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Historic Charleston Mortar and Stucco Study

An Analysis of Materials and Compositions

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This study of historic mortars and stuccoes was conducted by George Fore of George T. Fore and Associates of Raleigh, North Carolina and Raymond Pepi of Building Conservation Associates, Inc. of New York, New York. The study was initiated and administered by the Historic Charleston Foundation. This study is a is follow-up to a 1987 study conducted by George T. Fore and Associates of masonry and carpentry repair techniques of Charleston's historic structures. This latter study was made possible by the assistance of the South Carolina Department of Archives and History and the Marquette Charitable Organization.

The activity that is the subject of this study has been financed in part with Federal funds from the National Park Service, Department of the Interior, and administered by the South Carolina Department of Archives and History. However, the contents and opinions do not necessarily reflect the views or policies of the Department of the Interior, nor does the mention of trade names or commercial products constitute endorsement or recommendations by the Department of the Interior.

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In addition to the above, the consultant agrees to comply with the Age Discrimination Act of 1975, 42 U.S.C. 6101 Et. Seq. which prohibits discrimination in hiring on the basis of age.

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Introduction

The technology and practice of masonry construction has changed considerably since the early eighteenth century. The development of new manufacturing processes and the resulting change in masonry materials has been fairly steady during this period, but with several significant developments. We in the late twentieth century are separated by several generations from the technology and construction practices of the eighteenth and nineteenth centuries. When the "best" modern masonry practices, materials and techniques are applied to the buildings of this earlier period, the results are often frustrating. If one takes a walk through any of Charleston's historic districts one will encounter masonry buildings with significant changes in their original appearance, more rapid deterioration of the masonry in repair areas and the spreading of the deterioration to surrounding areas of masonry.

The masonry construction techniques and styles of Charleston's historic buildings are quite broad (Illustrations 1 through 10). Just as the architectural styles of the buildings vary, so do the mortars and stuccoes. A pointing mortar mix of the early eighteenth century may well be inappropriate for the repair of a masonry structure of the early nineteenth century. This is often confusing to the builder, owner or architect, for the mortars, upon close examination, appear to be indistinguishable from one another. But the distinction between the various mortars and stuccoes is an important factor in the preservation of historic structures. Beyond the important cosmetic function of pointing mortars and finish stuccoes are their mechanical functions of moisture dissipation and stress absorption. If a change is made in the original relationship between the masonry units and the mortar or stucco the principal purpose of the mortar and stucco may be compromised. Historically, the design of the mortar and stucco of a masonry system ensured that these materials were significantly more porous and plastic than the bricks. The purpose of this relationship was to allow all of the deterioration processes to be concentrated in those materials which were the easiest to maintain. The periodic repair of pointing mortar and stucco is considered a normal part of the maintenance of a building. In contrast, the replacement of the brick units would require the reconstruction of the affected area.

One of the solutions to the problem of maintaining and preserving our architectural heritage can be found in the understanding of the materials from which it was constructed; how the materials were manufactured, how they were applied, how they respond to various environmental and structural changes and how they respond to specific repair techniques. The following study of eighteenth and nineteenth century masonry examines the types and proportions of ingredients that were used to produce mortars and stuccoes.

Sample Selection and Analysis

The mortars and stuccoes of the eighteenth and nineteenth centuries are quite varied. The assorted binders and aggregates that are found in Charleston's mortars and stuccoes demonstrate the continuing search by the early builders to develop more durable masonry construction. The earliest mortars and stuccoes consisted of lime binders mixed with course and fine sands, ground brick and crushed oyster shells. For the most part the lime was made from the burning of oyster shells and was probably locally produced. The common mortar and stucco mixes were sometimes given a slight hydraulic quality by adding finely ground brick to the mix. In cases where a more durable mortar was required, such as pointing mortars, a hydraulic lime was used. This binder had an advantage over the non-hydraulic lime made from shells for it not only set in the presence of water but also was less resoluble.

The principal differences between the hydraulic and non-hydraulic binders is in the setting, or hardening, process. With non-hydraulic binders the lime does not react with the water. The setting of the mortar depends upon the transition of the lime putty into calcium carbonate as it reacts with carbon dioxide in the atmosphere. This reaction is somewhat slow and continues indefinitely. The hydraulic setting of mortars is a reaction between water and the complex silicates found in burned clays. This setting process occurs much quicker than the setting of non-hydraulic mortar and results in a stronger bond between the aggregate particles. The clays that were responsible for the hydraulic quality of the lime occur naturally, to varying degrees, in the limestones that were burned to make lime.

