joint on the southeast chimney appeared to have a mostly solid seal along the brick, with a smaller crack along the brick & mortar interface. As a result, water was absorbed more quickly on the northwest joint, as the larger crack facilitated easier entry. However, after a certain point it appeared that the absorption tapered off and plateaued in both cases. The test conducted on the more solid southeast chimney joint resulted in very slow water absorption.

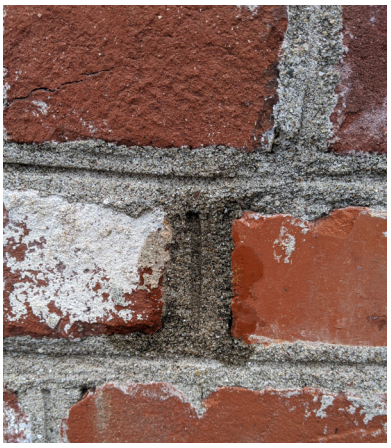


Figure 11 - (left) RILEM testing site on joint on northwest chimney

Figure 12 - (right) RILEM testing site on joint on southeast chimney

Initially, MC staff believed that this was due to an incompatible mortar made of Portland cement that might not allow for moisture movement as much as a lime mortar, however when the tests were conducted on the brick faces, an even lower absorption rate was found. The rate was so slow that not even 0.5 mL had been absorbed into the brick face after 25 minutes in both cases, and the testing was abandoned due to high winds along the roof. This was contrary to what was anticipated, as the brick face on the northwest lacked a fireskin and therefore should be extremely absorptive. On the second day of investigation MC staff noted water leaking from cracks along the brick/mortar interfaces as it was moving to the warm surface to evaporate (Figure 13). It was sunny and warm, and it hadn't rained in a few days. This, coupled with the very low absorption rate of the brick faces led us to conclude that both chimneys were likely treated with a water repellent coating sometime in the past, likely after the Brumbaugh reconstruction in 1958. Archival information also lends to this assumption, as a water repellent coating was used by Brumbaugh and J.S. Cornell & Son on the wing in 1956. In a letter from Cornell to the Colonial Dames, it was mentioned, "The leak in the toilet room and dampness on the wall of stairs in recently altered building is due to water getting through the masonry walls of light well and through the skylight. This skylight serves no useful purpose so we propose to place plywood over it and place a cold process felt and cement roof and flashings. On the exterior wall of this light well we will apply two coats of Hydrocide Color-Cote."

Figure 13 - Water movement through cracks along the mortar/brick interface to evaporate on the warm surface.

Figure 14 - RILEM test location on brick face without fireskin on northwest chimney

General Chimney Conditions & Recommendations:

Both chimneys exhibit cracking along the brick/mortar interface, as well as mortar loss/open joints near the tops of the stacks (Figure 15 & 16). These cracks are essentially allowing water to infiltrate to the interior of the masonry and negating any positive effects the water repellent coating had initially provided. Generally, a water repellent coating on historic masonry hinders the natural moisture movement patterns and can trap moisture in the wall. This is apparent at the chimneys, as water was moving to the surface days after a rain instance. However, because the chimney has been sealed below the roofline to accommodate the heating units in the attic, coupled with the fact that most water repellent coatings are generally difficult or impossible to remove without damaging the masonry units themselves, it would be acceptable to allow this coating to remain on the brick faces. However, it is recommended the extant mortar on both chimney stacks which have the water repellent coating be raked out, and repointed with an untreated, NHL 3.5 mix that matches the mortar in the body of the house in aggregate/binder ratio, appropriate aggregate profile, overall color, and pointing type. Both chimneys utilize a grapevine joint which is typical of Delaware Valley 18th century construction, and this should be replicated with the appropriate tools. This new mortar would allow a breatheable location for moisture to exit the masonry and close the currently open joints. This mortar replication would require an analysis of the mortar on the lower portions of the house. It is also recommended that RILEM testing be conducted on the main body of the house to discover if a water repellent treatment was used universally on the building, or only on the reconstructed chimneys. This information will inform future conservation treatment approaches.

Figure 15 - Cracks along the brick/mortar interface

Figure 16 - Mortar moving away from joints, creating open joints allowing water infiltration

Wood Framing Investigation Overview:

MC staff were on-site after the roofers had completed 2.5 sides of the building, therefore only the northwest side of the roof structure was investigated so that MC staff were not in the way of the roofing process. Samples of the extant roof framing and sheathing were taken for wood identification, loose historic nails were removed for dating analysis, molds were taken of the exposed marriage marks on the rafters, and joinery style and the conditions of the wood members generally noted.

Wood Identification:

Two samples taken from the roof framing, and two pieces of wood that were removed by the roofers were taken to MC's laboratory for wood species identification (Figures 17 & 18). Sample 1 was part of a nailer in the original roof sheathing, as evidenced by the embedded wrought nail with a French rose head. Sample 2 was a piece of sheathing cut and removed by the roofers, and a chisel point wrought nail was extracted from it, which dates the wood to a range of early to late 1700s. A small piece was cut off of these samples with a small-toothed saw, then the surface was finished with a razor along the end grain. This finished surface was then observed under reflected visible light using a Leica MZ16 stereomicroscope. Sample 1 which has the embedded wrought nail and the two samples taken from the rafters were determined to be White Oak, made apparent by the ring-porous hardwood anatomy, large rays, distinctive and abundant tyloses in the larger pores, and indistinct latewood pores (Figure 19). These oak members also exhibited hand pit saw marks, which denotes it as part of the original construction. Sample 2 was identified as a Southern Yellow Pine, as evidenced by the softwood anatomy with an abrupt early/latewood transition, as well as large and numerous resin canals (Figure 20) Southern Yellow Pine is a group of four species of pines that are very similar to each other, and even microscopically can be hard to differentiate. This group includes Shortleaf Pine *(Pinus echinata)*, Slash Pine *(Pinus elliotti)*, Longleaf Pine *(Pinus palustris)*, and Loblolly Pine *(Pinus taeda)*. The sample appears to be Longleaf Pine, which historically was the desired species to be cut into lumber.

