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Exterior Stuccoes as an Interpretive and Conservation Asset: The Aiken-Rhett House, Charleston, SC

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EXTERIOR STUCCOES AS AN INTERPRETIVE AND CONSERVATION ASSET: THE AIKEN-RHETT HOUSE, CHARLESTON, SC

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Though I will always be a visitor to Charleston, I will always remain one with a passionate belief that it is the most beautiful city in America and that to walk the old section of the city at night is to step into the bloodstream of a history extravagantly lived by a people born to a fierce and unshakable advocacy of their past.

Entering Charleston is like walking through the brilliant carbon forest of a diamond with light dazzling you in a thousand ways, an assault of light and shadow caused by light. The sun and the city have struck up an irreversible alliance. The city turns inward upon itself, faces away from visitors, alluringly contained in its own mystery.

- Pat Conroy
from The Lords of Discipline

Acknowledgments

The document which follows is an historical, analytical and technical analysis of the historic stuccoes which beautify and protect the Aiken-Rhett House, Charleston, SC, property of Historic Charleston Foundation, submitted to the faculty of the Graduate Program in Historic Preservation as a component requirement for the degree of Master of Science from the University of Pennsylvania, 1997.

I would like to express my deepest gratitude to Mr. Frank G. Matero, Chairperson of the University of Pennsylvania Graduate Program in Historic Preservation and supervisor of this research for providing a wealth of support, advice, insight and enthusiasm. Deepest thanks also to Mr. Jonathan H. Poston, Director of Historic Charleston Foundation's Preservation Programs Division, the reader of this thesis who encouraged and supported my research from beginning to end. I would like to sincerely thank Dr. Carter Hudgins and Mr. Thomas Savage, Historic Charleston Foundation, for their enthusiastic support of this research. I would like to acknowledge the assistance and support of Mr. James Crow, Mr. Jason Neville, Ms. Therese Munroe, Mr. Sean Houlihan, Ms. Katherine Saunders and Ms. Carol Borchert of Historic Charleston Foundation for assisting in the completion of my research. I am very much indebted to Mr. Timothy Noble for providing me access to facilities and equipment as well as the time, encouragement and enthusiasm necessary to complete this project. I would like to thank Dr. Gomaa Omar of the University of Pennsylvania Department of Geology for advice on issues mineralogical and geological, and Mr. Richard Marks of Richard Marks Restorations for on-site advice and support relating to Charlestonian building heritage.

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1.0 Introduction

The Aiken-Rhett House in Charleston, SC, listed on the National Register of Historic Places, provides historians, scholars, conservators and the public with an excellent document on urban plantation life in the ante-bellum American South, 19^{th} century building materials and the evolution of architectural style. Built circa 1818 and modified extensively in the 1830s and 1850s, its stuccoed brick walls and wraparound piazzas display distinctively Charlestonian architectural quotations while retaining forms and proportions characteristic of Federal, Greek Revival and early Victorian eras. Historically, Aiken-Rhett was home to the Aiken family and its descendants, which offered South Carolina her sons in positions such as State Representative, State Senator, Governor and United States Representative. Before the Civil War, this property was a seat of wealth and prestige, and home to South Carolina's largest slaveholding family. Today, it serves as a vehicle for interpreting nationally-significant historical perspectives, Charlestonian architectural character and historic building technology. Though appreciated and admired by generations of Charleston residents, Aiken-Rhett's potential to yield significant national historical, cultural and conservation-related information is somewhat untapped.

Because Aiken family descendants who owned the property made few major changes between 1858 and the 1970s, and because The Charleston Museum and Historic Charleston Foundation have adopted a strictly preservation-oriented philosophy ever since, Aiken-Rhett retains an unusually high degree of historic integrity. This property is a

significant historical and architectural asset which derives much of its value, character and charm from its unrestored state. Consequently, any and all activities which involve the ongoing maintenance and repair of original building materials must display the highest possible degree of sensitivity to these materials and the impression they create.

As a material unto itself, stucco has received precious little attention in characterization and conservation studies compared to its mortar counterparts. One goal of this research is to enhance the recognition of stucco as an important building component in a city where this material plays a critical role in both protecting buildings and establishing a sense of place. The relative deficiency of literature published on stucco is countered by a significant collection of property-specific studies and citywide information. A 1989 citywide survey of historic mortars and stuccoes characterized Aiken-Rhett's stucco as based on natural cement modified with lime, a mix with distinct hydraulic qualities.[1] Historic Charleston Foundation authorized a brief 1996 study confirming the structural and aesthetic failure of inappropriate stucco repairs at Aiken-Rhett and criticized the use of physico-chemically incompatible repair methods.[2]

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[1] George T. Fore, An Introductory Guide to the Repair of Charleston's Historic Masonry and Wood Buildings (Draft, Raleigh, NC: George T. Fore and Associates, 1990), 13.
[2] Pepi and Kavenagh, "Aiken-Rhett House: Charleston, SC, Draft Report of Findings (unpublished)," (New York, April, 1996).

The 19th century stucco envelope which covers significant modifications to Aiken-Rhett's brickwork is in need of attention. Cracks in brick substrate walls caused by structural inefficiency correspond to significant cracks in the stucco coat. In such areas, this material no longer serves either of its primary functions: the aesthetic function of presenting an unbroken, uniform facade and the protective function of sealing the interior from the weather. Detachment which threatens the long-term stability of historic material and poses an immediate health hazard is common. Other problematic conditions include total material loss, delamination, localized cracking due to incompatible repairs, improper color matches and regionalized efflorescence.

This study begins by assessing the importance of Aiken-Rhett's stuccoes in property-specific and regional contexts as well as the potential information which in-depth stucco analysis might yield to the field of architectural conservation. A survey of stucco on all facades establishes benchmark documentary information for the conditions of the material as of 1997. The primary focus of this research is a characterization of stucco applied during Aiken-Rhett's 1830s alterations and an evaluation of its important physical properties as a prelude to the development of a replication material which successfully approximates these properties and may be used as a compatible replication material.

In a broader context, it is very much hoped that the perspective provided by this study will present Historic Charleston Foundation, a nationally-recognized leader in the field of

historic preservation, with a significant research document and methodology for the interpretation, characterization and conservation of a building material which in many ways helps define the physical space of a city which rightfully cherishes its rich history.

2.0 Historical Significance of the Property

As an architectural form which bears witness to the lives of historically important public figures in South Carolina on the verge of the Civil War, Aiken-Rhett is significant both regionally and nationally. It expresses nuances characteristic of 19th century Charlestonian architectural style and documents the evolution of American architectural form. As a document, the property provides a wealth of interpretive possibilities historical, architectural, political, cultural and social in nature.

2.1 Description of the Property

Situated in Charleston's Mazyck-Wraggboro section at 48 Elizabeth Street, Aiken-Rhett is a three-story stuccoed brick structure with two prominent dependencies off its north

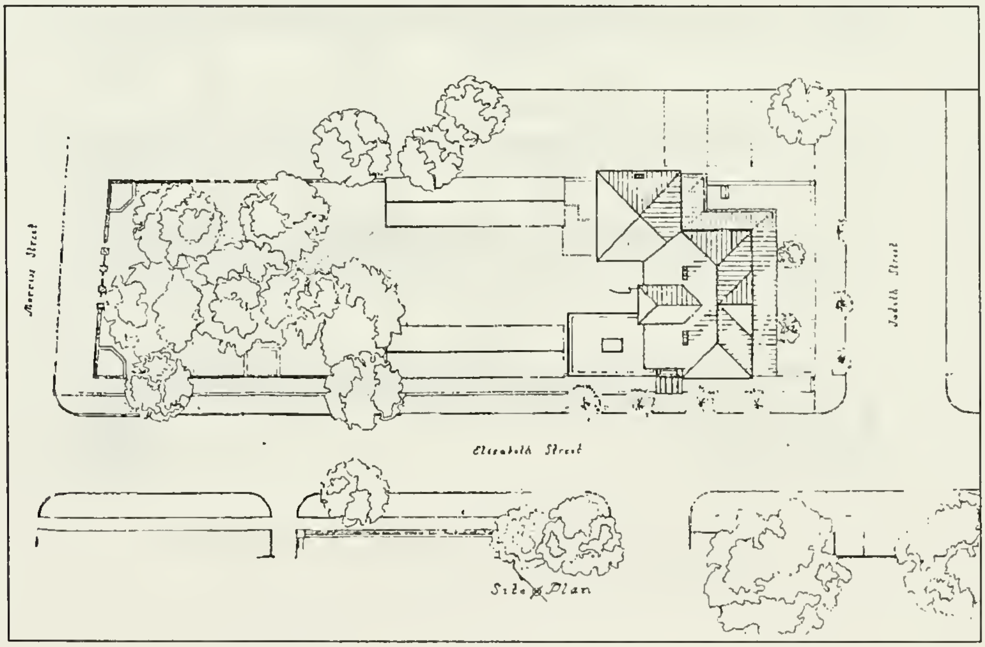

Figure 2.1. Site Plan, HABS Drawings, 1985.

elevation. The lot upon which Aiken-Rhett sits is bound on the south by Judith Street, on the west by Elizabeth Street, on the north by Morris Street, and on the east by an adjoining but unrelated property (Figure 2.1).

The south elevation (Figure 2.2) is the building's most prominent facade, and served as the main entrance prior to renovations in the 1830s. The main residence stands in two masses on this elevation, in what is essentially five bays in the house's main portion and

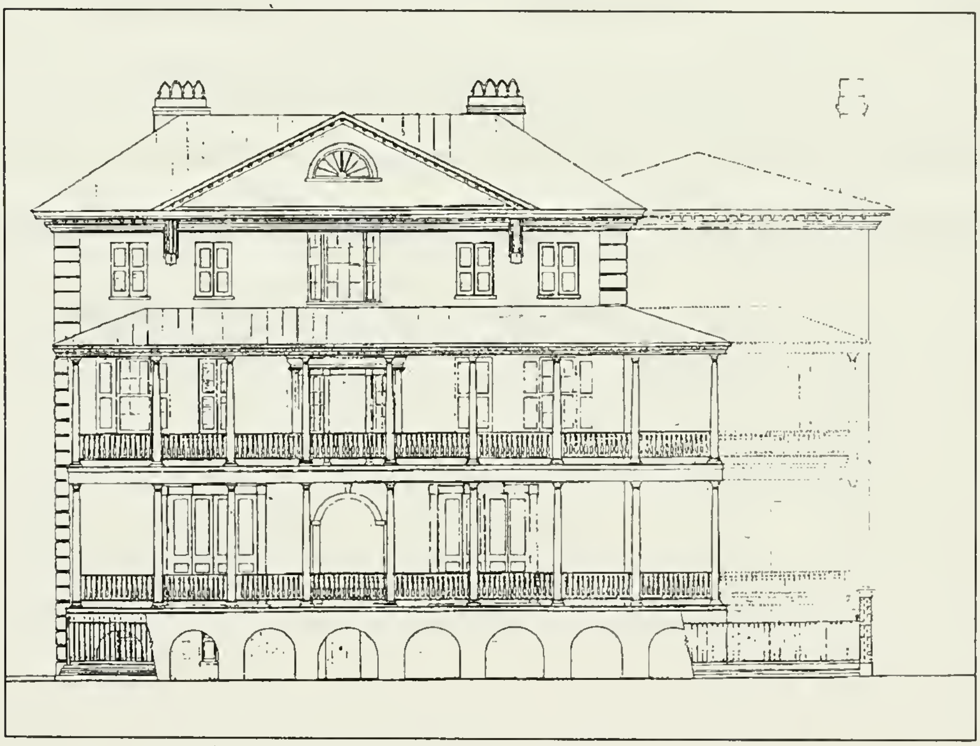

Figure 2.2. South Elevation, HABS Drawings, 1985.

one bay within an addition on the east side. Fenestration on the first floor consists of three sets of double-width doors which open onto projecting porches; there is also a round-headed niche at the center of this level. The layout of the second floor is somewhat different, with a double-width door at center and two 6-over-6 windows on either side; as on the first floor, a double-width door exists on the addition. Fenestration at the third floor level consists of windows arranged in seven bays. Among the most notable features of the south facade is a double-level Doric order piazza, a characteristic Charlestonian element which provides ventilation in a warm, muggy climate; these porches wrap around the entirety of the main residential structure to front the addition as well. A dentillated cornice articulates the top level of the piazza course, which is sheltered by a red metal roof. Dentils and decorative scrolls adorn the third floor cornice, above which projects the hipped roof of the attic level with a semicircular fan window. Atop the hipped roof project two chimneys sheltered by Charleston rain hoods.

The west elevation (Figure 2.3) now provides entry to the building from an arched doorway with decorative iron grill work at street level. The main residence is essentially four bays wide, with a double-wide window similar to those on the south facade at first floor level, and four 6-over-6 windows on both the second and third story levels. A stuccoed brick art gallery addition with a rusticated base and quoins is an 1850s addition to the main residence.

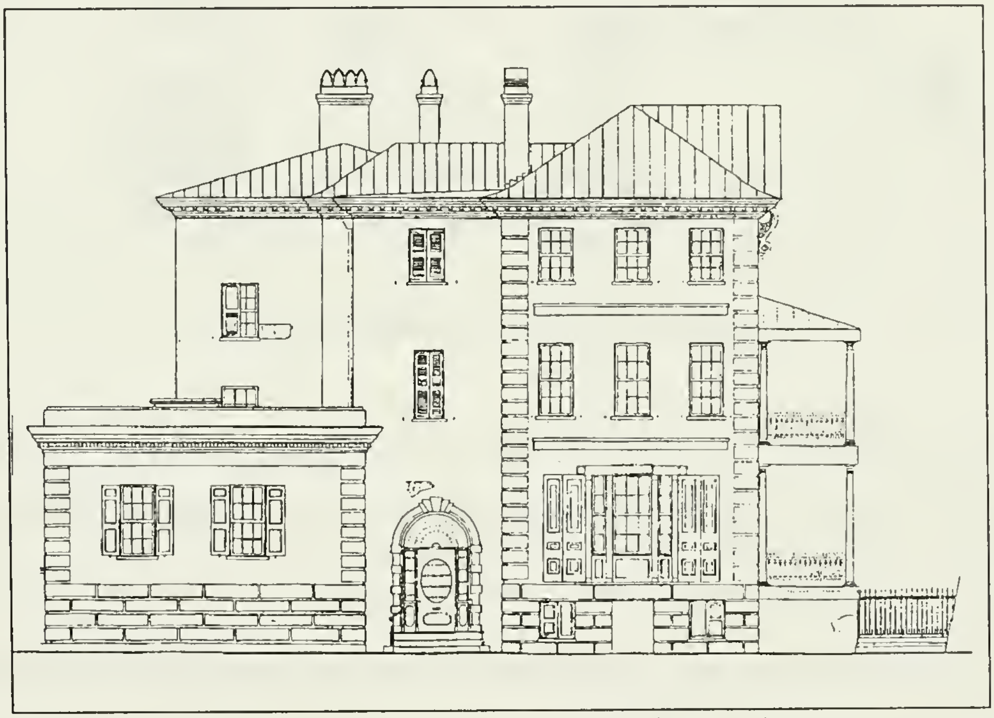

Figure 2.3. West Elevation, HABS Drawings, 1985.

The north facade (Figure 2.4) of the building consists of a series of asymmetrically-arranged window and door openings which overlook a rear courtyard. A sandstone

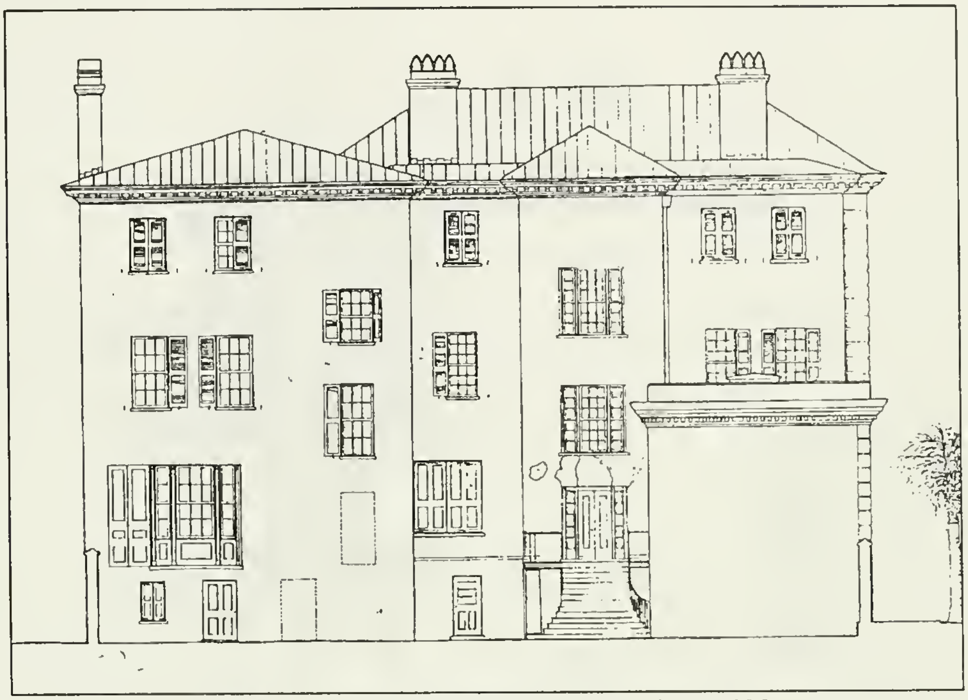

Figure 2.4. North Elevation, HABS Drawings. 1985.

staircase provides entry from the courtyard to the first floor level of the main residence, with auxiliary entrances through three doorways at ground level. Without exception, fenestration consists of 6-over-6 double hung sash windows at various positions. Detached from the north facade of the main residence are two dependencies, a two-story service and stable building with gothicized apertures on the west side of the courtyard, and a two-story slaves' quarters building along the east perimeter of the courtyard; each dependency features stuccoed brick construction.

The building's east facade (Figure 2.5) is a predominantly windowless span which abuts an adjoining property and is inaccessible except in areas which adjoin the piazzas.

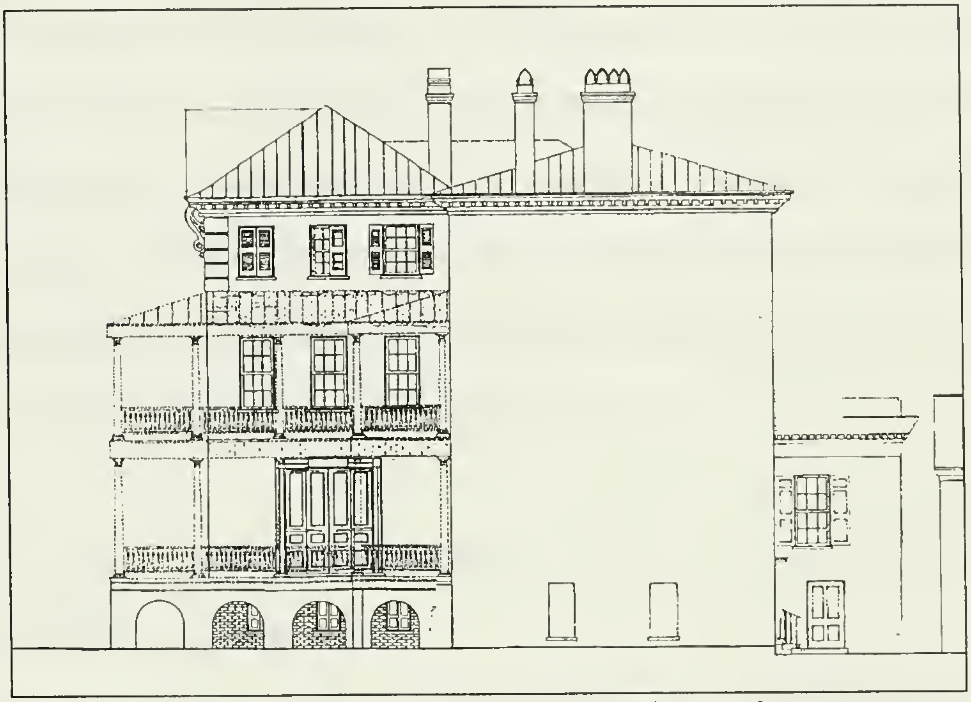

Figure 2.5. East Elevation, HABS Drawings, 1985.