Following the discovery of natural cement stone in New York, Connecticut, Kentucky, Pennsylvania and Maryland in the 1820's and 1830's the use of fully hydraulic natural cement became widespread. This new binder had been available from Europe since the 1790's, but before a more local source was discovered its use had been reserved for the more costly projects. Natural cement stuccoes were used on many Charleston buildings from the 1830's until the late nineteenth century, the most notable examples being St. Philip's Church and the City Market (Illustration 8).

The thirty-two mortar and stucco samples listed in "Mortar and Stucco Samples: Location and Description" represent the major catagories of material composition and sample types that have been identified in Charleston. Samples one through ten are lime-rich pointing mortars of the eighteenth and nineteenth centuries. For the most part these consist of moderately hydraulic lime putties with the addition of relatively small amounts of aggregates. The second group of mortars, eleven through fifteen, are lime bedding mortars. These are similar to the pointing mortars, but contain lower levels of lime and a higher proportion of aggregates. The component materials of the lime stuccoes of samples sixteen through twenty-one are more equally proportioned than the lime pointing mortars. The natural cement mortars and stuccoes of samples twenty-two through twenty-four and twenty-five through thirty-two contain a much higher proportion of hydraulic materials than the lime-based samples above. These latter samples are all from the first half of the nineteenth century and reflect the developing technology of cement production.

The technology of analyzing existing mortars has paralleled the development of the cement manufacturing industry. As portland cement and fully hydrated limes replaced natural cement and hydraulic limes the standards for mortar analysis were altered to reflect the characteristics of the new products. Today, all of the American Society for Testing and Materials standards for analyzing binders are designed to detect the quantity or quality of portland cement within mortars. The results of these tests have proven to be quite deceptive when applied to lime-rich or natural cement mortars. Presently there are no standard or accepted methods for fully analyzing the composition of historic mortars.

One method of historic mortar analysis that has been widely applied is that of E. B. Cliver, as described in the Bulletin of the Association of Preservation Technology, Vol. VI, No. 1, 1974. This technique has been used by the National Park Service, many of the state historic preservation offices and conservators in private practice. The test method involves the measurement of the differential weights of a mortar sample before and after its treatment with hydrochloric acid. This technique assumes that the difference in the weights is directly proportional to the calcium carbonate content of the original sample. In practice, this technique has proven to be quite unreliable in analyzing the components of eighteenth and nineteenth century mortars. This can be demonstrated by applying the method to samples of car fully prepared mortars that have been cured in controlled conditions. The results are consistently inaccurate. As reported by Stewart and Moore in 1981 the Cliver method of analysis was shown to be inaccurate in all of their prepared sample tests. The range of error in these tests was from 31% to 238%.

The most serious problem with the simple acid dissolution tests is with those catagories of materials which they cannot detect. If historic mortars contained only varying proportions of lime, clay and sand this type of test could show the approximate proportion of the components. But in addition to these materials most eighteenth and nineteenth century mortars contain varying amounts of soluble complex silicates which can account for a significant portion of the binder mechanism. In the Cliver test the complex silicates dissolved by the hydrochloric acid cannot be distinguished from the calcium carbonate in the sample.

A simple test for the semi-quantitative analysis of ancient mortars has been used for several years in archaeological studies to demonstrate patterns of material use. This technique has been shown to be quite useful in distinguishing between four mortar components; calcium carbonate, acid solubles, clay and aggregate. The chief developer of this technique was Hanna Jedrzejewska of Poland. Several papers have been published on this technique, including its comparison with the Cliver and ASTM methods by Stewart and Moore.

A variation of the Jedrzejewska method was employed in the analysis of the samples in this study. The ground and dried samples were placed in an enclosed reaction vessel. To the top of the vessel was fitted a reservoir to hold a 25% solution of hydrochloric acid. The only outlet from the vessel was through a hose connected to a 250ml gas burette and water reservoir. The resulting production of carbon dioxide by the reaction of the hydrochloric acid with the sample was measured by noting the relative change in water level in the burette. The volume of the carbon dioxide was converted into the weight of the calcium carbonate by using a conversion standard of one gram of calcium carbonate equal to 222.615 cubic centimeters of carbon dioxide. The weights of the clay and sand portions of the sample were determined by gravimetry. The remaining portion of the sample, that which could not be recovered, were the soluble complex silicates. Thus, by determining that portion of the sample weight loss which was a result of the reaction of the acid with the calcium carbonate the other proportions of the original mortar could be determined.