Figure 17 - Wood ID sample 1 with wrought nail embedded

Figure 18 - Wood ID sample 2

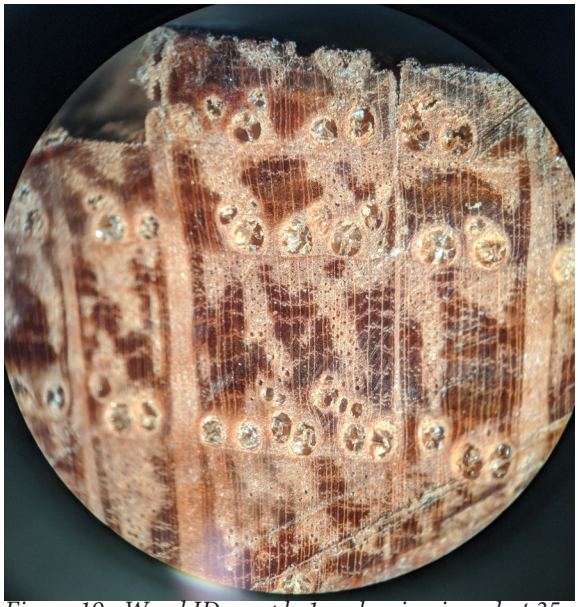


Figure 19 - Wood ID sample 1 endgrain viewed at 35x magnification

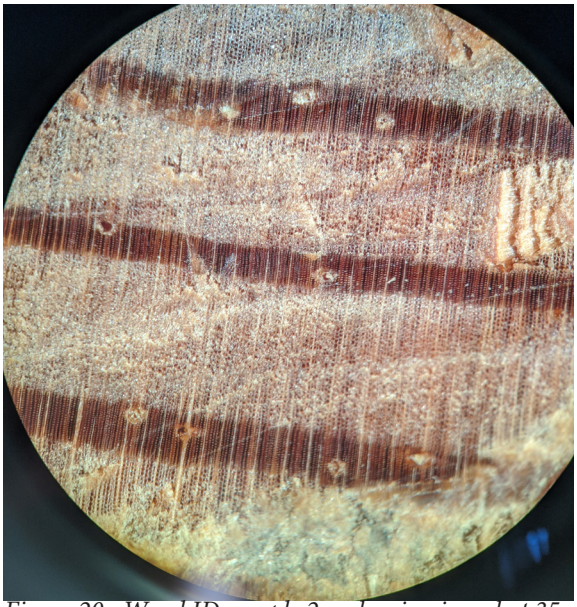


Figure 20 - Wood ID sample 2 endgrain viewed at 35x magnification

Figure 21 - French rose head of wrought nail embedded in wood ID sample 1

Figure 22 - Chisel point nail extracted from wood ID sample 2

Nail Analysis:

A total of 16 nails were sampled from the roof structure, one of which is still embedded in wood as described in the section above. Analysis of the technological features of these nails as described in Tom Well's *Nail Chronology: The Use of Technologically Derived Features* show a full range of dates, including wrought nails from the 1700s, cut nails from c.1820-1891, and modern wire nails from 1891 to the present (Figure s 23 & 24). Nail types as described in the following table are derived from Well's nail chronology, with more specific notes by MC staff. Note that these are not precise dates, but rather a range of when they were likely installed based on small distinctive features which indicate the change of nail production technology. The chisel point nails were found in the roof sheathing, the point was wrought this way to prevent thin wood from splitting when the chisel point was applied perpendicularly to the wood fibers, thereby severing them rather than forcing itself between them. There appears to be 3 consistent campaigns of roof sheathing visible: the first dating from the early 18th century with white oak nailers exhibiting pit saw marks and utilizing wrought nails, the second from late 18th-early 19th century using a combination of hand and machine-made nails in Longleaf pine showing vertical water mill marks, and the third using pine with circular saw marks and fully machined nails from the mid-late 19th century.

NAIL NUMBER	NAIL TYPE & DATE RANGE	NOTES
EMBEDDED NAIL	1 - 1700-1800	Hand-forged, hand-headed, French Rose head
NAIL 1	1 - 1700-1800	Hand-forged, hand-headed, Rose head
NAIL 2	1 - 1700-1800	Hand-forged, hand-headed, French Rose head, clinched
NAIL 3	1 - 1700-1800	Hand-forged, hand-headed, French Rose head
NAIL 4	1 - 1700-1800	Hand-forged, hand-headed, French Rose head
NAIL 5	1 - 1700-1800	Hand-forged, flat head
NAIL 6	1 - 1700-1800	Hand-forged, flat head
NAIL 7	2 - 1760-1820	Hand-forged, Rose head, chisel point
NAIL 8	2 - 1760-1820	Hand-forged, Rose head, chisel point
NAIL 9	8 - 1820-1891	Cut, machine-headed
NAIL 10	8 - 1820-1891	Cut, machine-headed
NAIL 11	8 - 1820-1891	Cut, machine-headed
NAIL 12	8 - 1820-1891	Cut, machine-headed
NAIL 13	8 - 1820-1891	Cut, machine-headed
NAIL 14	8 - 1820-1891	Cut, machine-headed
NAIL 15	12 - 1891-Present	Wire, machine-headed