Inside, a monumental entrance hall on the first story pronounces a vaulted ceiling and cantilevered marble staircase. The first floor landing is supported by two Doric columns and is embellished with heavy cast iron decorative panels. Double drawing rooms occupy the bulk of floor space on the first level, exhibiting mahogany sliding doors which divide them, ornamental cornices, decorative ceiling medallions, black marble mantelpieces, crystal chandeliers, and hand-painted decorative wallpaper. The building's main staircase at the rear of the first floor connects this level with all above stories. The addition at the

northeast corner of the first floor boasts a lengthy dining room replete with decorative features akin to those in the drawing room, as well as a central plaster ceiling medallion. At the northwest corner of the first floor is an art gallery, added in 1858, consisting of one room with an ornate cornice composed of fruit and acanthus leaf motifs; here a four-sided raised skylight allows natural light to filter in from above. The second story features decorative plaster cornices, paneled doors and wainscoting and remains basically intact from the original period of construction. The third floor is relatively simple in comparison with the more ornate lower levels of the building.[3]

2.2 Ownership and Building Morphology

2.2.1 John Robinson, 1818-1827

John Robinson, a Charleston merchant and housing speculator,[4] purchased the lot on the northeast corner of Judith and Elizabeth Streets in December, 1817 and constructed a spacious three-and-a-half story mansion shortly thereafter. It was a brick structure which displayed elements within the canons of the Federal style, symmetric and stately with suitably accessible public spaces on the first floor and more private areas on upper levels.

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[3] South Carolina Department of Archives and History, *National Register of Historic Places Inventory-Nomination Form: Governor William Aiken House, Robinson-Aiken House* (Columbia, SC, 1977), Section 7. The description of the interior of the Aiken-Rhett house is largely adapted in form and verbiage directly from the National Register nomination. Because this survey focuses primarily on an exterior material, a more careful examination of the building's outside is warranted.

[4] Allen Freeman, "Faded Glory," *Historic Preservation* (Washington, DC: The National Trust for Historic Preservation, October, 1995), 76.

Robinson constructed the south facade as the primary elevation, with a large center hall and staircase opening onto Judith Street.[5] Exemplifying the elegance of the interior, semi-elliptical fan light doorways opened from the staircase on both the first and second floor landings, creating symmetrical interior spaces on either side on the feature.[6] Prior to 1826, the mansion had acquired characteristic Charleston piazzas across its south facade.

Robinson's tenure of the property was relatively short, spanning less than a decade. Most accounts indicate that he encountered financial difficulties which forced him to put the property up for sale.[7] By September, 1825, Robinson had offered the building to prospective owners as a sanitary and spacious alternative to the higher-density urban streetscapes of the city:

> That desirable Mansion House occupied by the subscriber in Wraggsborough being one of the healthiest situations in or near Charleston, fronting on Judith Street on the south and to the west on Public Mall. The house contains twelve upright rooms, four on each floor, all well finished, the materials of the piazzas and fences all of cypress and cedar, underneath the house are large cellars and storerooms. The lot of 120 feet on Judith and 281 feet on Elizabeth Streets. Also the large new brick rough cast building to the east, lately finished, which contains eight upright garrett rooms, with large cellars and storerooms...at present rented...at $500 per annum.[8]

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[5] Freeman, 76.

[6] Hudgins, Carter L., Carl R. Lounsbury, Louis P. Nelson and Jonathan H. Poston. *The Vernacular Architecture of Charleston and the Lowcountry, 1670-1990,* (Charleston, South Carolina: Vernacular Architectural Forum, 1994), 252.

[7] The nature of Robinson's financial struggles appear to have been brought on by the loss of cargo, as noted in Ernest C. Shealy, Jr., "The William Aiken Family and the Architecture they Influenced in Charleston" (Independent Study, College of Charleston, 1984), 13.

[8] Hudgins, et al., 252.

2.2.2 Aiken Family and Descendants, 1827-1975

William Aiken, Sr. purchased the property from Robinson in January, 1827, adding it to his collection of rental properties instead of occupying it.[9] Just six months after purchasing the property from Robinson, Aiken offered the mansion for to purchasors or renters:

> For Sale or to Rent
> That elegant mansion house the corner of Elizabeth and Judith Streets, Mazyckborough; it contains twelve rooms, double piazzas, store rooms under the house, and every necessary outbuilding for the accommodation of a large family; for a planter it is one of the most desirable residences on the neck, it being completely secure from the stranger's fever. To an approved purchaser the price will be low, and the terms of payment accommodating. If not sold in eight or ten days, it will be rented for one, two, or three years; or the Subscriber will rent the house he now occupies, which is so well known that a description is thought unnecessary.[10]

Following Aiken, Sr.'s death in 1831, the mansion was acquired by William Aiken, Jr. by an 1833 deed of partition. Aiken, Jr. extensively remodeled the mansion in Greek revival fashion, resulting in significant structural, spatial and aesthetic alterations. Between 1833 and 1836, the main entrance was relocated from Judith Street to its present position on Elizabeth Street, inside of which was added a dramatic cantilevered marble staircase and a plastered groin-vaulted entrance ceiling.

> The removal of the central hallway transformed the two front parlours into one space when the pocket panel doors are thrown open. In these rooms large Greek revival window and door surrounds, deeply cut with acanthus leaf corners, replace

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[9] Shealy, 13.
[10] *Charleston Courier*, July 12, 1827, in Shealy, 13-14.

> what must have been simpler and smaller Federal ones. The northwest room of the original house was remodeled as a grand entrance hall...
>
> The northeast corner of the house accommodat[ed] a new. wide staircase. On the eastern side of the house, Aiken added a dining room on the first floor with the room above serving as a ballroom. These rooms could be reached either through the stairhall or from the piazza which Aiken extended around the side of the house.[11]

The extensive changes which created door and window openings onto the first floor piazza on the south facade and relocated the original entrance severely scarred the brickwork. It is during the first phase of remodeling that the exterior was stuccoed to conceal unsightly scars created by spatial and structural alterations and to confirm the growing trend in ashlar stuccoed facades.

> By 1836 the Aikens had completed an extensive remodeling of the house...and applied a unifying coat of stucco over the brick exterior. With the remodeling, the refined Federal-style elements of the original house were replaced or overshadowed by bold Greek Revival features, the house thereby becoming one of Charleston's first examples of a style that was destined to gain local popularity.[12]

Significant physical alterations extended to the rear of the mansion, where improvements during this restoration campaign extended to outbuildings along the brick patio.

> The backyard was never used for any sort of gardens, instead it functioned as a paved brick service area. To the right was a large kitchen and slaves' quarters doubled in size by Aiken, with a room for the slaves meals and work... The upstairs of the kitchen building was transformed from four unheated chambers with

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[11] Hudgins, et al., 254.
[12] Freeman, 76.

> two heated common rooms to a series of chambers, all but one heated, extending from a long hall on the front of the building.[13]

"Governor William Aiken...long resided in it, having improved and added considerably to the original house."[14] Aiken again remodeled the mansion in 1858, adding the art gallery wing on the west side of the property, and redecorating the interiors with new carpets, wall hangings, curtains and gas lighting fixtures. In addition to expanding the footprint of the mansion, the gallery wing boasts of interior plasterwork elaborately executed in rococo revival and a raised skylight.[15]

2.2.3 The Charleston Museum, 1975-1995

The Charleston Museum acquired the property from the Aiken family in 1975, spending more than $1.2 million on preservation-minded campaigns, repairs and maintenance during its 20-year tenure as owner. During this period, the Museum operated Aiken-Rhett as a house museum with limited administrative facilities. Though the form of the buildings was not altered, substantial improvements such as a new roof and the restoration of

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[13] Hudgins, et al., 257.

[14] Alice R. Huger Smith and D.E. Huger Smith, *The Dwelling Houses of Charleston, South Carolina* (New York: Diadem Books, 1917), 278.

[15] Maurie McGinnis, *The Vernacular Architecture of Charleston and the Lowcountry*, 1994, paraphrased in Historic Charleston Foundation pamphlet entitled "Robinson-Aiken House (Known as Aiken-Rhett House), 4.

characteristic piazzas on the South facade were completed. Escalating operating costs forced the Museum to close Aiken-Rhett in 1994 except for special occasions.[16]

2.2.4 Historic Charleston Foundation, 1995-present

Historic Charleston Foundation purchased Aiken-Rhett from the Museum in 1996 for $600,000 with a long-term payoff period and very low interest rate.[17] Since its purchase, Historic Charleston has modernized the basement of the mansion to include a visitors' and reception area and removed a non-contributing cinderblock 1950s kitchen from the rear courtyard. Since acquiring the property, Historic Charleston has expanded interpretive possibilities at Aiken-Rhett by enhancing interior exhibits, opening the gothic-inspired carriage house and slave quarters to the rear of the mansion to visitation.

2.3 Social and Cultural Significance

Aiken-Rhett testifies to the glory and heritage of one of South Carolina's most important and powerful families, as well as the African-American experience in ante-bellum Charleston. As a social document, building and its courtyard afford an extremely high amount of potential for architectural and archaeological investigations which build on those already completed.

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[16] Schuyler Kropf, "Sale of Historic House Goes On," *Post & Courier* (Charleston, SC: December 14, 1995), A-1.
[17] Kropf, A-1.

In a city renown for its architectural treasures, the Aiken-Rhett House is one of the city's crown jewels. Beyond its power to evoke an earlier time, the house is indisputably of national historical and architectural significance for more than a few reasons, among them:

(1) The house retains a high degree of what preservationist[s] term "integrity." that is, the building has been little altered since it[s] completion and therefore retains most of its original materials and finishes.

(2) In the case of the Aiken-Rhett House the matter of integrity extends to household furnishings, especially the significant art and furniture collected by the Rhett family during the ante-bellum period.

(3) The house contains the best-preserved, and quite possibly the last, essentially intact urban yard with its sheds, stables, quarters, kitchen and privies.

(4) The house holds the potential to interpret for the public not only the life and times of one of Charleston's most important merchant-entrepreneur[s] but the untold story of life within the walls of a Charleston estate. Nowhere else in Charleston is the potential to interpret urban slavery stronger.

(5) The house narrates major shifts in architectural taste in Charleston during the first decades of the nineteenth century with more clarity than any house in the city.

There are ample reasons why the Aiken-Rhett House should remain within the public domain and an interpretative program woven around it that would present the lives of both white owners and black laborers. Such a program would be the first in the nation to treat urban slavery in a serious, scholarly manner.[18]

2.3.1 National

Aiken-Rhett is a nationally significant historical site by virtue of the fact that it was inhabited by a wealthy, politically-influential family in the city of Charleston before, during

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[18] "Prospectus for Aiken-Rhett House." Historic Charleston Foundation Aiken-Rhett files.

and after the Civil War. During the course of William Aiken, Jr.'s tenure of the property, the Confederacy rose and eventually fell against the Union in the ravages of Civil War, slavery thrived before being abolished, South Carolina seceded from the United States, and Charleston was heavily bombarded by Union forces. Under Aiken, Jr.'s ownership, the property served as the headquarters of General P.G.T. Beauregard.[19] The city of Charleston is a fulcrum for interpreting the people and events which led to the split of North and South. Furthermore, the Aiken family, by virtue of its political importance during a defining historical era, its civic influence and its reputation as the largest slaveholder in South Carolina on the eve of the Civil War, are indeed worthy of national attention.[20]

2.3.2 Regional and Local

Aiken-Rhett is recognized as a significant historic property largely because of the influence and importance of the Aiken family. When he acquired the property in 1827, William Aiken, Sr. was president of the South Carolina Canal and Railroad Company and a member of the South Carolina House of Representatives (1824-1831). During his tenure

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[19] Kropf, A-1.

[20] That the Aiken family was considered influential even after the end of Aiken's tenure as Governor of South Carolina is evidenced by the fact that his Charleston mansion played host to an "enthusiastic reception" for President of the Confederacy Jefferson Davis in 1863. As the purpose of this research is not to define the context of the Aiken family's property and its role in the Civil War but rather to propose sympathetic material solutions to a building which hosted nationally significant figures and historically important individuals, this subject may be better left for further examination based on more complete archival and documentary examination.

of the property, William Aiken, Jr. extended the political and governmental influence of the family, serving in the South Carolina House of Representatives (1838-41), the South Carolina Senate (1842-44), as Governor of South Carolina (1844-46) and as United States Representative (1851-1857).

2.4 Architectural Significance

> "[T]he shadows are heavy and the contrasts intense...
> Charleston is Charleston and has its own individual style..."[21]

Architecturally, the evolution of Aiken-Rhett enunciates stylistic changes which occurred throughout the 19th century. Originally constructed in the Federal style, and later altered with Greek Revival and Victorian elements, the property documents the stylistic evolution of American architecture with a distinctly Charlestonian perspective.

> The Aiken [-Rhett] House exemplifies the changes which occurred in architectural design during the first half of the 19th century. The upper floors reflect the refined qualities (in both woodwork and proportion) of the late Federal period. The main floor exemplifies the height of Greek Revival design, while the art gallery (added in 1858) indicates the movement into the Victorian period.[22]

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[21] Robert Molloy, *Charleston: A Gracious Heritage* (New York: D. Appleton-Century Company, Inc., 1947), 4.
[22] South Carolina Department of Archives and History, Section 8.

2.5 Interpretation of the Property

> The city of Charleston burns like a flame of purest memory. It is a city distorted by its own self-worship. I do not believe there is another city like it on earth.[23]

Charleston is a city which casts a proud eye toward its architectural heritage. Between the Ashley and Cooper Rivers, Robert Mills' Fireproof Building, the Charleston County Courthouse and the Custom House provide stately public complements for the vibrant colors along Rainbow Row and impressive mansions on The Battery. In this city of elegance, splendor and architectural treasure, the amount of time, attention and expenditure devoted to the interpretation, continual re-examination and restoration of the past is understandable.

It is precisely this philosophy which makes Aiken-Rhett so special. Having existed in the hands of the Aiken family for nearly a century-and-a-half and not having undergone an extensive restoration which literally re-created a prior history, it is a true gem of preservation in its natural state.

> Because the Aiken-Rhett site remained in one family from 1826 until 1975, because the family used the property intensely in the nineteenth century and then maintained it and changed it minimally during most of the twentieth century, and because for the last two decades the site has remained in the conservation-minded stewardship of the Charleston Museum, the Aiken-Rhett House survives as an unrestored time capsule of nineteenth-century domestic architecture, decorative arts, and social history that is probably unrivaled in the American South.[24]

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[23] Pat Conroy, *The Lords of Discipline,* Toronto: Bantam Books, 1980, 3.
[24] Freeman, 76-77.

Elegant and refined inasmuch as it bears evidence of its more than 150 years of existence, Aiken-Rhett derives much of its charm from standing as an unadulterated survivor of the potential harm of economic expansion, war, modernization and full-scale restoration. The building is not remarkable simply because of its architecture and those who lived within its walls, but as a living property with the power to evoke senses and images of the past without an overwhelming sense of polish.

> Architectural historians familiar with the house and its outbuildings agree with its current stewards that this is a prime site for conservation rather than restoration. It retains layers of evidence concerning every phase of its history...[25]

It is critical that the results of this research and any future maintenance/restoration campaigns very carefully consider the impact which new, replacement or replication materials and features might have on the significant sense of place created by the natural integrity of the property.

Historic Charleston Foundation views Aiken-Rhett as a house museum rich in architectural quality and character, well-preserved in an unrestored state.[26] Docents,

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[25] Freeman, 76.

[26] Certain rooms and features have been restored, such as the main entrance hallway complete with faux marble wall finishes and a dramatic cantilevered marble staircase. Also notable is the restoration of an elaborate plaster cornice in the Art Gallery (this cornice has suffered extensive deterioration after restoration which resulted from a leaking roof above). However, the bulk of both interior and exterior spaces exist as left by Aiken family descendants.

publications and pamphlets reflect Historic Charleston's recognition that Aiken-Rhett, and those who lived in the house were substantial local, state and national historical figures. McGinnis' 1994 description of Aiken-Rhett summarizes perspectives which Historic Charleston employs in interpreting the property:

> ...one of the most complete documents of an ante-bellum house and urban plantation available to historians today. Remaining in the Aiken family until it was acquired by the [Charleston] museum in 1975, virtually unaltered in the twentieth century, the house is a dynamic text documenting changing nineteenth century tastes and the yard hordes a wealth of artifactural evidence just waiting to be unearthed.
>
> The Aiken-Rhett property presents an important site for archaeological research within the city of Charleston largely because it has been so little altered since the mid-nineteenth century. Six of the seven original buildings are still standing, and the property has not been partitioned or divided. The high brick wall which encloses the site has protected it from outside contamination.[27]

There is also the issue of untapped potential which contributes to the need for additional research, education and interpretation. Historic Charleston recognizes that Aiken-Rhett will provide unique insight into the African-American experience in the heart of the ante-bellum American South. As educational, research and preservation efforts at the site are ongoing, it is anticipated that its mission and comprehensive interpretation will also continue to evolve.

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[27] McGinnis, in "Robinson-Aiken House (Known as Aiken-Rhett House)", 1-4.

3.0 Exterior Stuccoes as an Interpretive Asset

3.1 Charleston: The Tradition of Stucco in the Holy City

Charleston is a city of modern life with conscious ties to its past, keeping alive the spirits and souls of its ancestors by proudly presenting the physical treasures of their existence which are their houses and monuments. This is a city which prides itself on the preservation of its historic built environment. Social, cultural and architectural historians alike have for centuries conducted extensive surveys of tradition and heritage, surveys which with little exception pay homage to the shapes and visions of the city which have shaped the Charlestonian experience. The general histories crafted by Rhett (1940) and Molloy (1947) weave intricate tales of power, revolution, commerce, siege and society with commentaries on specific vistas and building materials. Studies of architectural styles and building types by Huger Smith and Huger Smith (1917), Kimball (1922), Simons and Lapham (1927), and Stoney (1938) establish ties between the building materials prevalent in Charlestonian architecture and the impressions they create. Prime's 1929 compilation of references to the industrial arts and March's 1970 catalogue of Robert Mills' architecture critique individual components as part of an overall whole. Throughout many scholarly works, interpretations of the subtle to vibrant hues of Charleston's stuccoed facades are everywhere (Figures 3.1, 3.2, 3.3 and 3.4).

Figure 3.1. Colorful, painted stuccoed facades of "Rainbow Row" enunciate the vibrant tradition of adding flare to what is often considered a sacrificial, ephemeral material.

Charleston is a city defined in many ways by the stucco which adorns its buildings and defines its streetscapes. From the elegant homes which line The Battery along East Bay to the stately portico of Market Hall to the landmark tower of St. Philip's, this material not only defines exterior walls and elegant interiors, but in its subtle textures and varied hues creates a distinct architectural attitude. Through the streets of the Charleston, stucco is a tangible tie to nearly three centuries of architectural heritage derived primarily from British forms and Caribbean influences with local modifications.[28] To the casual observer and

[28]Samuel Galliard Stoney, *Plantations of the Carolina Low Country* (New York: Dover Publications, Inc. in association with Charleston, SC: The Carolina Art Association, 1989), 45. The use of the term *stucco* can be a bit misleading, as in the correct context it may refer to exterior coats which shelter the core of the structure from the weather, as a material used for interior elemental decoration, or as the semi-structural material applied over lath to form interior walls. Stoney cites stucco as a building material popular in the Lowcountry from the early eighteenth century.

seasoned resident alike, the time-honored link between this material and the Holy City creates an indelible impression:

> No Charlestonian can be expected to speak or write about his city objectively for it is so much a part of the background of his mind and emotions that detachment is never possible. The lovely and the shabby are all woven into the same warp and woof of the familiar scene. The stucco facade of some old house, its chalky colors weather-faded, its surface mapped with earthquake patches and crumbling at the windows, through a sort of empathy assumes a character akin to an aged face looming out of one of Rembrandt's later portraits, infinitely world-weary yet infinitely wise in human experience.[29]

Figure 3.2. Stuccoed facades on Meeting Street, Charleston.