Analysis Data and Interpretation

The results of the mortar and stucco analyses are recorded in Table 2. The proportions of the four principal components of the samples are given in both weight and volume ratios. Although the volumetric proportions of formulas are the most familiar form of ingredient comparisons the weight comparisons of Chart 1 demonstrate the formula differences between the lime mortars and stuccoes with low hydraulic qualities and the very hydraulic mortars and stuccoes produced by the natural cements. As one would expect the eighteenth and early nineteenth century samples contain a high proportion of lime. The percentages of lime proportion are somewhat higher than previously reported. Most of the lime pointing mortars contain 74% to 88% lime by volume. The lime stuccoes contain 58% to 72% lime by volume. The presence of significant levels of soluble complex silicates in several of the samples indicates that the lime mixes were slightly to moderately hydraulic. Those mixes containing less than ten percent solubles can be said to be non-hydraulic. Those mixes containing greater than ten percent solubles, and particularly above twenty percent, can be said to be moderately hydraulic.

The analysis of the natural cement stuccoes and mortars also showed the expected tendencies of the lime content. The mechanism of natural cement binding is somewhat different than that of the lime formulations. The level of complex silicates represents a much higher portion of the mix than that found in the slightly hydraulic lime mortars. In several of the natural cement stuccoes the weight of the solubles content exceeds that of the calcium carbonate content. The high level of the calcium carbonate by volume is accounted for by the addition of lime to the original natural cement mix in order to make the stucco more workable.

The interpretation of the formulations of Table 2 must be made in the context of the known performance qualities of modern materials. The lime-rich formulations of the first twenty-one samples are well beyond the performance ability of present day manufactured lime. The early tradesman often slaked and stored the lime materials at each project site. The freshly prepared lime paste could be mixed with relatively small amounts of clay, brick dust and sand. These mixes, if made in the same proportions using modern materials, would be considered unworkable .

Table 3 contains recommended mixes that approximate the lime, solubles and brick dust content of the original formulas. The principal differences between the original and recommended formulas are the addition of white portland cement in the place of the solubles content and the significant increase in the proportion of sand. The setting characteristics of fully hydrated lime requires an aggregate portion of at least twice the volume of the binder portion. Even at this some of the mixes may prove to be too rich in lime. It is recommended that fine, ungraded sands of a rounded shape be used in order to increase the binder volume of the lime putty pointing mortars. The solubles and brick dust, or clay, content of the mixes are responsible for the slight hydraulic quality of the mortars and stuccoes. White portland cement, being approximately fifty percent complex silicates and calcium hydroxide, is suggested as a substitute for the hydraulic component of the formulas. The proportion of brick dust has been left in the recommended formulas. The brick dust will act as a pigment, so the choice of brick color for producing the dust should be considered. In calculating the reproduction formulas care was taken to be conservative in estimating the equivalent amounts of solubles and portland cement. The cement will not have the exact same effect on the setting of the mix as did the solubles.

The recommended reproduction formulas of the natural cements should be interpreted with caution. The substitution of white portland cement for the natural cement portion of the original formulation cannot reproduce the same working characteristics, density, texture or durability qualities of the historic materials. Density and water absorption tests would be required before the long term effects of these mixes could be determined. These mixes may be used as a beginning point for reproducing the specific qualities of the natural cements. One might find some success by substituting other hydraulic-producing materials for a portion of the portland cement. These include high temperature insulation clay (HTI) and pulverized fly ash (PFA).

Although natural cements are no longer available one commercially available mortar material should be mentioned. The Jahn Restoration Techniques and Research Company of Holland produces a series of reproduction mortars that are formulated from natural cement. Presently this is the only known source of any product containing natural cement.

Conclusions and Recommendations

Though the range of samples included in this study of Charleston mortars are quite wide one should not assume that they represent the full breadth of variations within each category. Several hundred samples would be required to be truly representative of Charleston's mortars and stuccoes. And each of these in turn would have to be duplicated to ensure reliable analyses. Although the results of this study can be directly applied to the current preservation efforts in Charleston, it is recommended that the study be expanded by a continuing program of analysis that will add to the data. A follow-up analysis by the Metropolitan Museum of Art in New York using petrographic techniques is planned in the near future.

Several significant observations can be made concerning the mortars and stuccoes analyzed in this study. The lime-rich pointing mortars of samples one through ten were found to contain a much higher proportion of lime than had been previously identified. The level of burned clays in all of the lime pointing, bedding and stucco samples showed that these formulas were slightly to moderately hydraulic. Likewise, the complex silicates identified in the natural cement samples were shown to be a principle constituent of the binder in several of the samples.