Figure 23 - Nails # 1-12 extracted from roof

Figure 24 - Nails # 13-15 extracted from roof

Roof Framing Investigation:

A thorough roof framing survey was conducted by John M. Dickey, one of the foremost restoration architects in the Philadelphia area from the 1960s-1980s, which is included in Stenton's Historic Structures Report (HSR). During the brief investigation of the northwest side roof framing members, MC staff recorded both running measurements and measurements of the joist face, and also took molds of the visible marriage marks on the roof members. One difference between the extant conditions on this side and the Dickey roofing plan was that there are **three** rafters between the dormers rather than the two that are pictured in the Dickey plan. Overall, the roof framing members appear to be in good condition with no visible rot.

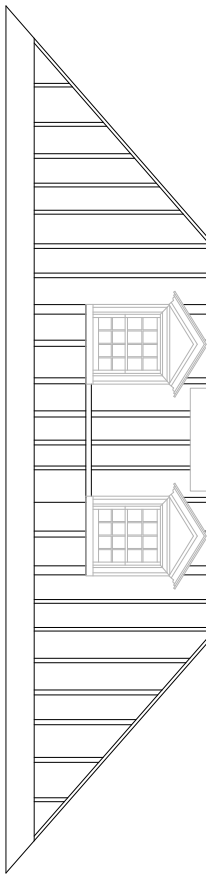


Figure 25 - As-found joists on NW elevation

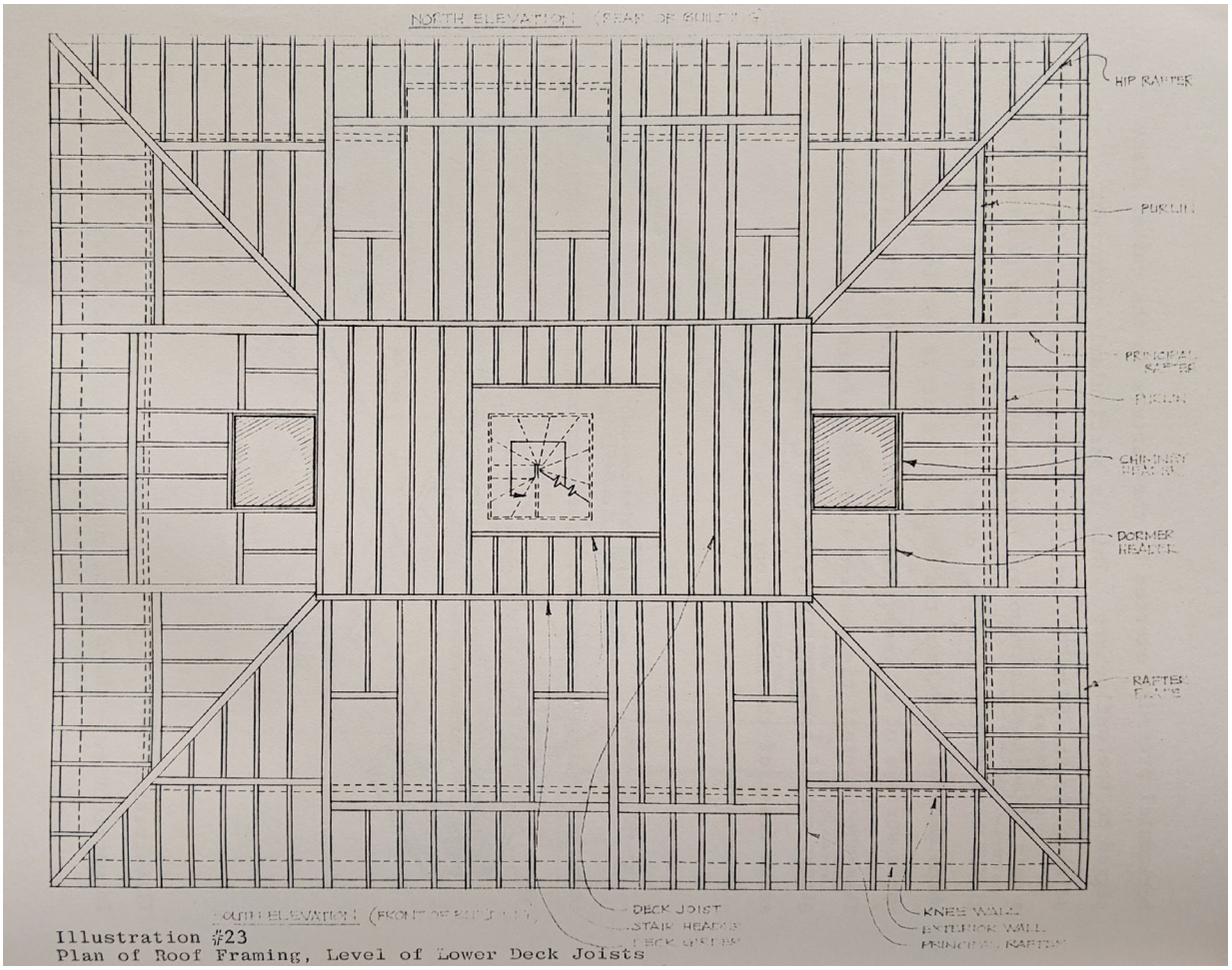


Figure 26 - Dickey Roofing Plan, Source: Stenton HSR

Dickey continued to lay out the roofing scheme in the HSR, however MC staff were not able to confirm some of these details in the field due to restraints on what roofing material was exposed. MC staff did confirm the layout of the corner between the northwest and southeast elevations, observing the first joist connected to a diagonal member spanning corner to outlooker, the second joist connected to the outlooker by a tusk tenon, and the rest of the intermediary joints utilizing a lapped dovetail, as depicted below. A lower, secondary tenon was also utilized on all the joists connnected to the outlooker.