The nature of the material itself is a form which provides insight into the architectural history of the Lowcountry as well as the fundamental nature of the place, while

[29]Albert Simons, 1964 Foreword to Samuel Galliard Stoney, *This is Charleston: A Survey of the Architectural Heritage of a Unique American City* (Charleston, SC: The Carolina Art Association, 1970), vii.

enunciating the city's architectural lineage with England. Deprived of the massive limestone formations common in Georgia, North Carolina, and other areas of the eastern United States, Charleston builders and architects relied instead on bricks which could be formed and burned from the sandy clays which comprise the region's soil .[30] As brick architecture was an obvious option with Charleston's geological resources, so was stucco an obvious option to provide both protection and style to brick architecture.

Figure 3.3. Stuccoed facades on Broad Street, Charleston.

The region's defect of stone available for masonry construction necessitated the use of stucco as a weatherproofing agent to enhance the lifespan of porous brick buildings.

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[30]Samuel Galliard Stoney, *Plantations of the Carolina Low Country* (New York: Dover Publications, Inc. in association with Charleston, SC: The Carolina Art Association, 1989), 17. Stoney's work cites "certain outcroppings of marl" as "the only stone worth mentioning," but discounts this material as being too soft to be used as a building material.

Limestone was unavailable for both dimension stone and lime-burning alike. The absence of calcareous stone deposits which might be had to produce lime forced builders to seek lime-bearing deposits elsewhere, namely in the abundant supply of oyster shells which could be obtained from the saline waters of the nearby salt marshes and Atlantic Ocean. Historically, this material created a demand for those who could fashion it[31] to the needs of the building as well as those who could reap the rewards of the maritime climate and from it manufacture a marketable building product:

> At the...place may be had...good Lime burnt from live shells, and slacked with fresh water, which makes great difference in building, particularly in Plaistering, as it won't give in damp weather.[32]

Stucco in Charleston dates to at least the eighteenth century; many buildings from that era owe their continued existence to benefits gained from the use of this material, "built with rather thick brick walls covered with stucco made of burnt oyster-shell lime."[33]

[31] An account of Charles Robinson, a Charleston "Stucco Worker" capable of "Plaistering and Carving in Stucco in all its Branches, either in the Modern or Gothic Taste" from the October 28, 1774 issue of the *South Carolina & American General Gazette* is reprinted, along with those of other building arts craftsmen, in Alfred Coxe Prime, *The Arts & Crafts in Philadelphia, Maryland and South Carolina, 1721-1785* (The Walpole Society, 1929), 290.

[32] *The South Carolina Gazette, December 8, 1769,* reprinted in Prime, 291-2.

[33] Albert Simons and Samuel Lapham, Jr., *The Early Architecture of Charleston* (Columbia, SC: University of South Carolina Press, 1970), reprint of Press of the American Institute of Architects, *The Octagon Library of Early American Architecture, Volume I,* 1972, 19. As a protective and stylish material, stucco has been applied to many buildings after original construction, evidence of which is portrayed by prestigious Flemish bond brick work which protrudes through cracks and holes in many buildings.

Figure 3.4. Charleston County Courthouse (under restoration).

Aiken-Rhett's stucco coat exemplifies the tradition of stucco in Charleston inasmuch as it occupies two roles. The material is *functional* in its role as a weather barrier between the Lowcountry's humid, saline environment and walls of porous brickwork bedded in lime mortar. It is also an *aesthetic* element which easily conceals 1830s brickwork repairs owed to structural and spatial modifications. Sealed originally with a white lime wash and later with a buff-colored lime wash, it was tooled with faux joints. This effect was employed ostensibly to re-create the appearance of ashlar masonry.

> Stucco was used from an early date...in Charleston and Philadelphia, as a covering for both brick and rubble. Increased warmth and weatherproofness seem to have been the principal reasons for its employment rather than a desire to imitate stone.[34]

Rough-faced or tooled, painted, lime-washed or in its natural state, intact or displaying the cracks, holes and patches of history, stucco is a distinct feature of Charleston architecture. As a vehicle for displaying evidence of the importance of this building material in this community, Aiken-Rhett is a striking and valuable specimen.

3.2 Aiken-Rhett: Stuccoes as Morphological Evidence

Simple visual examination of Aiken-Rhett's stucco envelope provides hard evidence of the stylistic and structural changes which the mansion underwent in the 19th century. Stucco applied during 1830s alterations is a hard gray-brown material applied in one coat and rough in texture. This material bears no distinctive tooling marks with the exception of channeled, scored joints which were penciled with a superficial layer of white lime wash to create the impression of pointing mortar between blocks of stone laid in ashlar fashion (Figure 3.5). Areas of the building which have been protected from heavy weathering, such as beneath piazza roofs and overhangs retain nearly 100% of original surface finishes including evidence of two campaigns of lime wash (one white, one pigmented with a buff color). Portions of the 1830s stucco are subject to cracking, delamination and

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[34] Fiske Kimball. *Domestic Architecture of the American Colonies and of the Early Republic* (New York: Dover Publications, Inc., 1966), 68. Though brick structures were common in both cities, it may be likely that Kimball's reference to the term *rubble* actually has more to do with the architecture of Philadelphia than it does Charleston. Geologically, southeastern Pennsylvania benefits from extensive formations of schist, limestone, gneiss and other types of stone, while South Carolina's stone resources are significantly more limited.

discoloration even in protected regions (Figure 3.6), and to total loss of surface finishes in areas exposed to constant weathering (Figure 3.7).

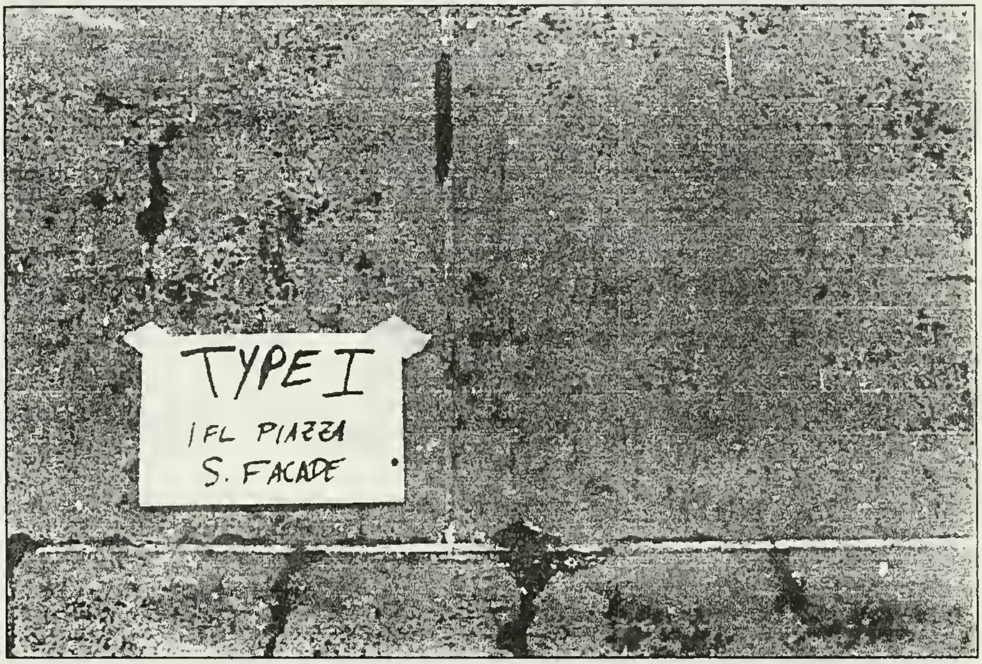

Figure 3.5. Example of stucco type 1, applied in the 1830s to cover repairs to brickwork. Protected areas retain most of their surface finishes including two layers of lime wash and scored joints. South facade, first floor piazza.

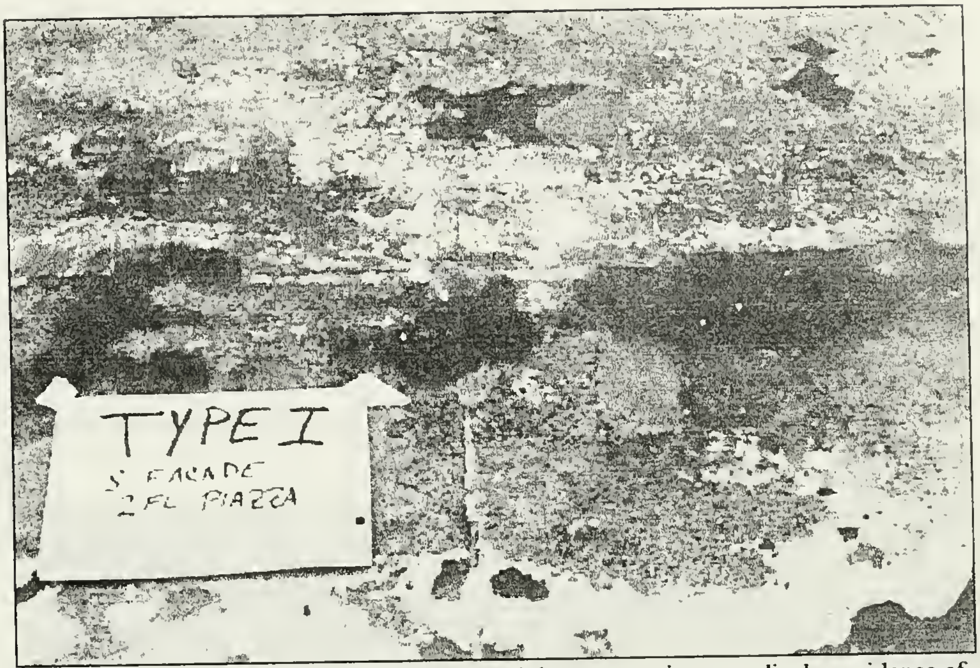

Figure 3.6. Example of stucco type 1. Though intact, certain areas display evidence of surface discoloration and detachment of surface finishes. South facade, second floor piazza.

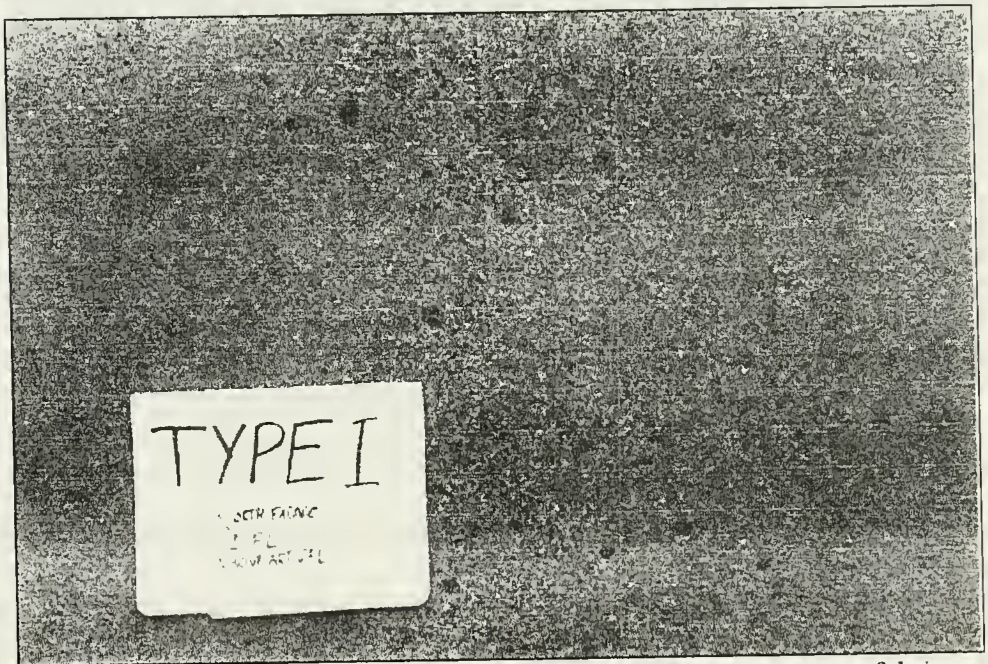

Figure 3.7. Example of stucco type 1. Weathered samples have lost most of their surface finishes, but in select spots display evidence of scored joints initially penciled to create faux ashlar masonry. North facade, second floor above art gallery.

A second stucco type, applied to the building with the 1858 addition of the art gallery wing and the third floor on the west facade is distinctly lighter in color, and displays evidence of floating tool marks applied in a circular pattern (Figure 3.8). These tool marks are most likely the trademark of the plasterer responsible for completing the work. That tool marks remain crisp after nearly 130 years of weathering indicates that stucco from the latter campaign may be more durable than that applied in the 1830s.

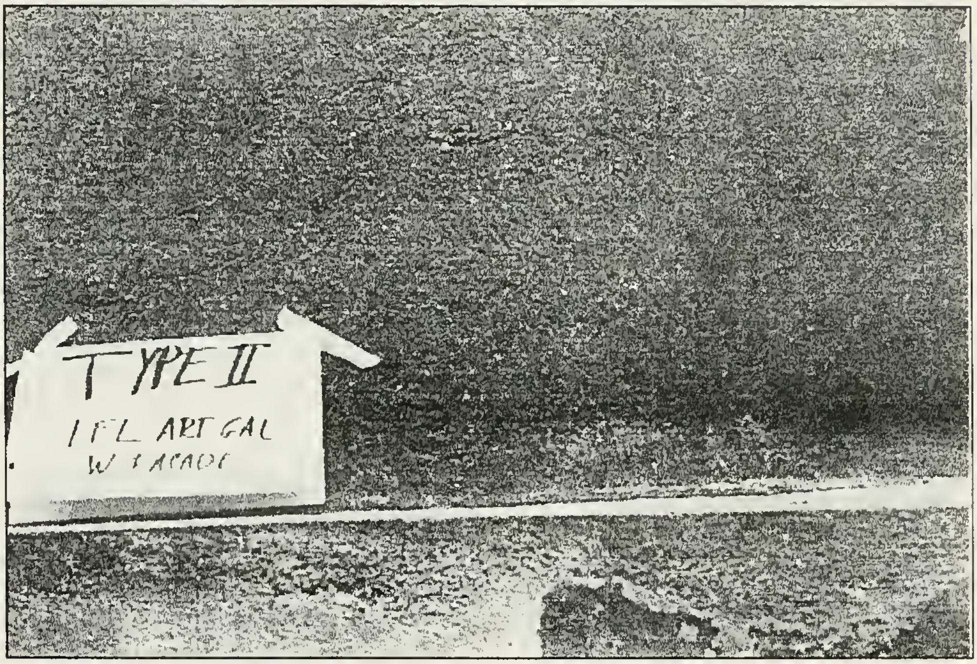

Figure 3.8. Example of stucco type 2, applied to exterior surface of 1858 art gallery. Visually and presumably compositionally different from type 1, it is characterized by floating tool marks applied in a circular pattern. West facade, first floor of art gallery.

It is possible somewhat to *read the building* by reading *variations* in the stucco. Joints between the 1830s and 1858 stucco coats are often distinct, marked by clear horizontal boundaries which might be expected at the junction of two different building campaigns. Because they appear to have two different compositions, behave somewhat differently and

are occasionally disrupted by the imbalance of different structural systems beneath, joints between the 1830s and 1858 material are often weak points which crack, shatter and detach more easily than cohesive material from one campaign (Figure 3.9). Where cracks and losses do exist, it is sometimes possible to examine different brickwork and pointing techniques which also coincided with different campaigns.

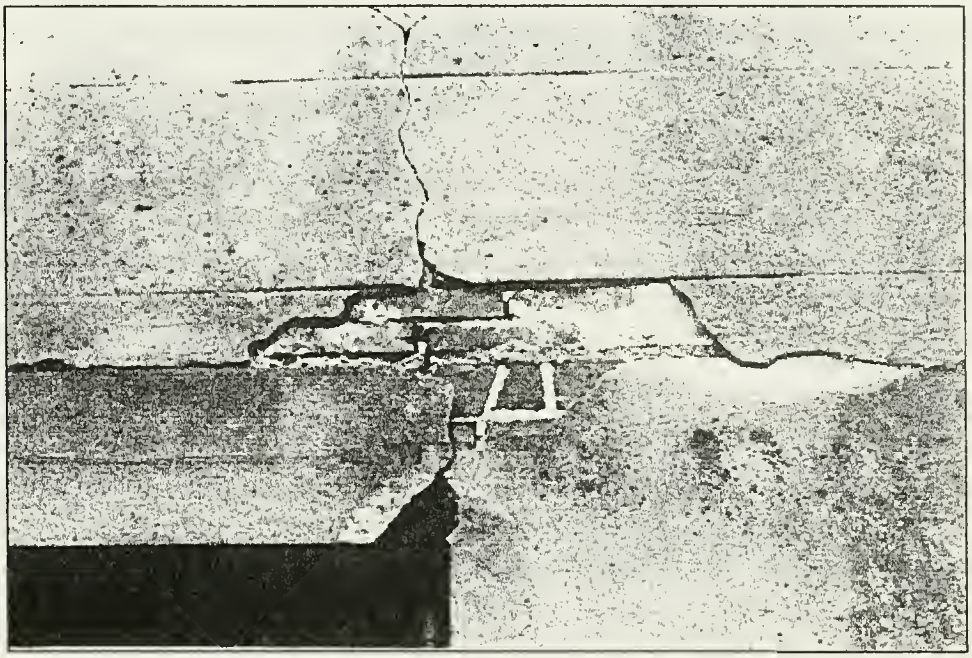

Figure 3.9. Example of joint created by structural problems at the boundary between original 1818 construction and 1858 additions. Differentiation between 1830s and 1858 stucco is evident by color, tooling patterns and horizontal joint boundary. North facade, second floor window header above art gallery.

4.0 Exterior Stuccoes as a Conservation Asset

The stucco of Aiken-Rhett's main residence is worthy of in-depth study and analysis in several respects. As a material which covers the entire mansion, it performs functions which are both structural/protective and aesthetic in nature. As it is a material widely used to protect and adorn brickwork throughout Charleston, analytical information yielded by field and laboratory examination may prove useful elsewhere in the city. Too often, the sensitivity of historic lime-based building materials such as stucco is not accompanied by sufficient research prior to restoration efforts:

> To a large extent, current practices have evolved through trial and error informed only by limited scientific and academic research. Although there is a significant body of experience in the use of lime-based materials in certain parts of the world, it is apparent that practice is not always matching theory and that there are still many partially unsolved problems.[35]

Because it is a material employed for centuries but not as often deemed significant enough to publish, expanding the knowledge base about stucco in an historically sensitive situation will address research deficiencies in the field of architectural conservation in America.

4.1 Constituent Parts

Stucco is a composite material which has historically been fashioned from three categories of ingredients: *binders, aggregate* and *additives* introduced during the mixing process to enhance or create certain physical and chemical properties. It is applied in a plastic state

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[35] Jeanne Marie Teutonico, Ian McCaig, Colin Burns and John Ashurst, "The Smeaton Project: Factors Affecting the Properties of Lime-Based Mortars," *APT Bulletin Volume XXV, Nos. 3-4* (Washington: Association for Preservation Technology, 1994), 32.

with a mason's or plasterer's trowels and often cured in damp conditions beneath sheets of burlap to control shrinkage, cracking and color.

4.1.1 Binder

The binding material, that which exists initially in a dry, powdered state, becomes workable with the addition of water and solidifies once again during cure, provides the matrix of the stucco, and is responsible both for the cohesiveness of the constituents and for the adhesiveness of the stucco to the wall surface.