Caution was used in making recommendations based on the formulations listed in the Analysis Data. The recommended reproduction mortars should prove to be at least as porous as the original formulations, thus ensuring that the repairs will not increase the stress in the bricks. Although the natural cements, solubles, clays and the hydraulic and non-hydraulic limes do not directly correspond to modern manufactured materials, this does not preclude the use of modern materials in the repair of historic buildings if their performance characteristics can be equated with those of the historic mortar and stucco formulas. The two most important characteristics of historic stuccoes and mortars has been observed to be their relatively high porosity and elasticity as compared to that of the associated brick units. If this performance relationship between the mortar and bricks can be maintained then the preservation of the construction can be assured.

Due to the time restrictions of this study the recommended formulas could not be prepared for evaluation. The assessment of the long term performance of the recommended restoration mixes will require their careful formulation in a laboratory. The porosity of the cured mortars and stuccoes should be measured to determine the effect of the addition of higher proportions of hydraulic materials. Though this evaluation could not be performed for this study the formulas can be used with some confidence for most of the recommended reproduction formulas fall within the range of formulas that have been used in the successful repair of historic structures.

Table 1: Mortar and Stucco Samples: Location and Description

1. Mulberry - Lime Pointing Mortar, Water Table Rubbed Bricks, 1714
2. Middleton Place Ruin - Lime Pointing Mortar, ca. 1740
3. 131 Church Street - Lime Pointing Mortar, South Elevation, ca. 1809
4. Nathaniel Russell House - Lime Pointing Mortar, East Elevation, 1811
5. Aiken Rhett House - Lime Pointing Mortar, South Elevation, 1817
6. Aiken Rhett, Dependency - Lime Pointing Mortar, 1817
7. 82 Pitt Street - Lime Pointing Mortar, West Elevation, 1840

8a 16 Charlotte Street Gate Post - Tuckpointing Mortar, 1834-40
8b 16 Charlotte Street Gate Post - Pigmented Dark Mortar, (from 8a)
9. 16 Charlotte Street Fence - White pointing Mortar
10a #9 East Battery - Pigmented Dark Mortar, 2nd Floor East Elevation, ca. 1838
10b #9 East Battery - Tuckpointing Mortar (from 10A), 2nd Floor East Elevation

11. Middleton Place Ruin - Lime Bedding Mortar, ca 1740
12. 60 Tradd Street, Garden Party Wall - Lime Bedding Mortar, East Elevation, 1726
13. 54 Tradd Street, Kitchen Building - Lime bedding Mortar, North Elevation, ca. 1740
14. St. Michael's Tower - Lime Bedding Mortar (below ridge line), 1761
15. Middleton Place, Rice Mill - Lime Bedding Mortar, Hydraulic Lime, ca. 1800

16. Brick House, Edisto - Lime Stucco, Quoins, ca. 1725
17. Brick House, Edisto - Lime Stucco, Niche Decoration, ca. 1725
18. 54 Tradd Street, Kitchen House - Lime Stucco, North Elevation, ca. 1740
19. 60 Tradd Street - Lime Stucco, East Elevation Quoin, 1726
20. Manigault Gatehouse - Lime Stucco, South Elevation, ca. 1802
21. 2nd Scots Presbyterian Church - Lime Stucco, North Elevation, 1811

22. 328 East Bay - Natural Cement Pointing Mortar, West Elevation, 1838
23. Bennet Rice Mill - Natural Cement Pointing Mortar, 1844
24. #9 Limehouse - Natural Cement Pointing Mortar, Scored and Pencilled, 1856

25. St. Philips Tower Base - Natural Cement Stucco, Torus Molding East Elevation , 1839
26. City Market - Natural Cement Stucco, West Elevation, 1841
27. Dock Street Theatre - Natural Cement Stucco, 2nd Floor East Elevation, ca. 1835
28. Aiken Rhett House - Natural Cement Stucco, South Elevation, 1835
29. Aiken Rhett House - Natural Cement Stucco, Art Gallery North Elevation, 1858
30. 8 Meeting Street - NaturalCement Stucco, ca. 1850
31. City Jail, Magazine Street - Natural Cement Stucco, North Elevation, ca. 1850
32. 6 Chalmers Street, Slave Market - Natural Cement Stucco, South Elevation, 1859