Figure 27 - As-found conditions of 3rd floor ceiling joists to outlooker.

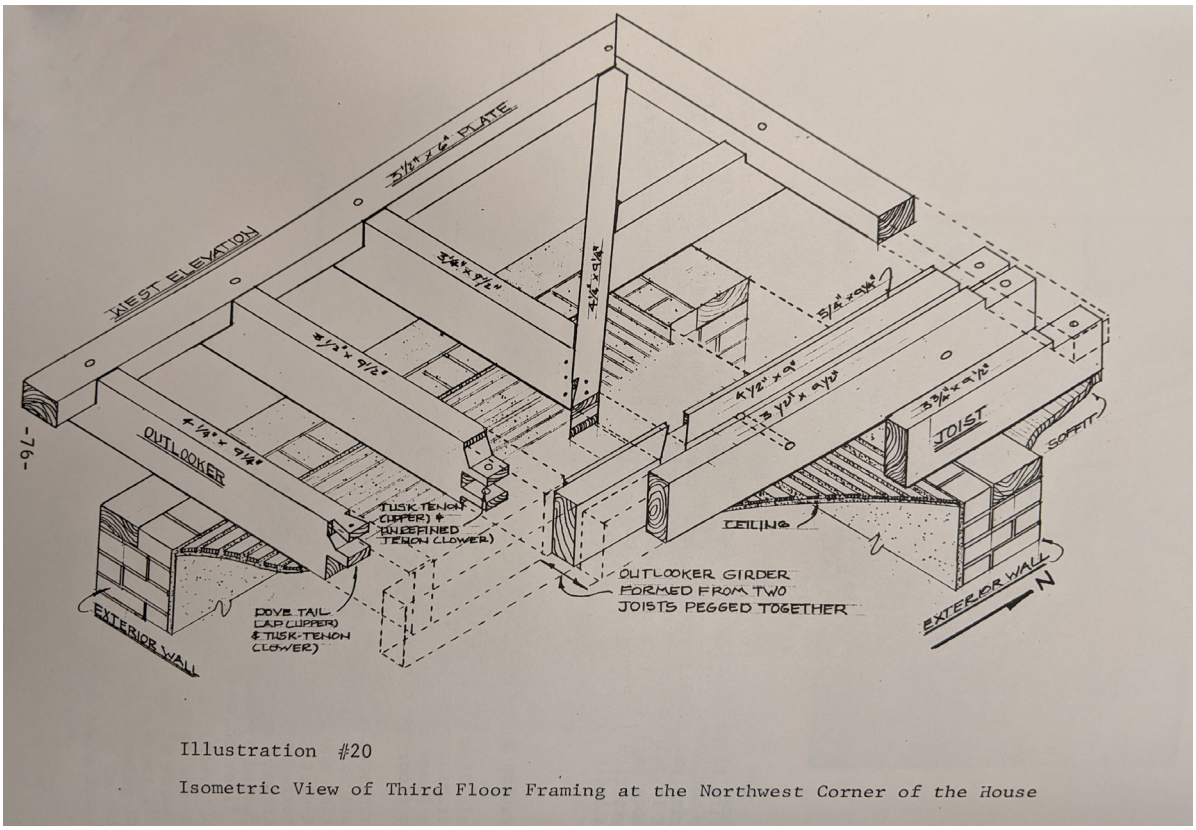


Figure 28 - Dickey layout of 3rd floor ceiling joists from outlooker to plate. Source: Stenton HSR

Dormer Investigation:

Due to accessibility restrictions, only the southwest and northwest elevation dormers were available for hands-on condition assessment, the other elevation dormers were assessed visually. The two flanking dormers on the southwest side appeared to be new, and the middle one found to be sound and recently patched, likely during the contemporaneous roofing procedures. The two southeast dormers also appeared to be new, as did those on the northeast elevation. The ones on the northwest side had signs of rot and deterioration, however the roofers had not yet reached that area during MC observation. If they were not replaced or fitted with a dutchman repair during the reroofing procedures, it is recommended that this be completed. More pressingly, the window sashes themselves appeared to require conservation work, particularly on the southern sides. Failing and missing glazing, wood deterioration, slight member racking, and general paint failure were noted. A sash on the southeast elevation appeared to be missing a pane of glass altogether. Again, if these conditions were not addressed during the final stages of the reroofing process, it is highly recommeneded that these sashes recieve conservation attention.