Charleston's earliest mortars employed lime binders (calcium carbonate $CaCO_3$) obtained by burning the region's abundant supply of sea shells.[36] Lime binders in nineteenth century Charleston were both *hydraulic* and *non-hydraulic*. The principal difference between hydraulic and non-hydraulic binders lies in the manner by which the binder sets after being mixed with water. In a *hydraulic* lime, chemical reactions occur between calcium carbonate and the complex silicates found in certain calcined alkali-reactive burned clays or reactive additives. Hydraulic lime-based materials generally set more quickly and form stronger bonds than do non-hydraulic limes. *Non-hydraulic* binders rely

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[36] Richard D. Marks III, "A History of Charleston Stucco (unpublished seminar paper)," (Philadelphia: University of Pennsylvania Graduate Program in Historic Preservation, 1994), 3

on the transition of wet lime putty to solid calcium carbonate by a reaction with atmospheric carbon dioxide and the loss of water.[37]

Lime-based composite materials such as stucco take their genesis as powdered quicklime (calcium oxide, CaO) becomes hydrated in the presence of water (calcium hydroxide, $Ca(OH)_2$). In modern hydrated limes, the quantity of water present is sufficient to dissolve only a small part of the lime and not enough to encourage the growth of crystals.[38] After mixing the hydrated lime with aggregate, and, if desired, additives, more water is added until the composite mix reaches a workable consistency. In their plastic state, lime binders take on an amorphous form which enables them to be applied readily to wall and unit masonry surfaces. Finally upon exposure to air (namely carbon dioxide, CO_2), calcium hydroxide loses water (H_2O), absorbs carbon dioxide and converts into calcium carbonate. As the lime continues to set, carbonation continues indefinitely, conferring an increasing degree of strength and stability in the process.[39]

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[37] George Fore and Raymond Pepi, *Historic Charleston Mortar and Stucco Study* (Raleigh, NC: George T. Fore and Associates and New York, NY: Building Conservation Associates, Inc., unpublished, 1989), 3. This study of historic mortars and stuccoes was administered by Historic Charleston Foundation provides extensive insight into the nature of Charleston's lime-based mortars and renders, which vary with location and date of origination. As a document for technological historians, architectural historians and conservators alike, it provides extremely useful insights into the rationale for, theory behind and historical importance of stucco as a building material.

[38] F.M. Lea, *The Chemistry of Cement and Concrete* (New York:Chemical Publishing Company, Inc., 1970), 251.

[39] Lea, 252.

As with Aiken-Rhett, masons sometimes employed cementitious binders in addition with lime to enhance the initial strength and long-term durability of stucco. Cements are generally harder than limes, and are combined with aggregates and additives in a powdered state prior to the addition of water. The set of cementitious binders occurs in two stages, the first of which results in a loss of mass, a decrease in workability and an increase in friability.[40] Consolidation of the binding material takes place during the second stage, as mass and hardness both increase; in hydraulic cements such as those believed to be employed at Aiken-Rhett, this change is accompanied by a relative impermeability to water.[41]

4.1.2 Aggregate

Properly selected, the aggregate used in stucco will impart important physical properties which are both visual and structural. Aggregate is generally composed of sand, which may consist of quartz, feldspars and other minerals produced by the weathering of rock. It may vary in particle shape from rounded to angular, and in texture from fine to coarse. The aggregate functions as an agent which reduces shrinkage during cure, contributes to the material's ability to resist abrasion, creates a degree of compressive strength and imparts qualities of color and texture. Sufficient mixing ensures an even distribution of the

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[40] Lea, 250.
[41] Lea, 250.

aggregate, and, as the plastic binding material sets and hardens, the aggregate becomes bound within a solid matrix.

The use of river-sands in stucco as at Aiken-Rhett (*Section 6.1: Compositional Analysis of 1830s Stucco)*, is a centuries-old practice which integrated long-lined empirical knowledge with the ease of obtaining good aggregate form Charleston's creeks and streams:

> But river sand, though useless in "signinium" on account of its thinness, becomes perfectly solid in stucco when thoroughly worked by means of polishing instruments.[42]

In addition to sand, plasterers may have used crushed shells which were easily obtained from the ocean, rivers, creeks and streams in Charleston as aggregate.

4.1.3 Additives

The addition of materials whose primary function is neither as a bulking nor a binding material to a mortar or stucco is common practice. Oxide and mineral pigments may be added to give the material color for a desired appearance. Stone powder or fragments may be added for color and texture. Natural and artificial pozzolanic additives have historically been added to lime-based as hydraulic additives which quicken set time and

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[42] Vitruvius, translated by Morris Hicky Morgan, *The Ten Books of Architecture* (New York: Dover Publications, Inc.), 45. Though the comments pertain to interior stucco, or what would currently be considered "plaster," they shed useful insight into the technology and rationale behind constituent parts.

increase initial strength. Pozzolanic additives such as brick dust combine with lime "in the presence of water to form stable insoluble compounds possessing cementing properties."[43]

4.2 Analysis as a Property-specific Asset

The stucco coat which envelops Aiken-Rhett's imposing exterior is an historic building material which bears witness not only to the many historic events which have transpired since the 1830s but as a material which contributes to the mansion's sense of historic integrity. Despite the many cracks which map across its surface and sections which have been lost over the years only to be replaced with physico-chemically insensitive materials, most of the original coat remains intact and may be considered a significant component which is both functional and aesthetic in design.

4.2.1 Functional

Stucco is a functional material which acts as a weather barrier protecting porous brick substrate walls from Charleston's naturally humid, saline environment. Over the course of a century-and-a-half, it has weathered variably depending largely on its immediate micro-environment and the forces to which it has been subjected. Severely weathered stucco is more prone to detachment which severs the moisture seal created by the bond between stucco and brick; and where voids exist, the material possesses a lesser degree of structural integrity than it did originally. Where humidity is constantly high due to contact

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[43] Lea, 414.

with the ground as well as the collection of rainwater, the material currently displays little, if any, functional integrity (Figure 4.1).

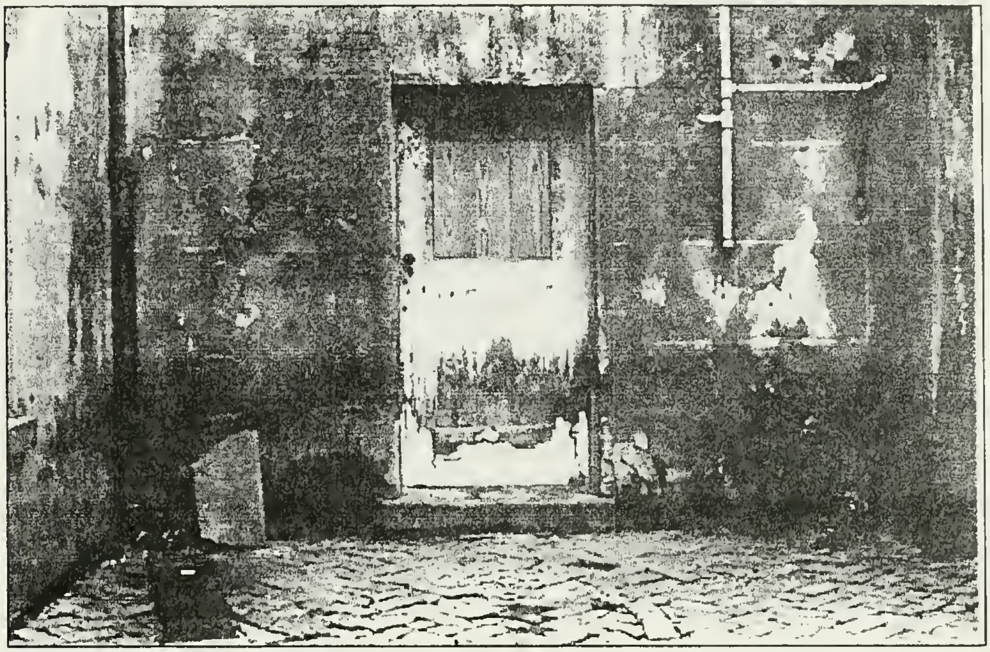

Figure 4.1. Stucco is functional in nature, designed as a sacrificial material which is more easily replaced than bearing masonry at points where damage is likely to occur. At ground level, stucco protects porous bricks from deteriorating from high amounts of moisture which might collect. North facade, courtyard.

Functional failure of the original stucco extends to portions of the coat which were intended to conceal structural alterations to the brickwork beneath. The structural system which opened previously-bearing spans to accommodate windows and doors in the 1830s is inefficient, and in a state of partial failure. As forces of tension and compression attempt to re-distribute the structural load of the building across these insufficiently-supported spans, stucco is prone to cracking and detachment (Figure 4.2). In some cases, these problems are symptomatic not only of functional failure, but may pose a threat to both staff and visitors.

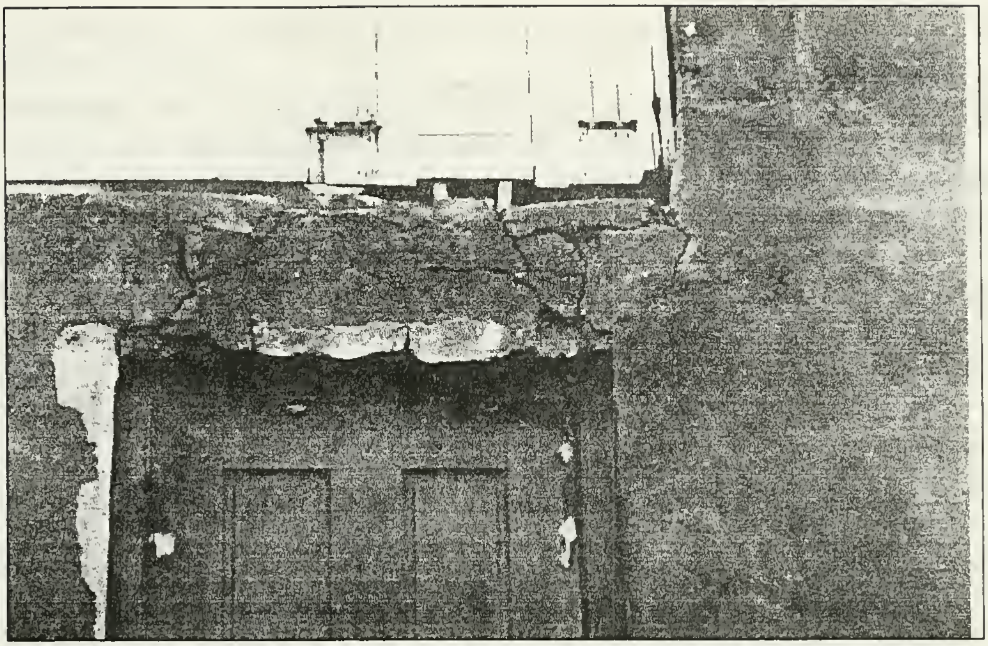

Figure 4.2. Where structural imbalances result from alterations, the function of stucco as a material which seals masonry has been compromised as well by the loss of structural integrity. North facade, door header between ground and first floors, courtyard.

Years of replacing lost stucco with cementitious stucco patches has taken a toll on the integrity and stability of the original material.[44] Feilden (1987) suggests that highly cementitious materials which attempt to patch historic lime-based stuccoes such as those at Aiken-Rhett may be inappropriate inasmuch as:

- Cementitious materials are incompatible. Attempts to remove cement-based stucco may result in extensive damage to the softer brick beneath.
- Cementitious stucco may be too strong in adhesion, rendering the bearing masonry materials below the sacrificial materials under stress.
- Cementitious stucco may not possess flexibility sufficient to accommodate shifts within bearing walls or to move with more flexible, existing, lime-based stucco.
- Composite materials with cementitious binders are generally less permeable than lime-based materials. While it is desirable that stucco may prevent water from

[44]Though the compositional analyses of repair patches were not performed as part of this study, replacement material has been identified as Portland cement based in previous surveys of Aiken-Rhett (Pepi and Kavenagh, 1996).

penetrating to substrate walls in the first place, it must also be able to pass water in the form of vapor.

- Shrinkage and cracking are problematic with cementitious-based composites. Incorrect set may compromise the ability of stucco to repel water.
- The occurrence of soluble salts which may damage both masonry bearing walls and existing lime-based stucco is often attributed to the reaction of cured cementitious materials with water.
- Cementitious stuccoes may have different rates of thermal expansion and contraction than do older materials, which can lead to cracking.
- Cementitious stuccoes generally possess a gray color which may present an aesthetic imbalance with the dark brown original stucco.[45]

Fielden further assesses the incompatibility of modern Portland cement in older buildings, suggesting that if cement-lime mixes are desired, that the volume of the cement not exceed 10% of the volume of the lime:

> Because it is modern, efficiently marketed by advertising and is readily available, and because it is indispensable to the modern building industry, many people think that Portland cement is ideal, but to sum up---unless correctly used, Portland cement is the enemy of historic buildings.[46]

Practically, however, lime-cement combinations with higher proportions of cement than advised by Feilden are the rule of thumb in many restoration mixes for historic buildings. Because unmodified lime-based mixes are weaker and more susceptible to deterioration in certain climates than are lime-cement mixes, the use of cement in proper proportions accompanied by proper evaluation is frequently a very viable option.[47, 48]

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[45]Bernard M. Fielden, *Conservation of Historic Buildings* (Oxford: Butterworth-Heinemann, Ltd, 1994), 72.

[46] Feilden, 72.

[47] Teutonico, et al., 33. *Smeaton,* in an effort to identify suitable mortars for the conservation of Hadrian's Wall, found that cementitious mortars had significantly contributed to the deterioration of softer masonry elements, but that easily-weathering lime mortars required an undue amount of maintenance.

Because of their physical incompatibility with Aiken-Rhett's historic building systems and original fabric, many repairs have either failed (Figures 4.3 and 4.4) or are at risk for failure in the future. Threatened by functional failure from within as well as resulting from the substitution of insensitive repair materials, Aiken-Rhett's original stucco is worthy of a more materially-sensitive approach than may have been applied in the past.

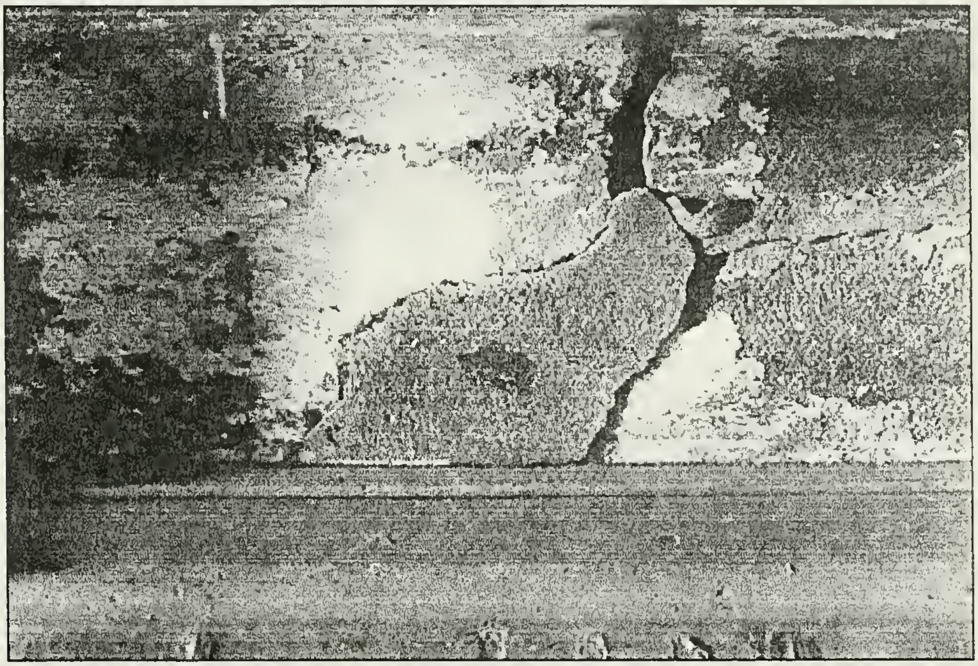

Figure 4.3. Functional failure is not limited to 1830s, but extends to subsequent repairs as well. Here, a 20th century repair patch fails in color, texture, and in its ability to maintain a bond with existing historic fabric.

[48] John Ashurst and Nicola Ashurst, *Practical Building Conservation, Volume 3: Mortars, Plasters and Renders* (New York: Halsted Press), 24. This document advises on the use of several appropriate mixes for exterior stuccoes composed of lime, Roman cement or Portland cement. While straight lime or hydraulic lime binders are recommended for straight lime-based stuccoes, lime-cement combinations are recommended for other stuccoes with cementitious components.

Figure 4.4. Cementitious composites used to patch original stucco may provide a temporary cure for unsightly cracks which result from structural inefficiency, but may also damage existing historic fabric. West facade.

4.2.2 Aesthetic

In addition to its performance qualities, stucco was applied in the 1830s as a reasonable solution to conceal brickwork which had been scarred by structural alterations and floor plan modifications. A coat of stucco finished with smooth lime washes and scored to create the impression of faux ashlar masonry was also in keeping with early 19th century Charlestonian tastes. Though weathered to the point that smooth lime wash finishes no longer exist in many places, this stucco is nonetheless a character-defining aesthetic feature rivaled on the exterior perhaps only by the building's wraparound piazzas. While the aesthetic intent has altered over time, the extent to which the original stucco has survived and the amount retained is extraordinary (Figure 4.5).

Regrettably, as the structural alterations which necessitated the use of stucco have failed, the integrity of the once-uniform envelope has become compromised (Figure 4.6). As the mansion continues to redistribute its mass, additional stucco will be lost, further sacrificing its aesthetic value.[49]

Figure 4.5. Stucco applied to the building in the 1830s was, in part, represents an aesthetic intention of providing unified, updated appearance to parts of the building which had been altered. View from southeast.

[49] Historic Charleston is developing an agenda which will address the structural inefficiency of the mansion, with the intent of stabilizing it. While structural stabilization is an absolute necessity, and arguably Aiken-Rhett's most pressing preservation issue, it is likely that these efforts will necessarily damage the building's stucco envelope.

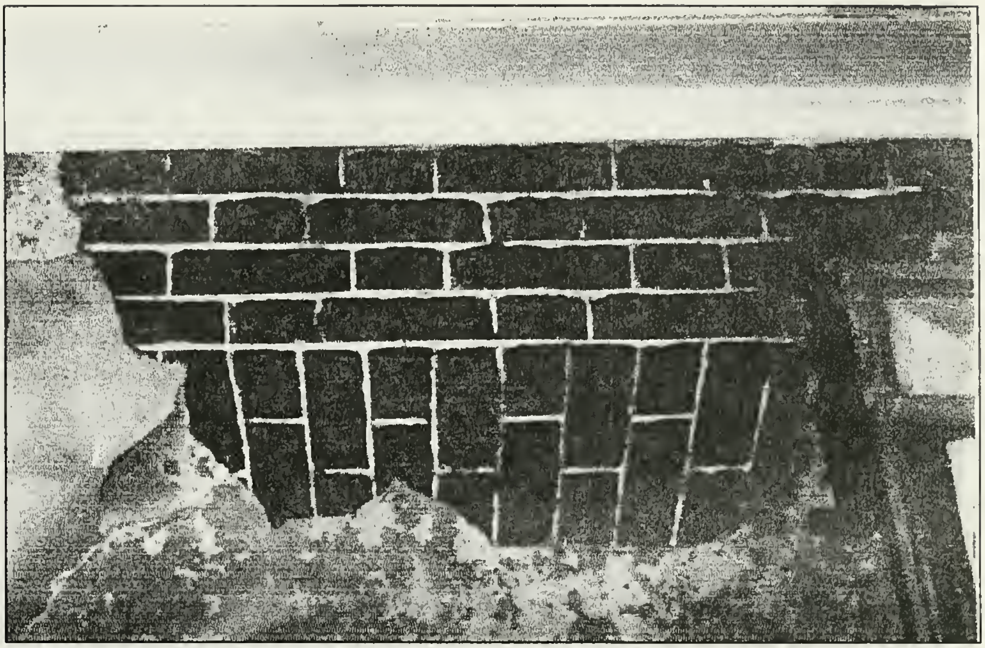

Figure 4.6. By presenting a uniform material across the breadth of every facade, stucco covered evidence of alterations; shown here, a previously-exposed brick jack arch which once provided structural support above a window. East facade, first floor piazza.

As is the case with the functional intent of the material, modern cementitious repairs have compromised the aesthetic integrity of Aiken-Rhett's original stucco by presenting a markedly different color and texture amid what is supposed to be an unbroken, continuous expanse of homogeneously-colored and -textured material (Figure 4.7).