Table 2: Charleston Mortars and Stuccoes
Analysis Data

Sample Number	*Sample Weight	Sand Weight	Fines Weight	**Gas Displacement	%Lime	% Acid Soluble	% Fines	% Sand	Volume Ratios ***L : AS : C : S
1	1.00	0.05	0.10	177.50	79.74	5.26	10.00	5.00	24 : 0.08 : 2 : 1
2	2.00	0.80	0.20	182.50	40.99	9.00	10.00	40.00	7.7 : 0.9 : 1 : 5
3	2.00	0.10	0.20	290.00	65.14	19.86	10.00	5.00	19 : 3 : 2 : 1
4	2.00	0.10	0.50	280.50	63.01	6.99	25.00	5.00	18.6 : 1 : 4 : 1
5	2.00	0.10	0.05	277.50	62.33	30.17	2.50	5.00	18 : 4.7 : 0.5 : 1
6	2.00	0.20	0.05	279.50	62.78	24.71	2.50	10.00	9.3 : 2 : 0.2 : 1
7	2.00	0.20	0.30	285.00	64.02	10.98	15.00	10.00	9.5 : 0.7 : 1 : 1
8a	2.00	0.10	0.40	282.50	63.46	11.54	20.00	5.00	18.8 : 1.8 : 3 : 1
8b	2.00	0.10	0.50	282.50	63.46	6.54	25.00	5.00	18.8 : 1 : 4 : 1
9	2.00	0.10	0.50	292.50	65.70	4.30	25.00	5.00	13.1 : 0.7 : 4 : 1
10a	2.00	0.40	0.50	155.00	34.82	20.18	25.00	20.00	3.3 : 1 : 1.3 : 1.3
10b	2.00	0.10	0.40	292.50	65.70	9.30	20.00	5.00	13 : 1.5 : 3.2 : 1
11	2.00	0.90	0.20	182.50	40.99	4.00	10.00	45.00	7.7 : 0.4 : 1 : 5.7
12	2.00	1.10	0.40	92.50	20.78	4.22	20.00	55.00	1.9 : 0.2 : 1 : 3.5
13	2.00	0.40	0.50	235.00	52.79	2.21	25.00	20.00	3.9 : 0.1 : 1 : 1
14	2.00	0.50	0.40	270.00	60.65		20.00	25.00	****
15	2.00	1.50	0.40	137.50	30.89		20.00	75.00	****
16	2.00	0.60	0.10	202.50	45.49	19.51	5.00	30.00	16.8 : 3.8 : 1 : 7.5
17	2.00	1.10	0.20	150.00	33.69	1.31	10.00	55.00	16.3 : 0.1 : 1 : 7
18	2.00	0.50	0.20	242.50	54.47	10.53	10.00	25.00	12 : 1 : 1 : 3.2
19	2.00	0.30	0.30	272.50	61.21	8.79	15.00	15.00	7.6 : 0.6 : 1 : 1.3
20	2.00	0.50	0.30	287.50	64.58		15.00	25.00	****
21	5.00	2.80	0.80	252.50	22.69	5.31	16.00	56.00	2.7 : 0.3 : 1 : 4.4
22	5.00	2.40	0.50	260.00	23.36	18.64	10.00	48.00	4.4 : 1.8 : 1 : 6
23	2.00	0.40	0.50	142.50	32.01	23.00	25.00	20.00	2.4 : 0.9 : 1 : 1
24	5.00	2.20	0.80	287.50	25.83	14.17	16.00	44.00	3 : 0.9 : 1 : 3.5
25	5.00	2.80	0.40	262.50	23.59	12.41	8.00	56.00	5.5 : 1.5 : 1 : 8.9
26	5.00	2.10	0.50	235.00	21.11	26.88	10.00	42.00	3.9 : 2.7 : 1 : 5.3
27	5.00	4.30	0.40	130.00	11.68		8.00	86.00	****
28	5.10	2.30	0.60	97.50	8.59	34.55	11.76	45.10	1.4 : 2.9 : 1 : 4.8
29	5.30	2.40	0.40	242.50	20.56	26.61	7.55	45.28	5 : 3.5 : 1 : 7.5
30	5.00	2.60	0.80	240.00	21.56	10.44	16.00	52.00	2.5 : 0.6 : 1 : 4.1
31	5.00	3.50	0.10	162.50	14.60	13.40	2.00	70.00	3.4 : 1.5 : 0.25 : 10.9
32	5.00	3.10	0.70	277.50	24.93		14.00	62.00	****