Figure 29 - (top) West dormer sill on SW elevation

Figure 30 - (middle) Central dormer sill on SW elevation

Figure 31 - (bottom) East dormer sill on SW elevation

Figure 32 - Dormers on SE elevation

Figure 33 - Dormers on NE elevation

Figure 34 - Dormers on NW elevation

Figure 35 - Failing paint and glazing on east window of SW elevation

Figure 36 - Missing pane of glass on SE elevation indicated by red arrow

Marriage Marks:

Molds were made of the visible marriage marks on the rafters on the northwest side of the roof framing. These marks were created by a timber scribe also known as a race knife (Figure 37) and ensured that the proper partners of each matched pair went back together in the final construction after joinery elements were crafted. All marks were recorded at the same elevation and were on consecutive rafters.

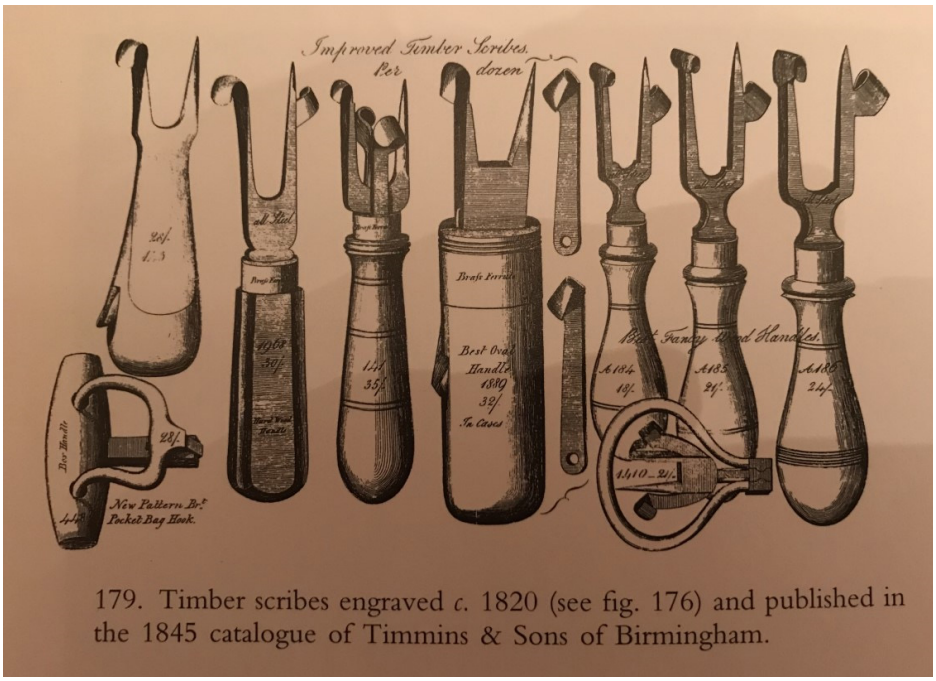


Figure 37 - Examples of timber scribe race knives. Source: Building the Georgian City by James Ayres.

Figure 38 - Elevation of marriage marks locations denoted with red arrow.