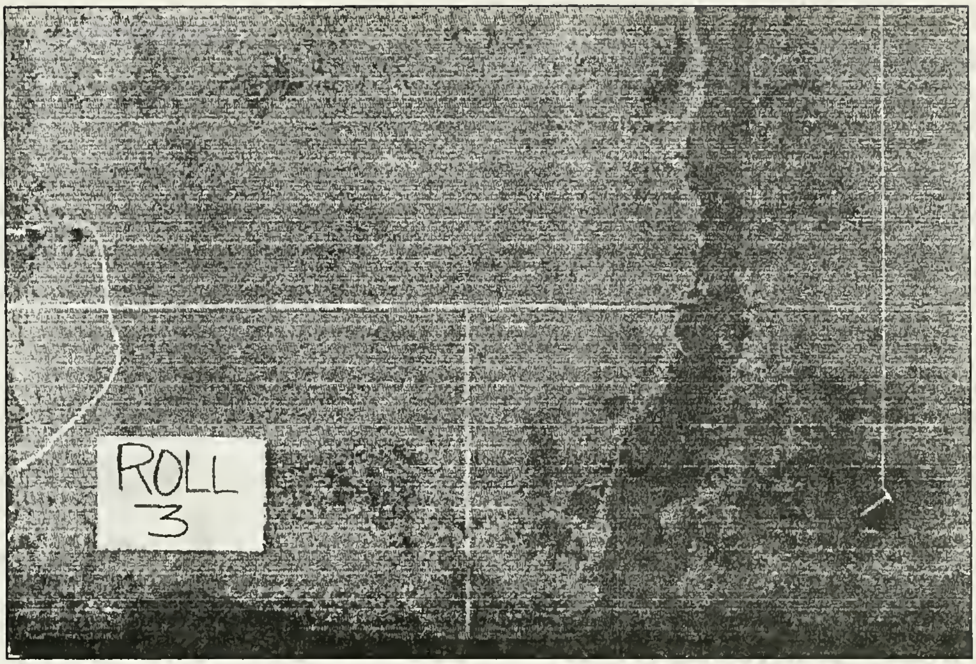

Figure 4.7. Overwhelming differences in color and texture define many repair patches applied to cracks in the original stucco.

4.3 Analysis as a Local Asset

As outlined in *Section 3.1: Charleston: The Tradition of Stucco in the Holy City,* stucco is an architectural device which creates a fundamental and distinct impression of Charleston as a place. The importance of stucco as a building material is not necessarily complemented, however, by sensitivity in preservation, restoration and conservation standards.[50]

> Charleston is recognized for its successes in preserving buildings from demolition and for its efforts in restoration. Yet as a whole, the distinguishing architectural

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[50] The efforts of Historic Charleston Foundation to do more than save buildings are most noteworthy in this sense. By commissioning citywide materials conservation studies (Fore 1987, Fore and Pepi 1989) as well as property-specific research, Historic Charleston exhibits an understanding that the preservation of cultural heritage extends outward throughout the city. With education, outreach and influence, Historic Charleston is uniquely poised to extend the preservation of important practices to the practical world.

> features of Charleston's buildings are being lost. The evidence of original production and tooling processes, the profile and shape of molded surfaces, and the mechanical performance of original materials, are all being severely altered.
>
> The repair of masonry structures commonly involves the use of damaging preparation techniques, the use of inappropriate substitute materials in mortar and stucco mixes, and finish details which have little resemblance to the existing masonry.[51]

By introducing a standard methodology for the basic analysis of this important material and providing data on replication materials which may be suitable for certain applications, this study will potentially benefit preservationists, conservators and architects interested in the stabilization, maintenance and conservation of this historically important material asset citywide.

4.4 Analysis as a Field-specific Asset

As a material whose primary physical function is to protect structural masonry systems below its surface, stucco is frequently classified as a sacrificial material, somewhat less notable because of its function.

> Such deficiencies can be identified...superficiality by which quite often we witness the destruction of original historic surfaces; the scarce consideration reserved to the role which [exterior] plaster represents, besides an element of notable aesthetique-formal importance, a determining factor to the protection of the supporting masonry...[52]

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[51] George T. Fore, "Project Report: Masonry and Wood Conservation Study: Charleston, South Carolina," (Raleigh, North Carolina: George T. Fore and Associates, 1987), 8.

[52] Mario Piana and Samuel Lapham, "A Research Programme on the Plaster of Historical Buildings in Venice," *Mortars, Cements and Grouts Used in the Conservation of Historic Buildings, Symposium, November 3-6, 1981* (Rome: ICCROM, 1981), 386.

Though written to critique the lack of conservation attention devoted to exterior plasters in the historic cityscapes of Venice, Piana and Armani's assessment could just have easily referred to the state of stucco conservation in Charleston.

The stucco which adorns and protects Aiken-Rhett's structural masonry system is not unlike other buildings elsewhere in Charleston. From high style to vernacular, the functionality and beauty of stucco in Charleston is a constant through years of Revolution, expansion, Civil War and modernization. The opportunity to study this significant Charlestonian material further will, with the correct perspective and voice, extend the recognition of stucco as a significant historical asset well beyond the walls of the Aiken-Rhett House.

5.0 Survey and Analysis of Current Stucco Conditions

A survey and analysis of the conditions of stucco at Aiken-Rhett was conducted during the week of January 3-10, 1997 to identify original and subsequent campaigns and repairs as well as the conditions of each.

5.1 Methodology and Parameters

The survey and analysis of stucco conditions employed a series of visual examinations of the exterior of the main residence, with conditions of deterioration and loss noted on 1985 HABS drawings. Conditions which could be identified visually included cracking, total loss, partial loss, repair, biological growth, discoloration, delamination and efflorescence. Voids were determined to exist where light tapping of the original stucco with a wooden mallet produced a hollow sound compared with surrounding material. All representative conditions were photographed.

Considering its age and weathering environment, Aiken-Rhett's stucco coat is in remarkably good condition. There are, however, certain areas which experience problems that should be addressed in future stabilization and restoration campaigns. The drawings which follow (W.1., N.1, E.1, S.1) provide a visual reference for such problematic conditions, and may eventually be adapted for on-site use by architects, contractors and conservators.

Repair — Because the stucco has experienced innumerable repairs over the period of 150 years, only repairs which might serve as candidates for eventual replacement have been noted. These include repairs which have separated from the brick substrate wall as a result of structural redistribution, repairs which fail aesthetically as they do not approximate the color and/or texture of the surrounding original material, and repairs which appear to be composed completely of cement, and may pose a long-term threat to the stability of the surrounding original material.

Color Change — Notable changes in color occur mainly in sheltered areas which retain their original surface finishes, especially on the second floor south piazza. Generally, surface discolorations appear as dark brown to black stains which penetrate through the stucco as well as surface finishes. The cause of this deterioration has not been determined, but may be either chemical or biological in nature. Should Historic Charleston Foundation seek to rectify this particular problem in the future, a testing agenda including analysis of the affected material ought to be included.

Cracking — Cracking is both a stucco problem and a symptom of deeper-rooted problems. Throughout its history, Aiken-Rhett's exterior has been subject to settling and structural redistribution (discussed earlier) which have caused sometimes extreme movement in the stucco coat; the result is that, as the brick substrate shifts, the weaker and thinner stucco attached to the brick walls cracks. These stuccoes almost certainly bear witness to the power of earthquakes which, like structural re-distribution, may crack surface materials with forces which cause the brick substrate walls to shift. Certainly, structural issues are more critical than those affecting the appearance of the stucco. However, cracks ranging in size from hairline to half an inch and more do threaten the stability of this material by providing an additional venue for moisture penetration. Generally, cracks run the full width of the material, and may run just a few inches or the entire height of a particular facade.

Detachment — Caused by shifting, settling and earthquake damage, detachment occurs where stucco has lost its bond with the brick substrate wall beneath but has not (yet) fallen away from the surface of the building. By opening up additional space between the stucco and the wall, detached areas may allow moisture to become trapped in voids, and may also encourage water to react with and erode the bond between stucco and walls in adjacent, non-detached areas.

Partial Loss This refers to the loss of a portion of the original stucco in a particular place, notably in the form of gouges caused by impact, or occasional differential weathering in a particular area. In such instances, the bulk of the stucco remains attached, and thus may be considered structurally stable. This condition is of some concern, but does not occur to frequently compared to other problematic deterioration conditions.

Total Loss In some areas, such as above 1850s door headers, at many corners, and above the piazza roof on the south facade, a host of problems including excessive structural redistribution and heavy weathering have created a situation so hostile that all stucco has become detached and completely lost from the surface. Such areas are prime candidates for selection as mock-ups for selected replication stuccoes.

Biological Biological growth is most problematic on the north elevation which, because it receives less insolation than do other facades, and because courtyard walls may inhibit the freedom of air circulation, is more damp than are other facades. This generally appears as a brownish-green discoloration. Dampness and the lack of sunshine generally favor the development of algae and other organisms, and, as this elevation is simply less able to "dry out," it is more susceptible to this form of deterioration.

5.1.1 South and East Facades

Although it is inappropriate to say that one portion of Aiken-Rhett's stucco is more *important* than another, it is possible to prioritize survey and conservation efforts where the material displays its greatest degree of integrity. 1830s stucco protected under piazza roofs on the south and east facades, because it has not weathered as severely as the bulk of the building, possesses the greatest extent of material capable of yielding information. Additionally, because these areas are easily accessed at piazza and ground levels, they

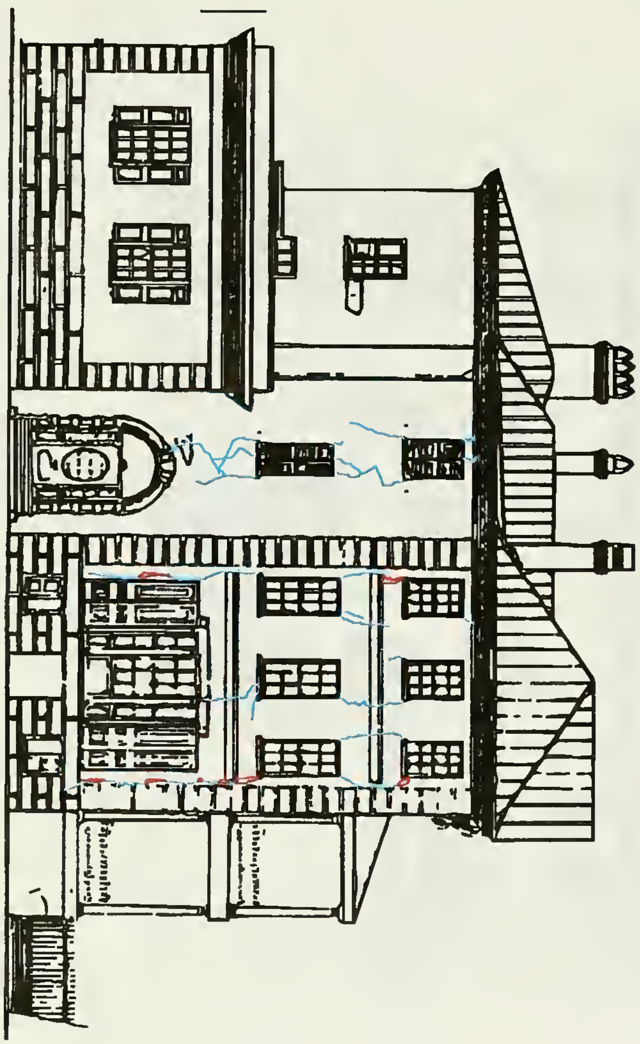
could be easily surveyed without the costly erection of scaffolding. Consequently, the conditions analysis and survey concentrated most heavily on these areas.

Stucco on the south and east facades was documented photographically with Kodak T-Max 100 black and white film from a standard distance of eight feet from the wall surface, which was gridded with string lines to ensure complete photographic coverage. Photographs were scanned, assembled into continuous photographic montages in Adobe Photoshop 4.0, digitally converted, and conditions of deterioration traced directly onto the images with Spittin' Image. 1985 HABS drawings were scanned into Adobe Photoshop and converted with Adobe Streamline into AutoCAD drawing format. Vector lines from the conditions drawings were converted into AutoCAD format, scaled, and inserted into HABS drawings AutoCAD files to approximate the actual extent of deterioration conditions on previously-completed measured drawings. The rationale behind this effort was to provide Historic Charleston with an easily-reproducible document which approximated results which could be obtained with rectified photography.

5.1.2 North and West Facades

The north and west facades of the main residence possess a significant amount of original stucco which exists largely in a weathered state, having lost virtually all traces of historic surface finishing campaigns. Because their height precluded a feasible in-depth analysis as outlined in *Section 5.1.1: South and East Facades,* survey conditions were logged onto

HABS drawings on site and photographed. Survey drawings were then transferred onto scanned, digitized HABS drawings and all conditions drawn in AutoCAD.