*All weights given in grams

**Gas displacement given in ml

***Lime : Acid Soluble : Clay : Sand

****Sum Greater than %100

Chart 1. Distribution of Component Materials

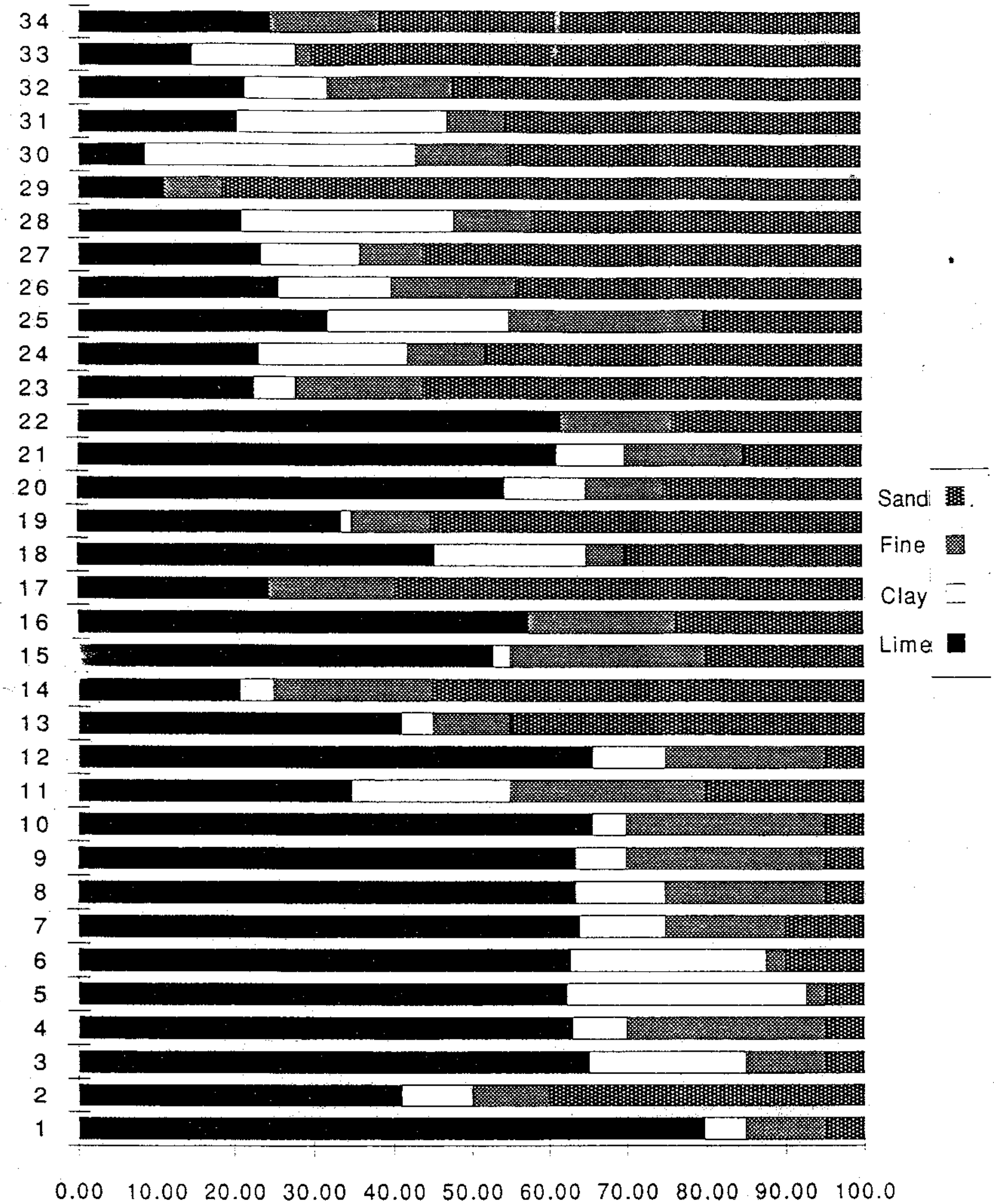
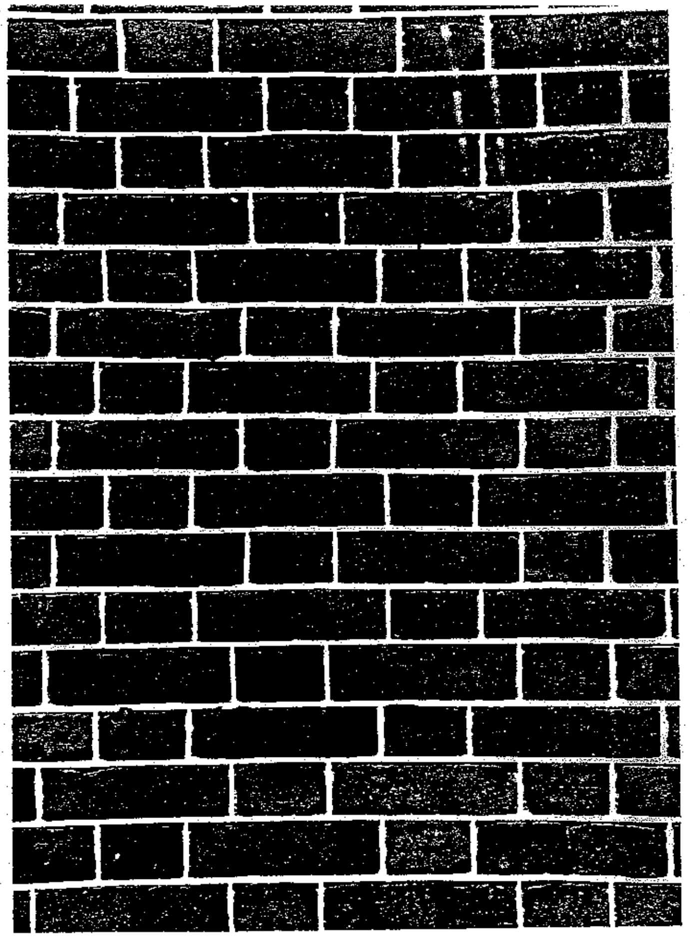