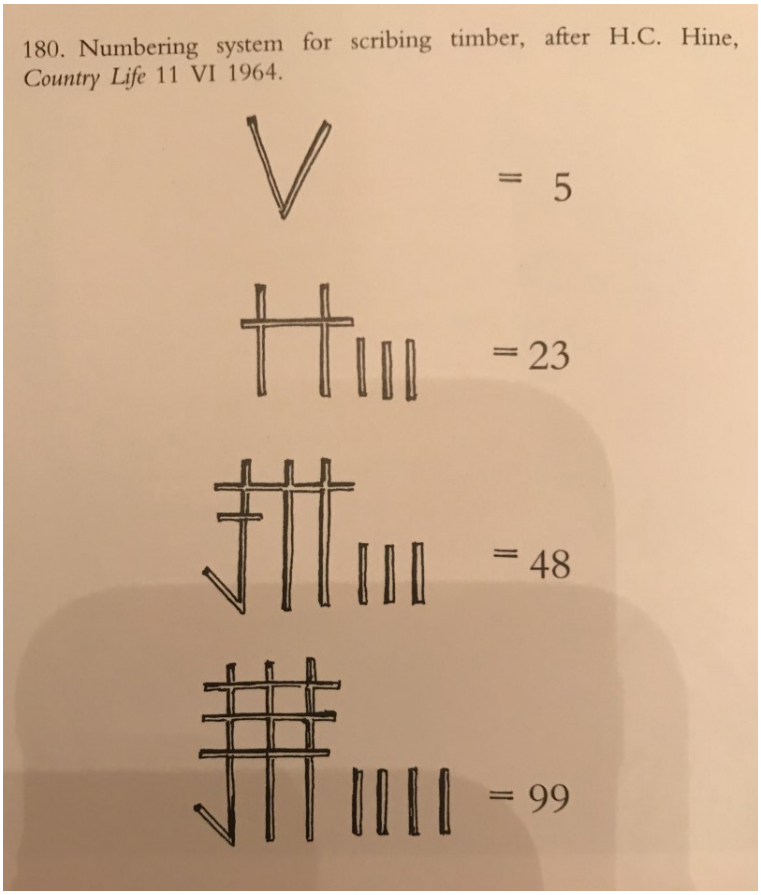
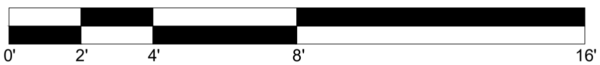
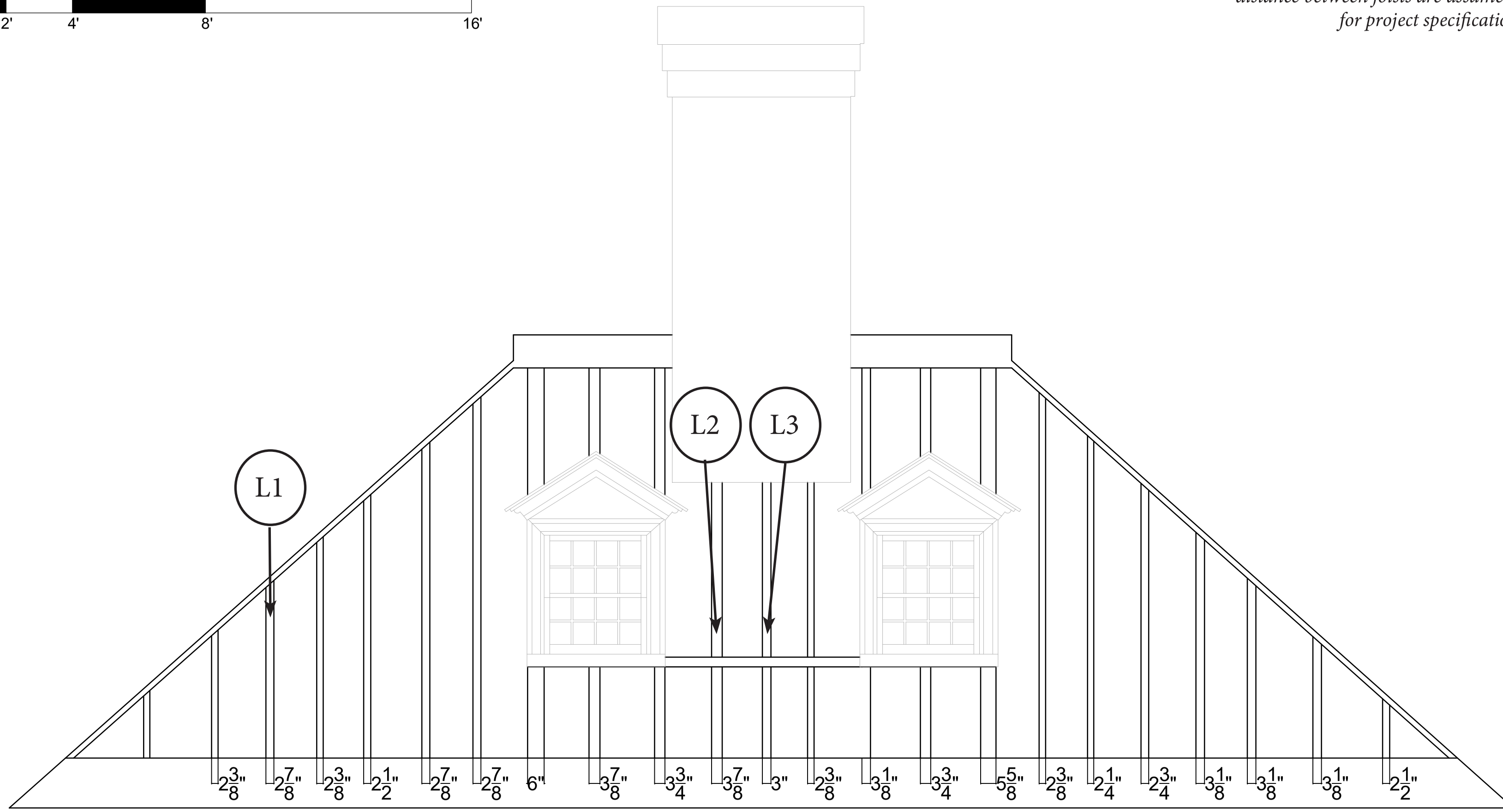


Figure 39 - Numbersing system used in timber scribing, similar to marks found on rafters at Stenton. Source: Building the Georgian City by James Ayres.

Figure 40 - Marriage mark visible on rafter. Location 1 on subsequent drawing.



Note: All dimensions except joist width and distance between joists are assumed, not to be used for project specifications



MM1 - L1

MM2

MM3

MM4

MM5

MM6 - L2

MM7 - L3

KEY
M# - Marriage Mark #
L# - Location #

MATERIALS CONSERVATION
1625 N. Howard Street Philadelphia, PA 19122

1.0

Stenton Mansion 4601 N. 18th Street Philadelphia, PA 19140
Northwest Elevation Roof Framing

March 19, 2020

Scale = $\frac{3}{16}$" = 1' 0"

MATERIALS
CONSERVATION

March 13, 2020

Laura Keim
Stenton Curator
4601 N. 18th Street
Philadelphia, PA 19140

INTRODUCTION

The following summary provides the results of a mortar analysis performed by Materials Conservation Co., LLC (MC) at the request of Laura Keim of Stenton Mansion. Two samples of pointing mortar were extracted by the MC staff from the exterior of both chimneys on the main house (house built c. 1728, chimneys rebuilt 1958) on N. 18th Street in Philadelphia, PA. Sample 1 was loose at the top of the northwest chimney and was removed by hand, sample 2 was removed with hammer and chisel from the lower portion of the southeast chimney without causing an area of possible water infiltration.