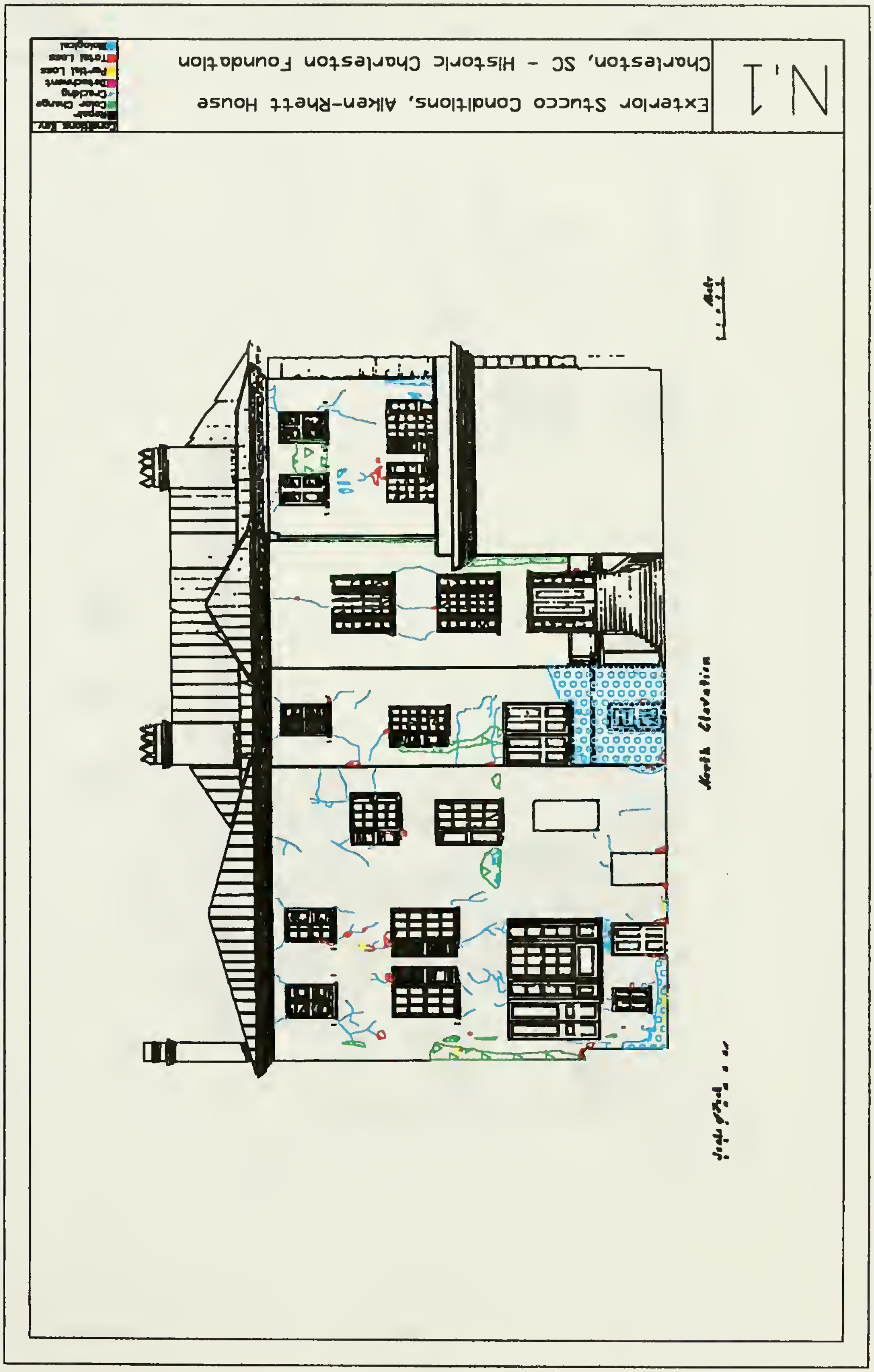


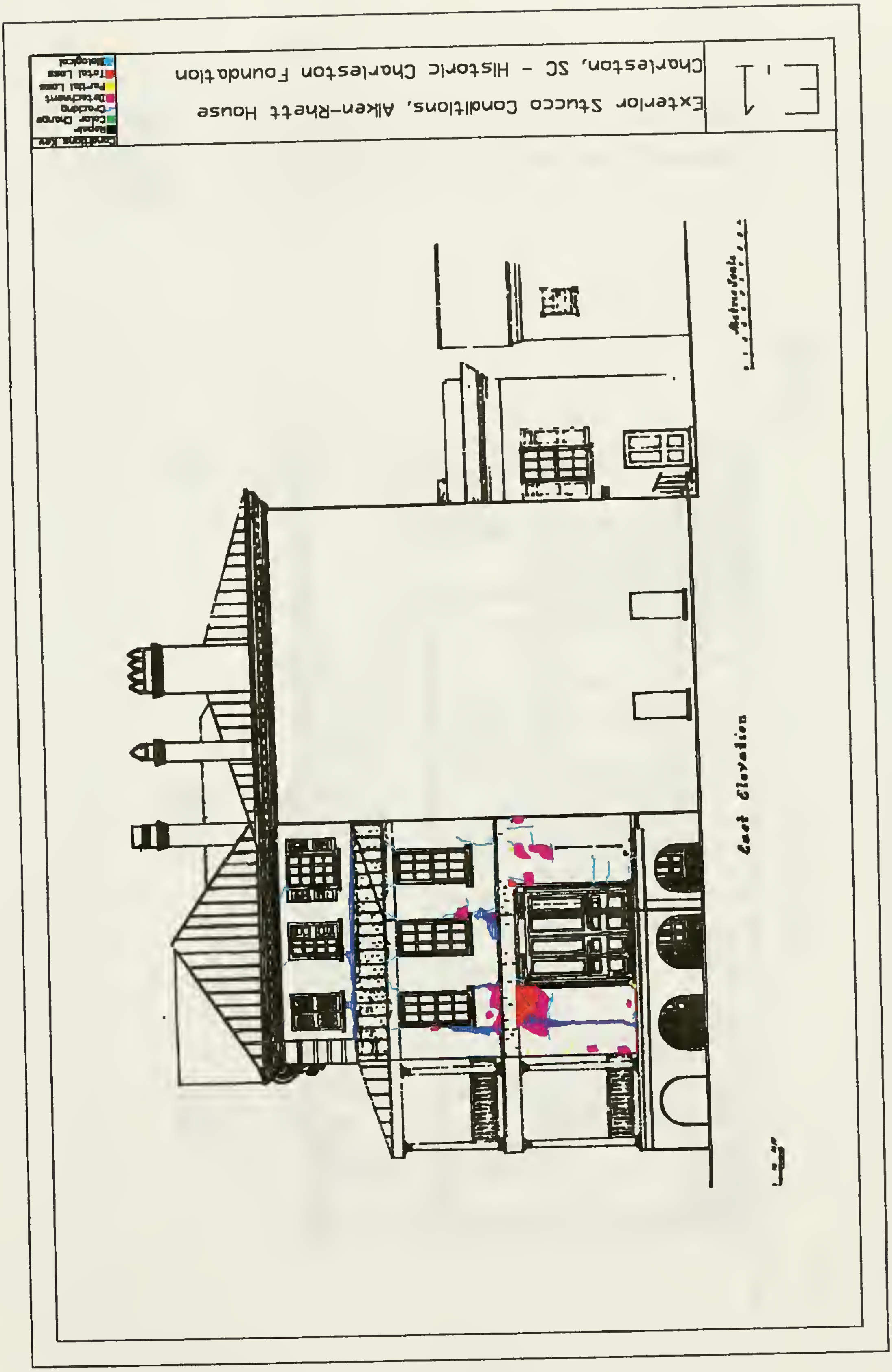
W.1

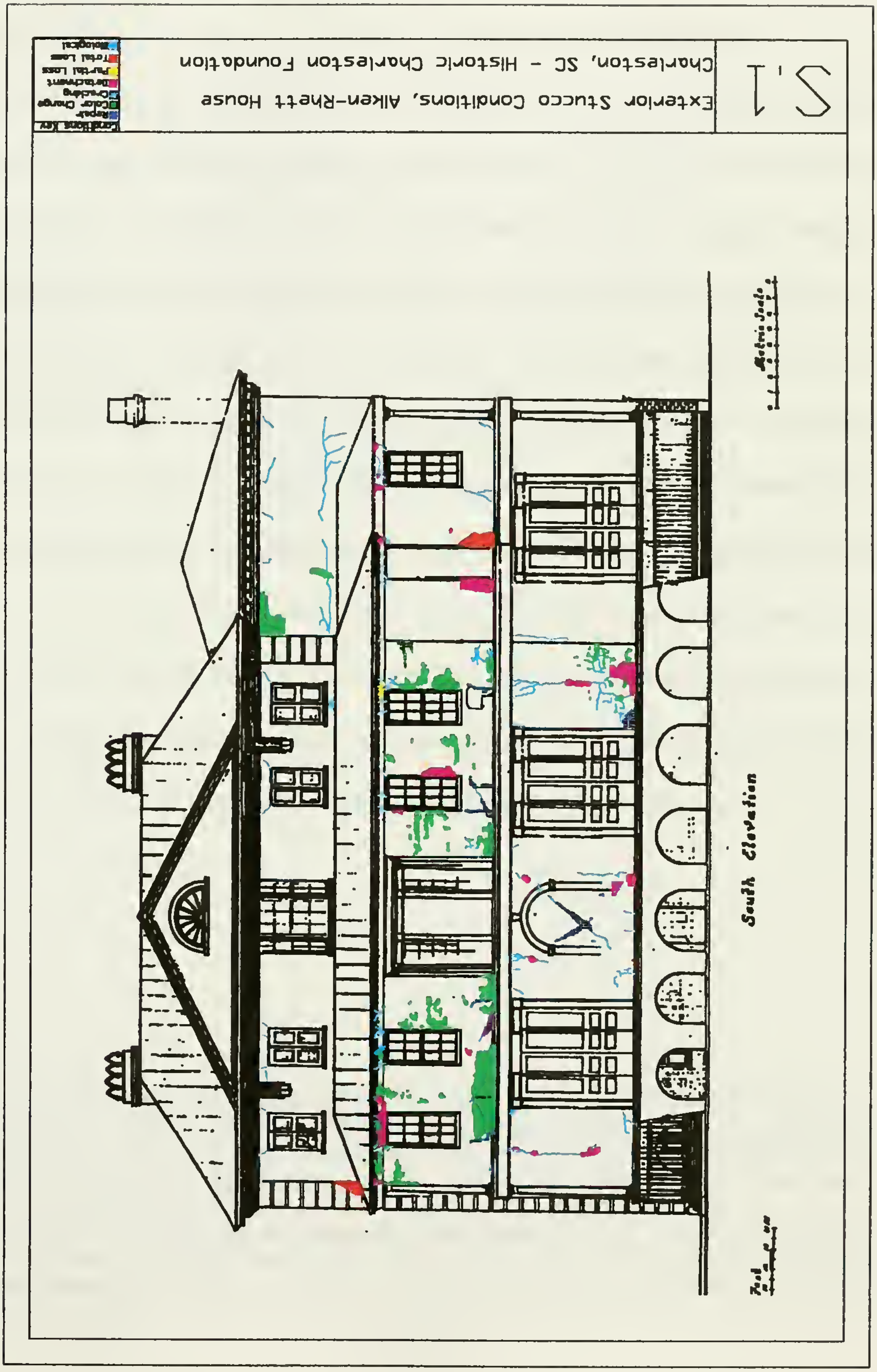
Exterior Stucco Conditions, Aiken-Rhett House

Charleston, SC - Historic Charleston Foundation

Conditions Key
Repair
Color Change
Cracking
Detachment
Partial Loss
Total Loss
Biological


N.1
Exterior Stucco Conditions, Aiken-Rhett House
Charleston, SC - Historic Charleston Foundation
Conditions Key
Repair
Color Change
Cracking
Detachment
Partial Loss
Total Loss
Biological
North Elevation


E.1
Exterior Stucco Conditions, Aiken-Rhett House
Charleston, SC - Historic Charleston Foundation
Conditions Key
Repair
Color Change
Cracking
Detachment
Partial Loss
Total Loss
Biological
East Elevation


S.1
Exterior Stucco Conditions, Aiken-Rhett House
Charleston, SC - Historic Charleston Foundation
Conditions Key
Repair
Color Change
Cracking
Detachment
Partial Loss
Total Loss
Biological
South Elevation
Metric Scale
Feet

6.0 Characterization of 1830s Stucco

The physico-chemical analysis of Aiken-Rhett stucco which follows expands on the findings of Fore and Pepi 1989, which indicated that this was a natural cement stucco, most likely modified with lime to make it more workable.[53] While this research was extremely useful in determining the volumetric relationships between calcium carbonate, non-carbonate acid soluble, sand and clay fractions, it stopped short of recommending an appropriate replication stucco mix for Aiken-Rhett's 1830s stucco, indicating that the natural cement portion could not be equated in an appropriate formula.[54] The analysis which follows recognizes that natural cement may be an important component of the original material, but employs additional experimental standards to outline other potential scenarios. What is clear from previously-completed research, and expanded upon in the following sections, is that Aiken-Rhett's original stucco has significant concentrations of calcium carbonate, high concentrations of non-carbonate acid-soluble material indicative of a hydraulic binder, clays, hydraulic additives and aggregate.

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[53] Fore and Pepi analyzed two stucco samples from Aiken-Rhett. One, taken from the south portico of the main residence, is representative of the 1830s material analyzed herein, and was determined to be composed of a 1.4:2.9:1:4.8 Lime:Acid-Soluble:Clay:Sand volumetric ratio, indicating the presence of a moderately hydraulic natural cement binder with a significant clay component. The second sample, removed from the 1858 art gallery, was composed of a 5:3.5:1:7.5 volumetric ratio.

[54] Fore and Pepi, 15. The study recommended an appropriate mix of 1.5:3.5:1:12 Lime:Portland cement:Brick Dust:Fine Sand for repairs to the Art Gallery. However, because this is a later stucco with a different composition, it does not necessarily translate to the earlier material which are the main subject of this analysis.

Prior to identifying and evaluating replication mixes which might be compatible with the 1830s stucco, a characterization and analytical program was carried out to evaluate important physical and chemical properties, components and performance characteristics of the original stucco. Experimentation and analysis was conducted on 26 samples representative of current conditions of Aiken-Rhett's 1830s campaign from six locations.[55] The analytical program which follows borrows techniques from previously-completed research on mortars and stuccoes in historic buildings. Macroscopic physical examination of the current condition of stucco on the building was conducted prior to laboratory examination (Ciach and Penkala 1984, Feilden 1994). Compositional analyses (Jedrzejewska 1960, Stewart and Moore 1982, Teutonico 1988 and Banta 1995) were performed to provide information on the binder, aggregate and additives used to create the original material. Reflected- and polarized-light microscopy was used to describe its constituent parts as well as to identify microstructure (Ciach and Penkala 1984, Banta 1995 and Carr 1995). Recognizing that many of the primary functions of stucco are related to its ability to keep moisture out of a building and that many problems at Aiken-Rhett result from moisture-related damage, evaluations of the moisture-related properties of the original stucco such as density, porosity, water absorption capacity, water vapor transmission, and evaporation characteristics were obtained in accordance with widely

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[55] Where possible, examination of samples economized as much as possible the number and extent of samples taken. For instance, if a sample broke into several fragments or small portions of original material became detached during the taking of samples, these fragments were collected and used whenever feasible.

documented analytical standards (Ciach and Penkala 1984, Teutonico 1988, Jacob and Weiss 1989, Teutonico et al. 1994, and Carr 1995).

6.01 Sampling

In order to conduct laboratory examination of the physical properties of the 1830s stucco, six disc-shaped samples were removed from Aiken-Rhett's main residence. Upon removal, samples were given a number corresponding to the floor level and facade from which they were taken. Samples taken from first floor level were given the prefix "1", from the second floor "2". Samples taken from the south facade of the main residence were provided the suffix "01", the east facade "02", the south facade of the east wing "03" and so on (Figure 6.1). Samples were provided a final notation of ".1", ".2" etc. based on the order in which they were examined in the laboratory. Consequently, the second sample examined in the laboratory which was taken from the south facade of the second floor piazza of the east wing of the main residence would carry a sample number "203.2."

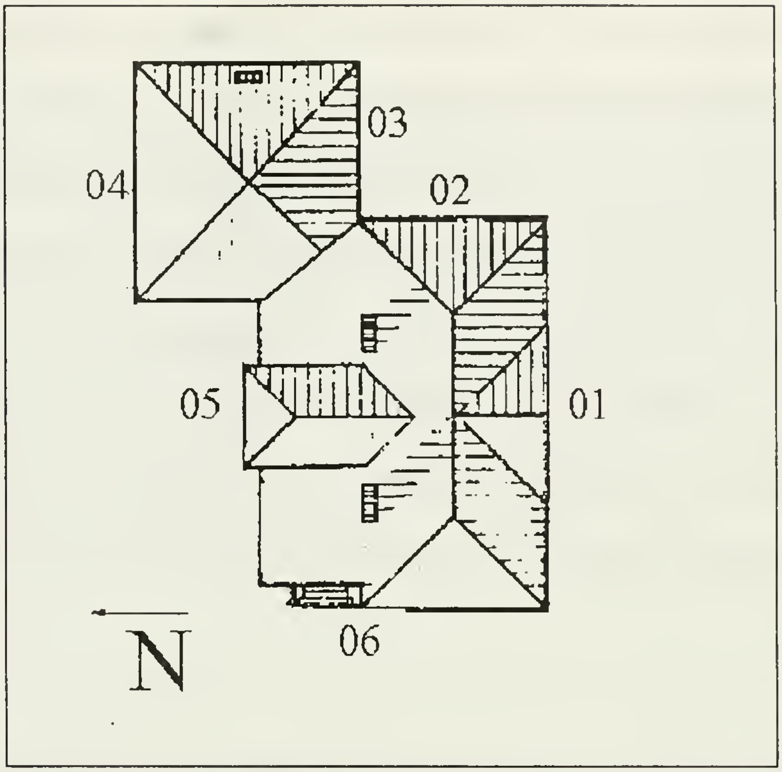

Figure 6.1. Numerical key corresponding to facades from which samples were taken for testing. Based on 1985 HABS drawings for main residence.

Samples representative of various conditions were collected from the building during the week of January 3-10, 1997. Samples which represent the current condition of the 1830s stucco in a protected environment were taken from three locations (101, 102, 203). Samples which represent the current condition of the 1830s stucco in an exposed environment were taken from two locations (005, 206).

In light of the anticipated experimental program slated for potential replication stuccoes, it was decided to procure disc-shaped samples from the building which could be used for

water vapor transmission testing.[56] The material was too abrasive to cut with a standard metal hole saw. This led to the use of a diamond-tipped carbide hole saw bit (with the pilot removed) mounted in a standard electric drill (Figure 6.2). The removal of the pilot made the saw difficult to control against a vertical surface. Consequently, it was decided to remove representative samples with a standard masonry hammer and chisel (Figure 6.3), place the sample in a template pre-drilled in a cedar shingle, anchor the stucco sample from above and below, and then remove a disc-shaped sample. Material which fractured in the process was collected and labeled for additional experimentation in the laboratory.

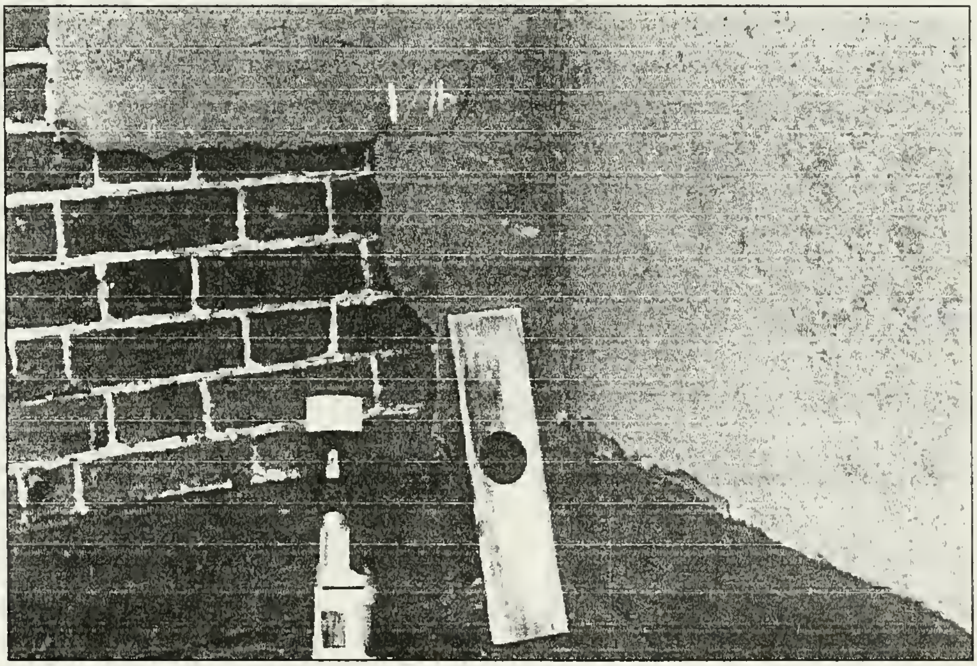

Figure 6.2. Standard metal hole saw bits proved ineffective at cutting through the original material, necessitating the use of a diamond-tipped carbide hole saw bit (not shown) and a pre-drilled template. East facade, second floor above art gallery.

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[56] Parameters of this test are provided in Section 6.3.6: Water Vapor Transmission.

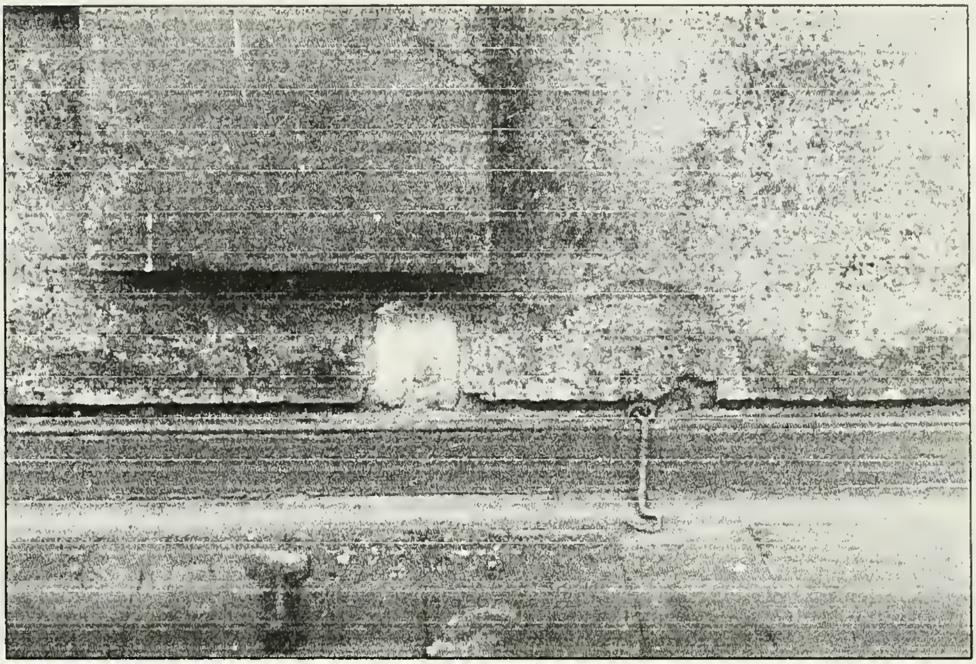

Figure 6.3. In some cases, square-shaped samples were first removed with a masonry hammer and chisel prior to being cut to a disc-shape with a hole saw. South facade, first floor piazza.

6.1 Microstructure

Rationale

In conjunction with visual field observations and physico-chemical analysis, the examination of composite building materials such as stucco with microscopic techniques is a powerful tool to evaluate micromorphology and to identify deterioration mechanisms which may occur on a microstructural level.

Methodology

The original stucco was examined at various magnifications using reflected and polarized light with an Olympus SZ60 Stereo Zoom Reflected Light Microscope, a Nikon Optiphot Polarized Light Microscope and a Zeiss Polarized Light Microscope. Photo-micrographs were taken of areas representative of particular inclusions and conditions.

Data and Observations

The original material is a grayish yellowish brown stucco (Munsell 0.63Y 4.8/1.93) applied in one layer approximately 13mm thick which displays evidence of at least two campaigns of surface finishes (Figure 6.4) The first coat is white and believed to have been applied when the building received its first coat of stucco in the 1830s. The second coat is a "light yellowish brown" campaign corresponding to Munsell 0.2Y 6.80/3.03 believed to have been applied during 1858 renovations.[57] Surface finishes have been lost from the bulk of the material due to years of weathering. Consequently, most of the exposed stucco is now characterized by a warm gray-brown color, created predominantly by a combination of the binding matrix of lime and natural cement possibly extended by clay. Surfaces are generally rough where they have weathered, as grains of aggregate now project beyond the surface of the matrix. This is a moderately well-graded aggregate,

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[57] Confirmation that these finishes were lime-based was determined by digestion of surface layers with dilute hydrochloric acid which produced an expected evolution of carbon dioxide gas. It was not possible to remove enough of the top layer of lime wash to perform a color space measurement on the original white coat.

though it is more coarse than fine. The aggregate appears to have been well-blended into the original mix.

Microscopical examination confirms the presence of both white blebs of lime and tan blebs of clay in a porous matrix, which presumably result from incomplete mixing of a binary binder (Figure 6.5).

Figure 6.4 Aiken-Rhett Sample 101.2, first floor piazza, south facade. Following application of a single coat of stucco, the building was adorned with a layer of white lime wash (A) and a subsequent layer of light yellowish brown pigmented lime wash (B) Munsell 0.2Y 6.80/3.03. Cross-section in reflected light @ 40x magnification.

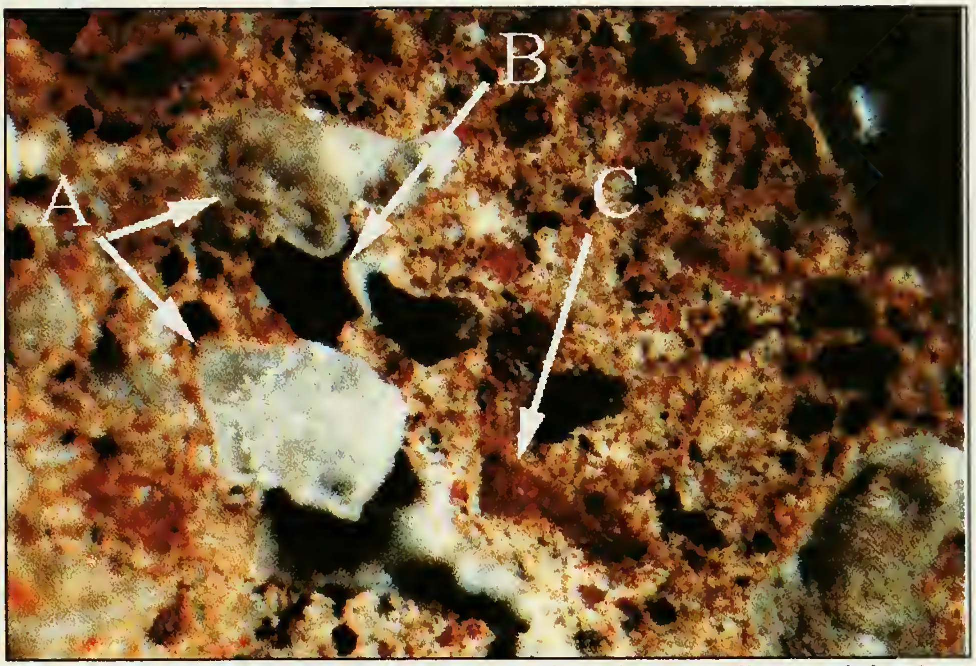

Figure 6.5. Aiken-Rhett Sample 206.6, second floor above art gallery, north facade. Composite material is characterized in part by angular to subangular clear quartz (A) cemented in a porous (B) matrix composed of moderately hydraulic lime and partially-mixed clay (C). Cross-section in reflected light @ 40x magnification.