Table 3: Data Interpretation

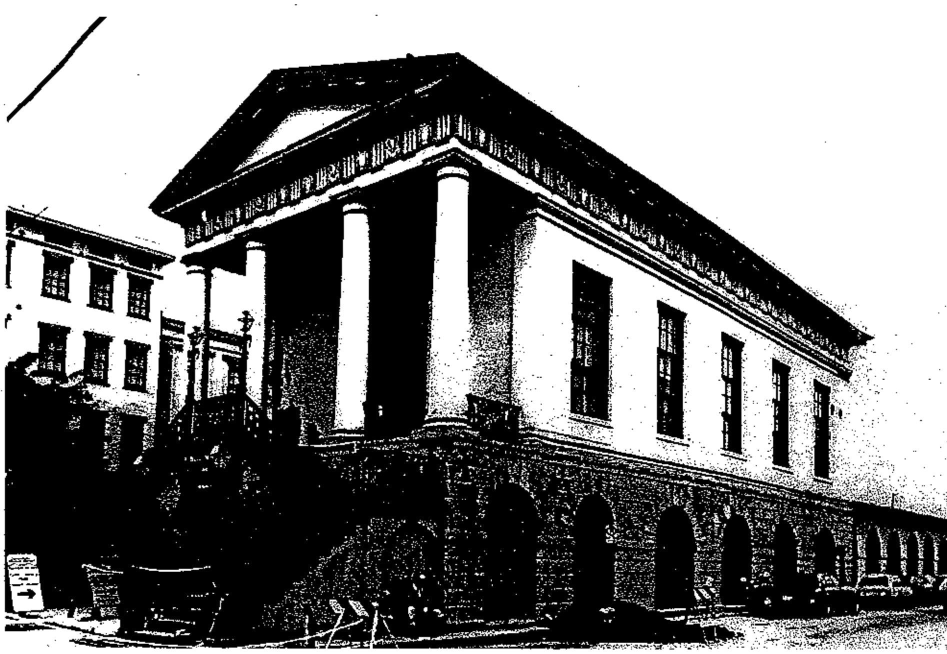
Sample Number	Volume Ratios ***L : AS : C : S	Interpretation Formulas Lime : Portland : Brick Dust : Fine Sand
1	24 : 0.08 : 2 : 1	12 : 0 : 1 : 26
2	7.7 : 0.9 : 1 : 5	7.5 : 0 : 1 : 17
3	19 : 3 : 2 : 1	9.5 : 1.5 : 1 : 24
4	18.6 : 1 : 4 : 1	5.5 : 0 : 1 : 11.25
5	18 : 4.7 : 0.5 : 1	4 : 1 : 0 : 10
6	9.3 : 2 : 0.2 : 1	4.5 : 1 : 0 : 11
7	9.5 : 0.7 : 1 : 1	9.5 : 0 : 1 : 21
8a	18.8 : 1.8 : 3 : 1	9.5 : 1 : 1.5 : 24
8b	18.8 : 1 : 4 : 1	4.75 : 0 : 1 : 11.5
9	13.1 : 0.7 : 4 : 1	3.25 : 0 : 1 : 8.5
10a	3.3 : 1 : 1.3 : 1.3	3.5 : 1 : 1.25 : 11.5
10b	13 : 1.5 : 3.2 : 1	8.5 : 1 : 2 : 23.5
11	7.7 : 0.4 : 1 : 5.7	7.75 : 0 : 1 : 17.5
12	1.9 : 0.2 : 1 : 3.5	4.75 : 0.5 : 2.5 : 16.25
13	3.9 : 0.1 : 1 : 1	4 : 0 : 1 : 10
14	****	
15	****	
16	16.8 : 3.8 : 1 : 7.5	4.25 : 1 : 0.25 : 11
17	16.3 : 0.1 : 1 : 7	1 : 0 : 0 : 2
18	12 : 1 : 1 : 3.2	1 : 0 : 0 : 2
19	7.6 : 0.6 : 1 : 1.3	7.5 : 0 : 1 : 17
20	****	
21	2.7 : 0.3 : 1 : 4.4	9 : 1 : 3.25 : 26.5
22	4.4 : 1.8 : 1 : 6	2.5 : 2 : 1 : 11
23	2.4 : 0.9 : 1 : 1	1.5 : 1 : 1 : 7
24	3 : 0.9 : 1 : 3.5	2 : 1 : 1 : 8
25	5.5 : 1.5 : 1 : 8.9	4 : 1.5 : 1 : 13
26	3.9 : 2.7 : 1 : 5.3	1.25 : 2.75 : 1 : 10
27	****	
28	1.4 : 2.9 : 1 : 4.8	*****
29	5 : 3.5 : 1 : 7.5	1.5 : 3.5 : 1 : 12
30	2.5 : 0.6 : 1 : 4.1	3.75 : 1 : 2 : 13.5
31	3.4 : 1.6 : 0.25 : 10.9	1.75 : 1.5 : 0.25 : 10.5
32	****	