METHODOLOGY

The samples were removed by MC staff and transported to their conservation laboratory in Philadelphia, PA for analysis. The analysis included microscopic examination of the sample, dissolution of the binder using the gravimetric/acid digestion method, and characterization of the aggregate and binder components. A 14% solution of hydrochloric acid was used to perform acid digestion. Each sample was agitated for 24 hours, the fine particles filtered from the aggregate, and dried for 24 hours. Following the acid digestion of the binder, the dried aggregate was sieved to determine the distribution of particle sizes. All samples were observed under reflected visible light using a Leica MZ16 stereomicroscope.

Figure 1 - Bedding Mortar Samples

Figure 2 - Pointing Mortar Samples

SAMPLE: POINTING MORTAR FROM NORTHWEST CHIMNEY

The mortar sample is off-white in color and moderately hard. The exterior surface is weathered, with exposed aggregate grains. Microscopic examination of the sample under 10x magnification shows some very small clumps of partially dissolved lime in a moderate to dense binder matrix with similar sized aggregate particles.

Figure 3 - Sampling area on northwest chimney called out with red arrow

Acid Soluble Fraction: Approximately 26% of the total sample weight is acid-soluble. A vigorous reaction occurred when the solution of hydrochloric acid was added to the sample, indicting a mortar with a high lime content. The presence of very small lime blebs indicates the inclusion of lime in the original mix.

Fines: Approximately 3% of the total sample weight is fines, primarily light grayish brown particles.

Aggregate: Approximately 71% of the total sample weight is aggregate comprised of white, clear, orange, and gray particles that are sub-rounded to sub-angular in shape (Figure 3). Several particles of brick were visible throughout. Separation of particles by size was achieved by sieving the aggregate and weighing the quantity of particles retained on each sieve pan. Approximately 56% of the particles were retained on the 50 sieve and 19% were retained on the 30 and 100 sieves, indicating a poorly sorted aggregate with little range in particle sizes.

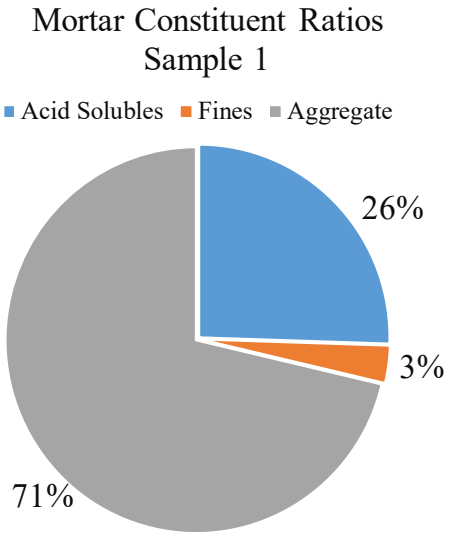


Figure 2 - Ratio of Aggregate, Fines, and Acid Solubles

The approximate reconstruction mix probably contained lime and aggregate. The aggregate is very poorly sorted. An appropriate replication mix would be a standard 3:1 aggregate to NHL 3.5 mix in a color that matches the clean pointing mortar in the body of the house. The replacement aggregate should display a more even distribution of particle sizes.

These findings are estimations and should not be used for project specifications.

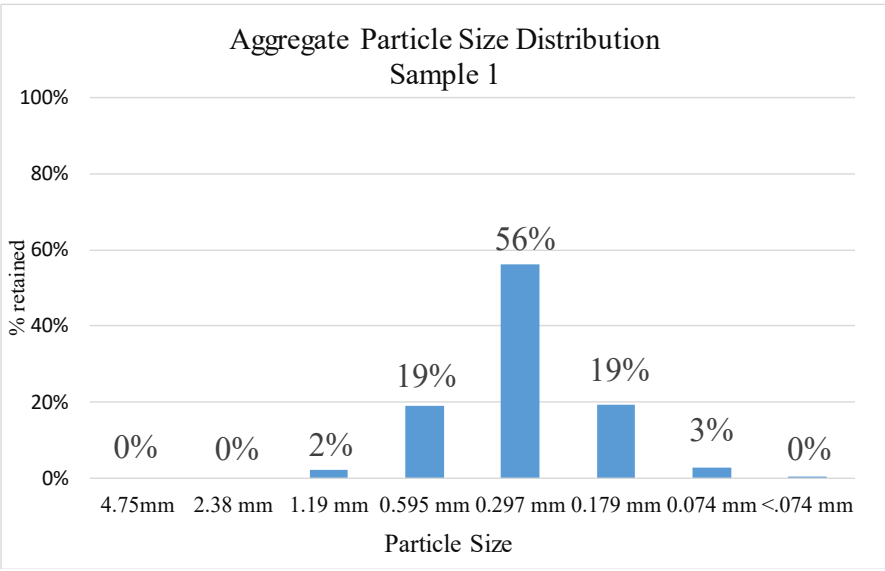


Figure 3 - Particle size distribution chart (left) and aggregate at 10x magnification (right)

SAMPLE: POINTING MORTAR FROM SOUTHEAST CHIMNEY

The mortar sample is off-white in color and moderately hard. The exterior surface is weathered, with exposed aggregate grains. Microscopic examination of the sample under 10x magnification shows some very small clumps of partially dissolved lime in a moderate to dense binder matrix with similar sized aggregate particles.