The aggregate is composed predominantly of quartz and feldspar, which ranges both in particle size and shape (Figure 6.6). Individual crystals range from subrounded to angular, with mostly clear, glassy quartz displaying evidence of iron oxide deposition within irregular, conchoidal fractures and feldspars displaying evidence of oxide deposition within perfect cleavage planes. The presence of iron oxides within quartz and feldspar crystals, visible to the naked eye, in cross-section and in thin-section is likely due in part to the natural formation of the crystals and in part to the migration of iron ions in water from elsewhere in the binding matrix. Notable as well are inclusions of red-orange brick dust and what appear to be shell fragments (Figures 6.8 and 6.9).

Figure 6.6. Aggregate used for the original stucco varies in color, composition and particulate shape. As shown, aggregate removed from matrix by digestion with hydrochloric acid. Reflected light @ 40x magnification.

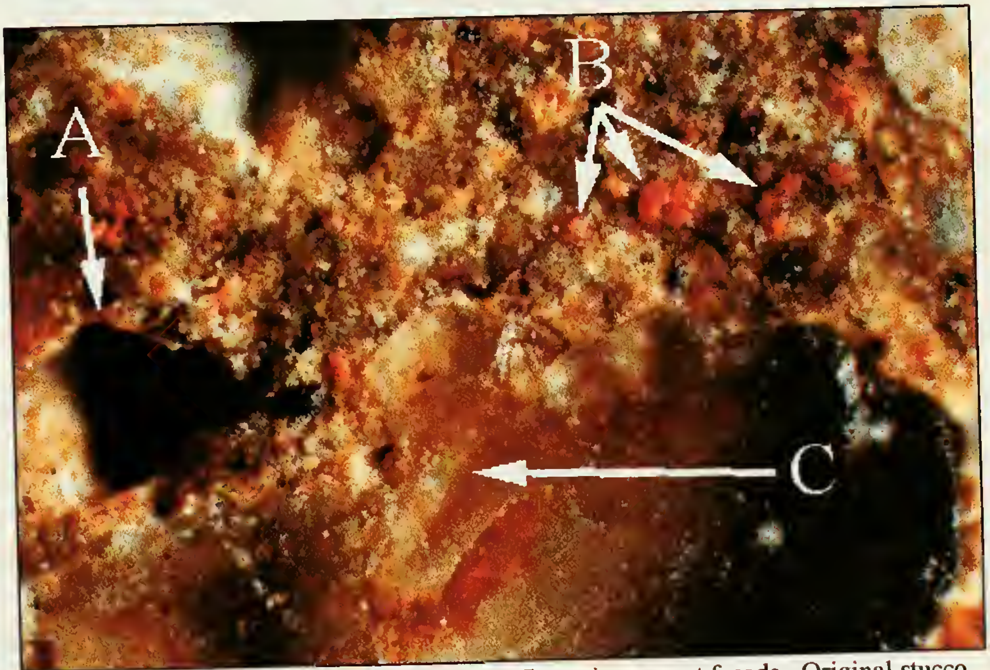

Figure 6.7. Aiken-Rhett Sample 102.2, first floor piazza, east facade. Original stucco characterized in part by open pores (A), brick dust (B) and feldspathic aggregate (C) with iron oxides deposited in natural cleavage planes. Cross-section in reflected light @ 100x magnification.

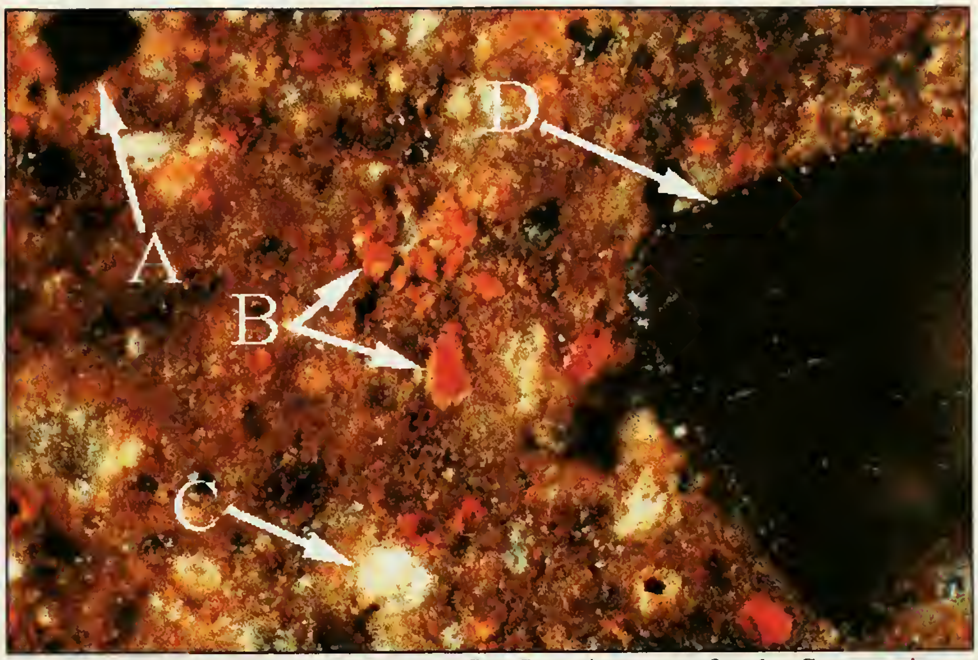

Figure 6.8. Aiken Rhett Sample 102.2. first floor piazza, east facade. Cross-section indicates presence of pores (A) caused both by air entrainment during application and by the alteration of aggregate, brick dust (B) which may have been added to enhance set time and initial hardness, shell fragments (C) used as aggregate or resulting from incomplete lime-burning, and subrounded aggregate (D) which may correspond to the use of a river sand. Cross-section in reflected light @ 100x magnification.

The natural cement and lime binder extended by clay currently creates a porous network whose level of porosity constantly increases as feldspar crystals naturally alter to soluble clays which weather out of the material more readily than do solid elements (Figures 6.10 and 6.11). Feldspars, which are the most abundant group of minerals common to all types of rock, may naturally alter to clay in the presence of water; this alteration may be uniformly distributed, occurring along twin lamellae (Figure 6.11), at the core of the grain (Figure 6.12), or both.[58] Generally, the degree of alteration appears to be greatest at the

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[58] William D. Neese, *Introduction to Optical Mineralogy* (New York: Oxford University Press, 1991. 267-282.

weathering surface where exposure to both liquid water and water vapor is most severe (Figure 6.13). However, select samples display evidence of feldspar alteration to clay and subsequent erosion deeper within the matrix (Figure 6.14) and at the boundary between stucco and brick substrate wall (Figure 6.15)

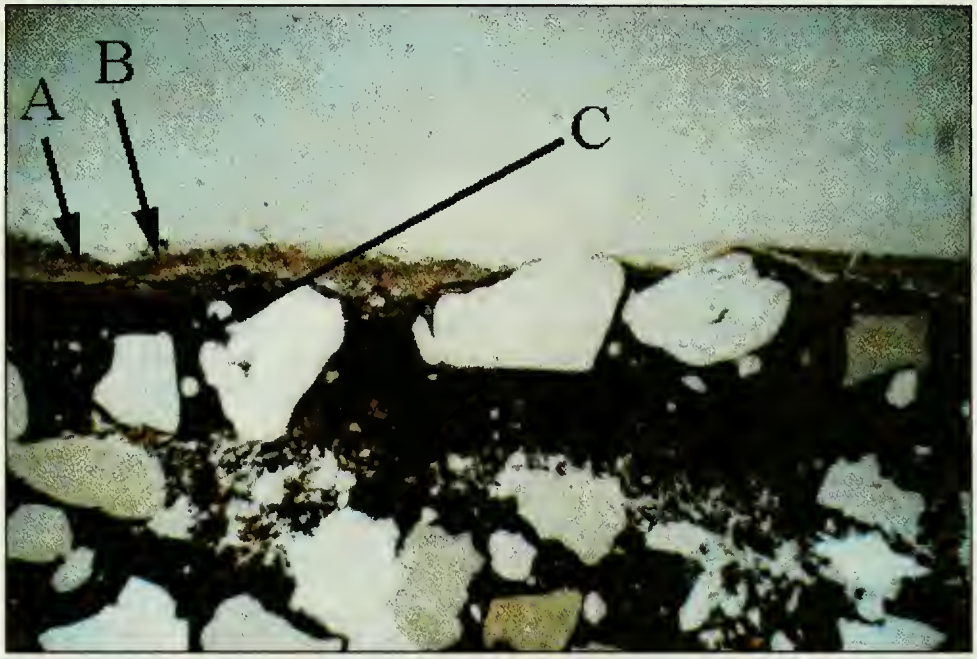

Figure 6.9. Aiken-Rhett Sample 203.1, second floor piazza, south facade. Evidence of two finish coats (A and B) applied to a single layer of rough stucco is provided by definitive white and tan stratigraphies. Aggregate consists of quartz (C) and feldspar. Thin-section in plane-polarized light @ 39x magnification.

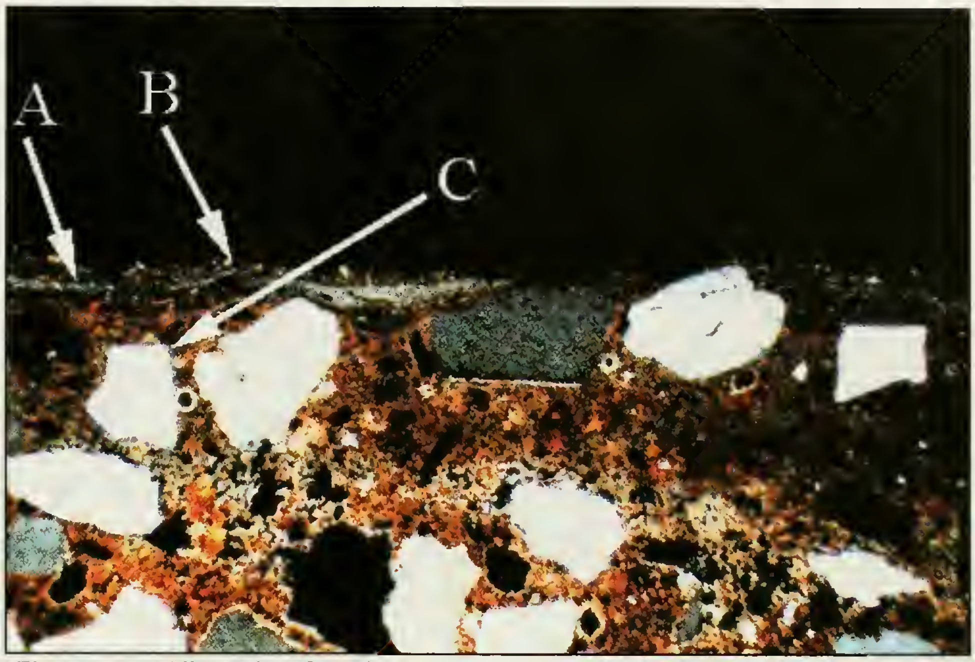

Figure 6.10. Aiken-Rhett Sample 203.1, second floor piazza, south facade. Two finish coats (A and B) applied to a single layer of rough stucco is provided by distinct white and tan stratigraphies. Aggregate consists of quartz (C) and feldspar, distinguished in part by evidence of conchoidal fractures or perfect cleavage. Thin-section in cross-polarized light @ 39x magnification.

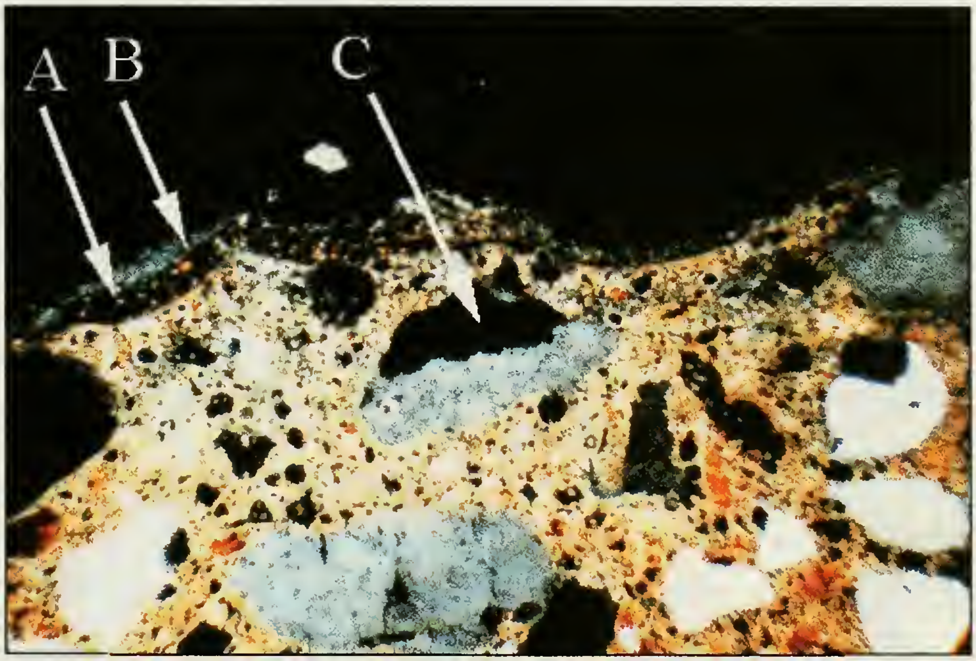

Figure 6.11. Aiken-Rhett Sample 101.1, first floor piazza, south facade. Two finish coats (A and B). Near the surface, partially-weathered feldspars (C) exhibit alteration to clay and perfect cleavage planes; solid matrix outlines space originally occupied by the entire crystal. Thin-section in cross-polarized light @ 39x magnification.

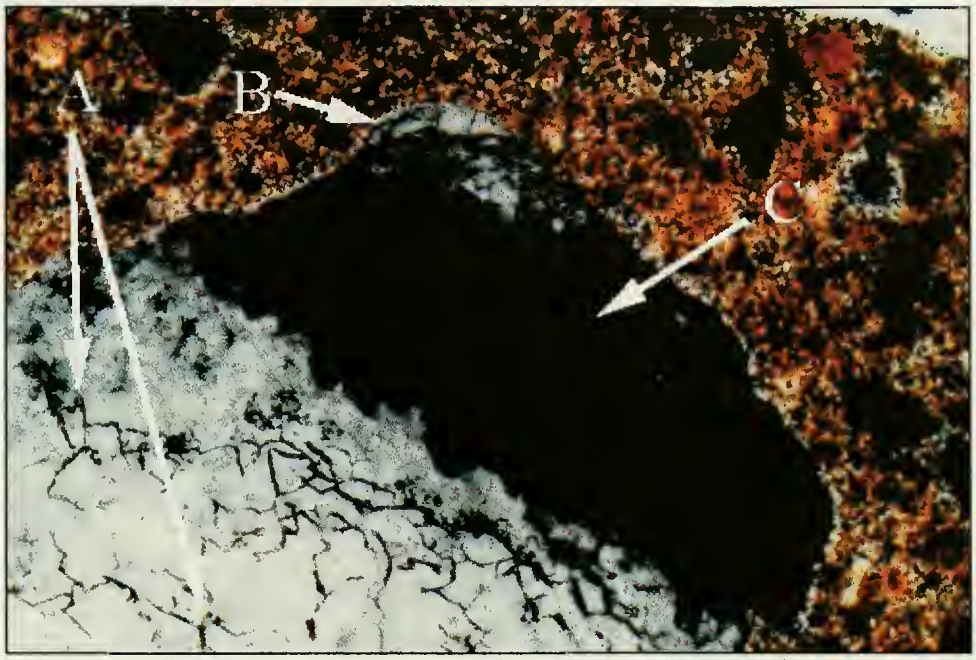

Figure 6.12. Aiken-Rhett Sample 206.1, second floor above art gallery, north facade. Aggregate which displays evidence of iron oxide deposition within cleavage planes which are natural points of weakness (A) provides the original stucco both color and texture. The partial retention of feldspars in the process of alteration at the crystal-matrix boundary (B) is common, as are open pores in the center of the grain (C) left behind with total alteration. Thin-section in cross-polarized light @ 116x magnification.

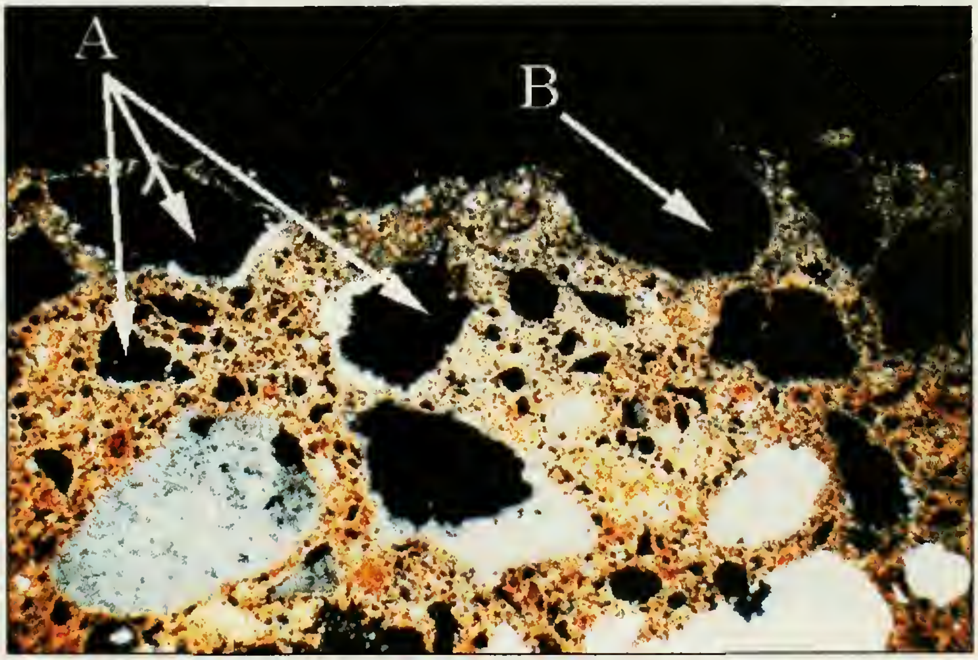

Figure 6.13. Aiken-Rhett Sample 101.1, first floor piazza, south facade. Feldspars closest to the weathering surface are most likely to alter partially (A) and completely (B), leaving open pore space behind as aggregate is lost. Thin-section in cross-polarized light @ 39x magnification.

Figure 6.14. Aiken-Rhett Sample 101.1, first floor piazza, south facade. As feldspars alter by reaction with water, empty pore space, (A) is left behind and the overall porosity of the original material increases. Thin-section in cross-polarized light @ 39x magnification.

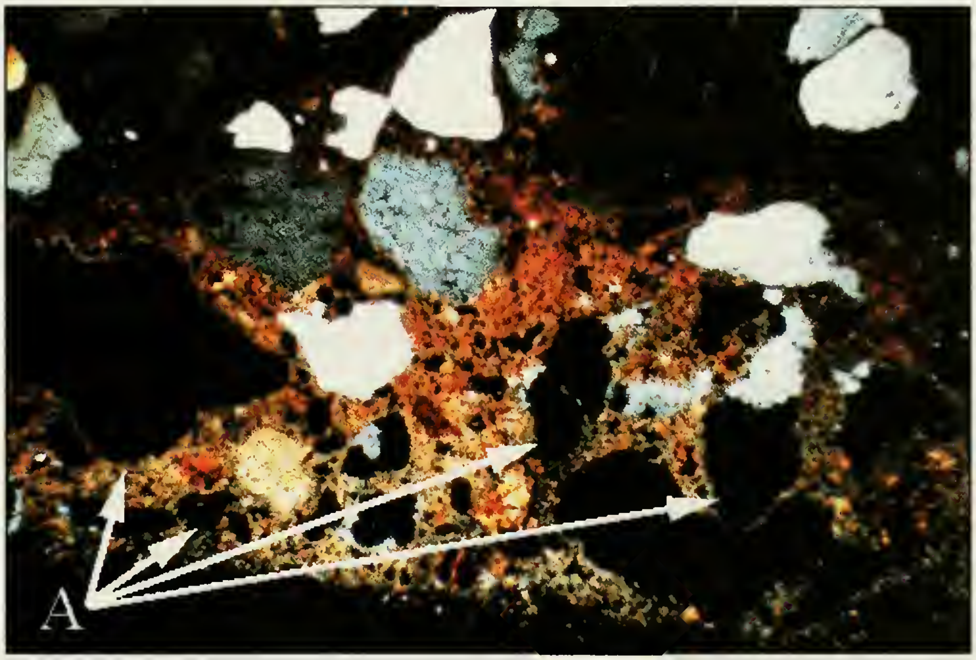

Figure 6.15. Aiken-Rhett Sample 102.1, first floor piazza, east facade. Alteration of feldspars is common both at weathering surfaces and at the boundary with brick substrate walls (A), presumably as water trapped between the original stucco and the wall reacts with aggregate. Thin-section in cross-polarized light @ 39x magnification.