***Lime : Acid Soluble : Clay : Sand
****Sum Greater Than %100
*****Natural cement Portion Can Not Be Equated
Conversion Factor for Natural Cement, 1 part Solubles : 1 part Calcium Carbonate



Illustrations 1 and 2. The appearance of a regular geometry in eighteenth and nineteenth century masonry is produced by the fine tooling of the mortar joints. A close examination of the masonry reveals that the bricks are actually somewhat irregular. The white lime mortar was very plastic when freshly mixed, and was easily tooled and shaped to form the various joint profiles. Shown here is an example of ribbon joint tooling from the first quarter of the nineteenth century.

Illustrations 3, 4 and 5. The appearance of a very regular geometry could be achieved by several techniques. Above, at 9 Limehouse Street, a natural cement mortar similar in color to the bricks was applied in a flush joint. The white lime "mortar joints" were painted in, or pencilled. From a distance, this created the appearance of finely tooled mortar joints. At center, at 9 East Battery, a combination of the techniques shown in Illustrations 2 and 3 was employed. The masonry was pointed with a lime mortar finished with a ribbon joint. The uneven edges of the bricks were hidden by rubbing a brick-colored mortar into the space between the brick edges and the white mortar. Below, at 16 Charlotte Street, is an example of tuck pointing. The finished appearance of this masonry is very similar to that of the example at center. The technique of tuck pointing, though, is somewhat more refined. The mortar joint was first filled flush with a brick-color, pigmented mortar. The surface of the mortar was then scored and then a fine bead of a white lime mortar was stencilled into the score line.



Illustrations 6, 7 and 8. Stucco has been a important finish for Charleston's historic buildings. It was typically used to imitate ashlar stone construction and molded stone elements, such as quoins, cornices and architraves. Many buildings of exposed brick construction were later stuccoed to conceal new additions or repairs. At top is the Manigault gate house on Meeting Street. The unpainted original lime stucco is intact above the level of the splash zone. From the courtyard of the Aiken-Rhett House, at center, can be seen the principal additions to the originally exposed-brick residence. The 1830's addition of the wing at left and the 1850's addition of the art gallery at the far right fall within the transition period when the natural cement stuccoes were beginning to replace the lime stuccoes. Both of these additions, as well as the original portions of the house, were stuccoed with the natural cement stuccoes. The 1841 City Market, at bottom, is an example of the full use of a natural cement stucco. The cornice and capitals of the Market were cut from brownstone. The stucco used on all other elements of the building was formulated to match both the color and texture of the stone. Because of its durability the stucco did not require painting.

Illustrations 9 and 10. Above is an example of the full history of the stucco materials used in the eighteenth and nineteenth centuries. The original white lime stucco has been repaired several times, first with natural cement stuccoes, seen as the dark patches, and more recently with Portland cement stuccoes, seen as the medium grey patches. It is interesting to note that the lime and natural cement stuccoes are weathering at similar rates, indicating that the two materials have similar porosity characteristics. The Portland cement stucco is somewhat more dense, as indicated by the more rapid deterioration of the surrounding lime stucco. Below is a micrograph of a nineteenth century lime stucco. The oyster shell lime used in the lime stucco mixes in Charleston was generally non-hydraulic. One way of producing this quality in the stucco was to add crushed and ground brick to the mix. In this sample the particles of brick are the medium and dark particles. The lumps of white are ground oyster shell added to "seed" the mix with calcium carbonate.