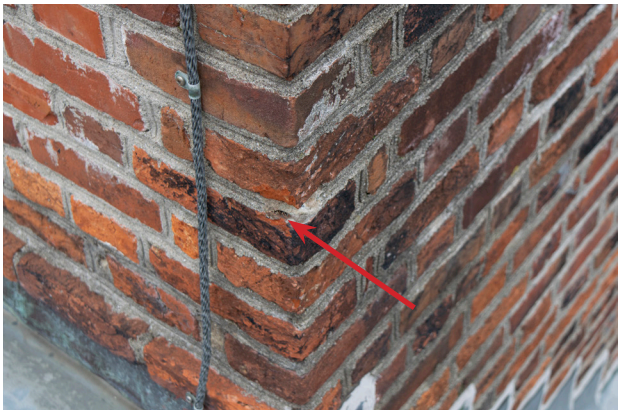


Figure 3 - Sampling area on southeast chimney called out with red arrow

Acid Soluble Fraction: Approximately 24% of the total sample weight is acid-soluble. A vigorous reaction occurred when the solution of hydrochloric acid was added to the sample, indicting a mortar with a high lime content. The presence of very small lime blebs indicates the inclusion of lime in the original mix.

Fines: Approximately 4% of the total sample weight is fines, primarily light grayish brown particles.

Aggregate: Approximately 72% of the total sample weight is aggregate comprised of white, clear, orange, and gray particles that are sub-rounded to sub-angular in shape (Figure 3). Several particles of brick were visible throughout. Separation of particles by size was achieved by sieving the aggregate and weighing the quantity of particles retained on each sieve pan. Approximately 52% of the particles were retained on the 50 sieve and 22% and 18% were retained on the 30 and 100 sieves respectfully, indicating a poorly sorted aggregate with little range in particle sizes.

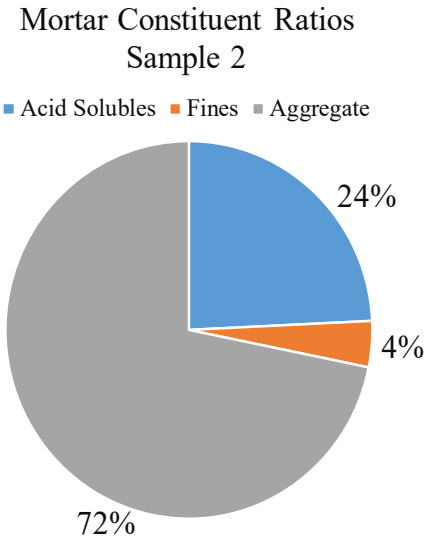
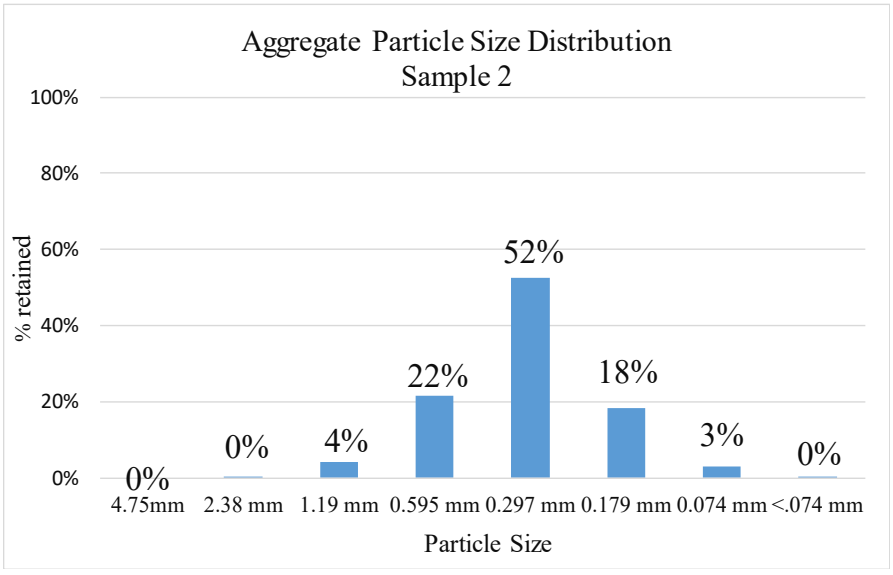


Figure 2 - Ratio of Aggregate, Fines, and Acid Solubles

The approximate reconstruction mix probably contained lime and aggregate. The aggregate is very poorly sorted. An appropriate replication mix would be a standard 3:1 aggregate to NHL 3.5 mix in a color that matches the clean pointing mortar in the body of the house. The replacement aggregate should display a more even distribution of particle sizes.

These findings are estimations and should not be used for project specifications.



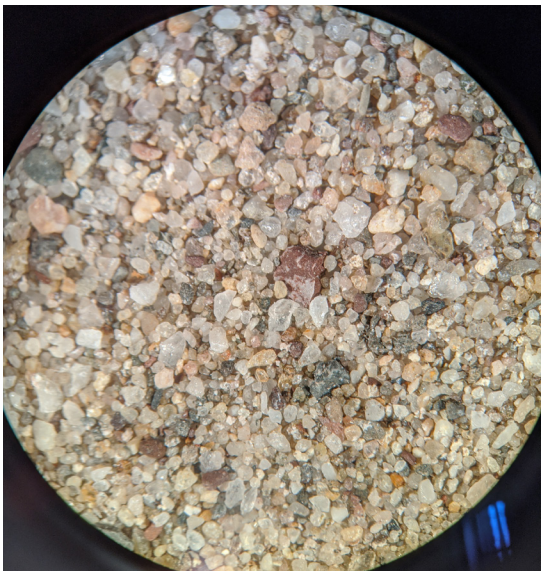


Figure 3 - Particle size distribution chart (left) and aggregate at 10x magnification (right)