Conclusions

Stucco applied to the building in the 1830s is in generally good condition on the surface, but is in an active state of internal deterioration as weak feldspar crystals which form a significant portion of the original aggregate absorb water, alter to clay, and wash out of the matrix. As solid material is lost, the porosity of the original material increases as does the susceptibility of the material to additional water- and weather-related damage. Though more severe damage might be expected where stucco has been exposed to the greatest amount of weathering (i.e. areas which are not sheltered by piazzas or overhangs), feldspar alteration appears to be a constant in all samples, both protected and exposed. However, no exposed samples were found to retain lime-based surface finishes, indicating that these finishes were the first portions of the material to deteriorate.

Generally, the natural cement- and lime-based stucco appears to have provided durable and stable covering for more than a century, as all samples examined display neither a significant amount of microcracking nor delamination.

6.2 Compositional Analyses

Rationale

Compositional analyses of the constituents of the original stucco provides valuable information about technology and materials employed at the time of construction. Properly executed, chemical and physical analyses of the original material provide information relevant to the preparation of replication mixes. Generally, materials with similar chemical, physical and mechanical properties will stand a better chance of behaving in similar manner over time when placed in similar situations than will materials which are physico-chemically different from one another. As a major goal of this research is to identify a material which may serve as a suitable repair for Aiken-Rhett's original stucco, it was deemed necessary to identify as closely as possible the materials originally used in type and proportion.

Methodology

Compositional analyses of the binder and aggregate used in the original material were conducted using two gravimetric test methods recognized as applicable conservation standards: Jedrzejewska 1960 and Teutonico 1988.[59] The identification of crystalline portions of fine material was accomplished with x-ray diffractometry (XRD).

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[59] Several samples of Aiken-Rhett stucco were analyzed in accordance with procedures outlined in Jeanne Marie Teutonico, "Exercise 21, Mortar Analysis: A Simple Method," *A Laboratory Manual for Architectural Conservators* (Rome: ICCROM, 1988), 113-116 and Hanna Jedrzejewska, Studies in Conservation (1960). The method described in Teutonico method provides acceptable information on the percentage of a specimen composed of binding material (calcium carbonate plus soluble material)

In accordance with the method described by Teutonico, representative samples were dried at 60°C, weighed, crushed with a mortar and pestle, and reacted with a 14% concentration of hydrochloric acid (HCl) to dissolve the acid-soluble portion of the stucco, presumably the binder. Upon completion of the reaction, the non acid-soluble fraction of fines is separated and filtered, while the non-acid-soluble aggregate is washed, dried and weighed. By comparing the amount of mass lost during acid digestion to the mass of the dry aggregate to the mass of the fines, it is possible to calculate compositional mass percentages. By dividing the masses of separate parts by their respective densities, it is possible to obtain relative volumetric information:[60]

$$Volume_{binder} = (mass_{CaCO3}/density_{CaCO3})$$
$$Volume_{aggregate} = (mass_{aggregate}/density_{aggregate}) + (mass_{fines}/density_{fines})$$

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and aggregate (sand plus fines plus property-enhancing additives and solid pigments). The advantage of this particular method is that, because it requires relatively large samples (50 g minimum), analysis will most likely produce aggregate representative of the overall whole. However, the shortcoming of this method is also the primary advantage of the Jedrzejewska method. By measuring the volume of carbon dioxide displacement as well as the amount lost by acid dissolution without displacement, the latter method provides volumetric readings of how much of the binding material is pure calcium carbonate and how much is simply soluble non-carbonate material; in this sense it is the more accurate test. There is concern in sampling, however, as the Jedrjezewska method uses an extremely small amount of material (0.50 g), it may not provide representative assessments of percentage aggregate and fines.

[60] Given that a primary objective of this research was to develop an acceptable replication material which closely resembles the composition and properties of the original stucco in its current state, quantitative mass percentages were converted to volumetric percentages based on the densities of constituent parts. Densities employed for this analysis were computed as follows: High Calcium Lime Putty/$CaCO_3$ (1.244 g/ml), Aiken-Rhett sand (1.60 g/ml), Aiken-Rhett fines (0.52 g/ml). While a 2:5 binder: aggregate mix may have been used for the original stucco, it is not possible to state this conclusively. There is an inherent weakness in this method which assumes that the binder is composed completely of calcium carbonate (CaCO3). Traditionally, however, the density of lime used for stucco would vary with grade and hydraulicity. As acid digestion removes the calcium carbonate portion of the binder, it is not possible to directly measure the density of the original binding material.

By comparing the volumes of binder and aggregate relative to one another, a binder:aggregate ratio which reflects the composition of the original stucco in its current state may be determined (*See Appendix A: Gravimetric and Calcimeter Analyses*).

The analytical method outlined by Jedrzejewska employs similar principles with more precise apparatus in a more controlled setting. Representative samples were dried at 60°C, weighed, crushed, and reacted with dilute hydrochloric acid inside a calcimeter. As the acid dissolves the acid-soluble portion of the stucco, the volume of carbon dioxide (CO_2) produced is measured. Upon completion of the reaction, fines are separated and filtered, while the aggregate is washed, dried and weighed. By comparing the amount of mass lost during the reaction to the mass of the dry aggregate to the mass of the fines, it is possible to calculate compositional mass and volumetric percentages.[61]

Data and Observations

Comprehensive analyses of the constituent parts of 9 samples (005.1, 101.3, 102.3, 102.4, 102.10, 102.11, 203.5, 203.6, and 206.2) are provided in *Appendix A: Gravimetric and Calcimeter Analyses*. In each instance, the reaction of original material with dilute hydrochloric acid produced significant discharge of carbon dioxide and a yellow filtrate,

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[61] This analysis employed the use of a ldirplus computer program written specifically to analyze calcimeter data for the purpose of analyzing historic mortar samples. As outlined, the respective weight volumes of binder ($CaCO_3$ + solubles):aggregate (sand + fines) was computed using aforementioned densities.

results consistent with what would be expected from reaction with a binder composed at least partially of lime. Calcimeter analyses indicated high concentrations of non-carbonate soluble material indicative of a hydraulic binder which would not be found in a matrix composed completely of lime (basically, the higher percentage of solubles in a mix the more hydraulic a material is). All samples examined contained more than 20% non-carbonate acid-soluble material, which, according to Fore and Pepi's observations indicates the presence of complex soluble silicates and a moderately hydraulic binder such as hydraulic lime or natural cement.[62]

The aggregate used for this stucco is a well-graded sand composed mainly of quartz and feldspar, with crushed shells added for texture or as unburned component of binder. Other elements added into the mix include brick dust and clay. Overall, the aggregate portion consists of mainly subrounded, cloudy feldspar and subangular to subrounded, clear quartz, angular feldspar with iron streaks, with notable inclusions of amorphous, red brick dust, and minor inclusions of crushed white shell.

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[62] Fore and Pepi, 7. This assertion is a relative gauge of hydraulicity amongst samples, but the 20% value is left unqualified. The actual figures for samples analyzed in this study are reported in Appendix A: Gravimetric and Calcimeter Analyses, and generally fall within the range of 30% acid soluble material.

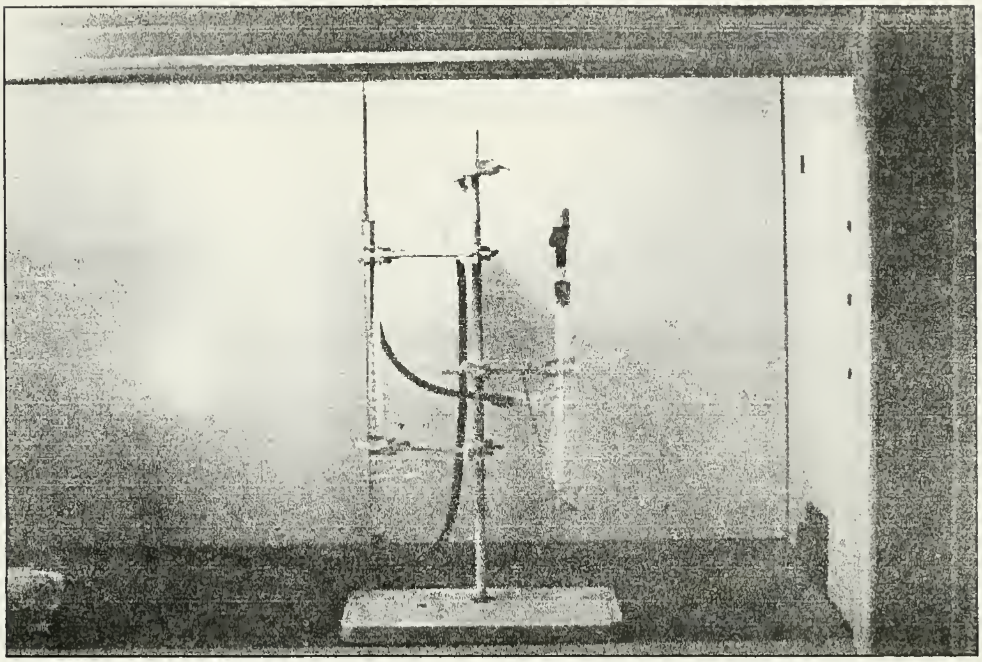

Figure 6.16. A calcimeter conforming to the parameters of the Jedrjezewska method was employed to analyze the constituent parts of original stucco.

Fine particulates were analyzed using X-Ray Diffraction, which confirmed the presence of calcium carbonate in samples which had not been completely reacted with hydrochloric acid *(Appendix B: X-Ray Diffraction Data).* Also identified were quartz (SiO_2) from crushed sand and iron oxides (Fe_2O_3) and alumino-silicates, ostensibly from clays added to the mix.[63] Because the diffraction spectra of clays are not conclusively detectable, confirmation of the specific nature of the clays used in the original stucco is not possible. Additionally, though complex soluble calcium silicates indicative of a hydraulic binder might be present, detection of these compounds with XRD was inconclusive.

[63] The identification of clay types with XRD is an inexact science as their diffraction peaks are obscured by spectral noise and their intensity levels are not as high as those for other elements. Still,

Examination of samples which had undergone acid digestion indicated no presence of calcium carbonate, but did provide evidence of quartz, iron oxides and alumino-silicates.

Compositional percentages of binder and aggregate varied with location and exposure to weathering elements. Calcium carbonate binder fractions ranged from 15.90% in sample 102.11 to 30.91% in sample 203.6. Aggregate fractions ranged from 32.00% in sample 203.6 to 62.00% in sample 102.10.

Conclusions

Gravimetric and calcimeter analyses of this stucco provide insight into its compositional nature, but prove inconclusive at establishing a precise volumetric formula which could be used for replication stuccoes, simply because the original has weathered for more than 150 years, and has changed somewhat during this period.

The reaction of hydrochloric acid with the original stucco suggest that the binder contains a significant amount of calcium carbonate (averaging 23.41 ± 4.71%, and ranging from 15.90% in Sample 102.11 to 30.91% in Sample 203.6), the presence of which was confirmed by XRD. Furthermore, the presence of shell fragments in cross-section suggests that the lime used for this stucco may have been produced by burning shells into pure calcium carbonate (it is also possible that these fragments may have been included in the aggregate portion of the mix). The presence of a significant amount of complex

solubles (averaging 29.09 ± 3.78%, and ranging from 21.20% in Sample 102.10 to 37.09% in Sample 203.6) suggests that there is a significant concentration of hydraulic material which would be present in a cementitious binder. XRD analysis revealed the moderate presence of complex silicates soluble in hydrochloric acid and indicative of hydraulic material. When compared with previous academic research, the calcium carbonate content is consistent with what would be expected from a lime binder and calcareous aggregate, but the solubles content is consistent with what would be expected from a cementitious binder and clayey aggregate (Table 1). Simply stated, it is not entirely possible to determine the nature of the binding matrix by direct comparison with previously-established experimental standards. Additionally, as the parameters of gravimetric analysis do not allow for a precise identification of binding components, it is difficult to definitively state what the binding matrix of the original stucco is composed of.

	Mixture	**$CaCO_3$**	**Solubles**	**Aggregate**
	Aiken-Rhett 1830s Stucco	**23.41 ± 4.71%**	**29.09 ± 3.78%**	**47.50 ± 7.62%**
1:3	lime:sand	10.0[**] ± 0.4%	2.4 ± 0.7%	87.6 ± 0.3%
1:3	lime:calcareous sand	26.2[***] ± 1.3%	3.0 ± 0.9%	70.9 ± 2.2%
1:3	lime:clayey sand	10.2 ± 0.2%	13.2 ± 0.6%	76.6 ± 0.9%
2:1:5	lime:pozzolanic cement:sand	11.0 ± 0.1%	6.6 ± 0.4%	82.4 ± 0.3%
100%	Portland cement	7.2 ± 0.4%	92.1 ± 0.3%	0.6 ± 0.2%
1:3	Portland cement:clayey sand	7.9 ± 0.1%	29.6 ± 1.6%	62.6 ± 1.6%
1:3	Portland cement:sand	6.4 ± 0.4%	27.4 ± 3.0%	66.2 ± 3.4%
1:3	Roman cement: sand	8.5 ± 0.6%	16.1 ± 0.2%	75.3 ± 0.4%

Table 1. Compositional data for Aiken-Rhett 1830s stucco versus experimental standards set forth by Stewart and Moore.[64]

[64] Stewart and Moore, "Chemical Techniques of Historic Mortar Analysis," *Bulletin of the Association for Preservation Technology*, Vol. XIV, No. 1, (Washington: Association for Preservation Technology, 1982), pp. 11-16.

Based upon a comparison of Stewart and Moore's experimental standards and data for Aiken-Rhett, there appear to be no fewer than three possible binder sources which might yield the results obtained:

1) The binding matrix is composed of a lime-natural cement blend combined with an aggregate with calcareous inclusions (shell fragments) extended by clay. Lime and shell fragments yield high $CaCO_3$ readings, with high soluble readings attributable to solubles from the cement, clays and brick dust. This much has been established by Fore and Pepi:

> 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 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.[65]

2) The binding matrix is composed of a hydraulic lime combined with an aggregate with calcareous inclusions (shell fragments) extended by clay. Lime and shell fragments yield high $CaCO_3$ readings, with high soluble readings attributable to solubles from impurities in the lime, clays and brick dust.

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[65] Fore and Pepi, 7.

3) The binding matrix is composed of natural cement combined with an aggregate with calcareous inclusions (shell fragments) extended by clay. Shell fragments may yield high $CaCO_3$ readings (but not likely to the extend indicated in the data), with high soluble readings attributable to solubles from the cement, clays and brick dust.

Sand used in this material is most likely a river or ocean sand, as suggested by rounded to subrounded crystal edges which could result from the continual action of water on previously angular surfaces. Brick dust is a notable additive. It is plausible that plasterers added brick dust in an attempt to speed up the setting rate of this stucco in a humid climate which would not be conducive to the natural cure of lime mortar.[66] The significant presence of clay included in the "fines" portions of Samples 005.1, 101.3, 102.3, 102.4, and 206.2 (ranging in percentage from 15.27-44.60%), further suggests that the binder was either a hydraulic lime or natural cement, that a lime/natural cement compound binder was employed, or that non-reactive clay adulterants were added to extend the mix and/or to provide color.

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[66] John Glengary Carr, *An Investigation on the Effect of Brick Dust on Lime-Based Mortars* (Masters' Thesis, Philadelphia, PA: University of Pennsylvania, 1995) provides a comprehensive analysis of the effects of pozzolanic materials such as brick dust on lime mortars. In addressing the potential hydraulic qualities which brick dust additives may impart, Carr notes "The fundamental property of a pozzolana is its ability to combine with alkaline lime or cement to yield a material with improved performance. As well, the addition of a pozzolana results in a fundamentally different setting process. Lime mortars modified with either artificial or natural pozzolanas produce a relatively insoluble and durable material that differ[s] from lime mortars. Generally, lime-based mortars require long periods of time to set up or harden and are less resistant to destructive agents including water, freeze/that cycles and salts in solution than those modified with pozzolanas," 1.

Compositional percentages vary with the location of the building from which samples were taken, and appear to relate both to the microclimate and aesthetic intent. Samples exposed to the greatest amounts of moisture (005.1, removed from ground level above a brick landing in the rear courtyard, and 206.2, removed from the roofline above the art gallery) retain less aggregate than do intact, sheltered samples; this results as moisture erodes binding materials, causing the gradual loss of individual grains. Additionally, where plasterers desired smooth, crisp edges at door and window corners (samples 203.3, 203.5 and 203.6), the effect of troweling and tooling appears to have decreased the percentage of aggregate in a specific area.

6.3 Presentation and Analysis of Critical Performance Data

6.3.1 Color

Rationale

Most of Aiken-Rhett's stucco dates to the 1830s, when interior alterations and the re-location of the main entrance caused extensive disruption to the original brickwork. As disturbances in brickwork would have compromised the aesthetic integrity of the building, the stucco which concealed masonry repairs took on an important role. Color is an important component of the continued aesthetic impact this material imparts to the building. The analysis which follows provides valuated data regarding the current color of the original material.

Methodology

Six samples of original stucco were analyzed for color using a Minolta Chroma Meter. Properly calibrated and operated, the Chroma Meter provides an electronic assessment of color space in several internationally-recognized formats.

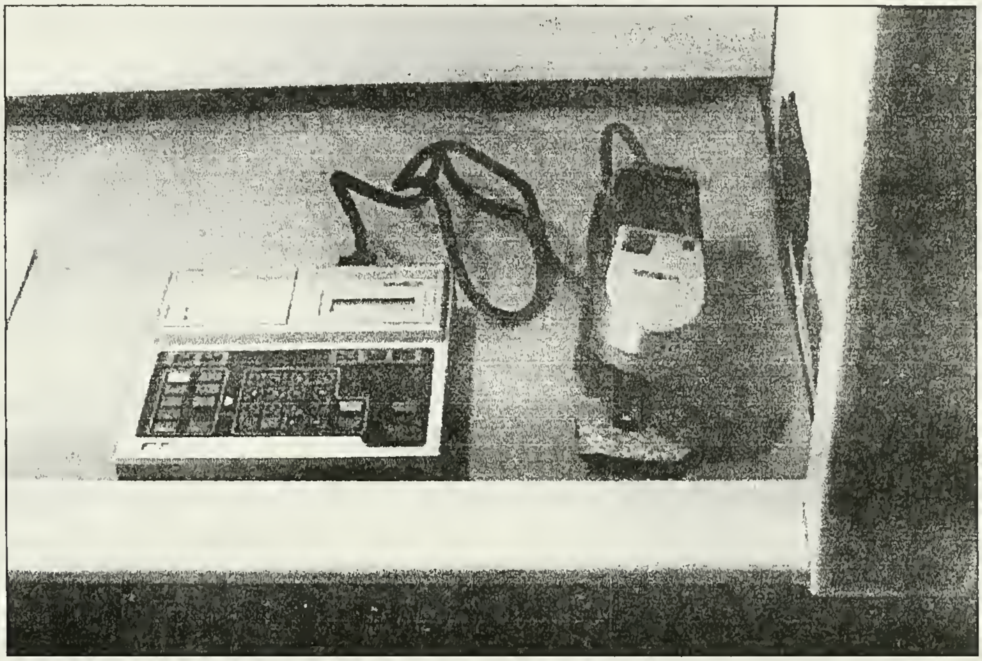

Figure 6.17. A Minolta Chroma Meter was employed to evaluate the color space measurements of all samples of original stucco.

For the purpose of standardization with previous analyses conducted for Historic Charleston Foundation, all samples for this survey were analyzed with the Munsell System of Color. The Munsell system evaluates the color of a material with respect to three variables: *hue, chroma* and *value*. The hue notation indicates the relation of the color sampled in relation to other standard colors ("Y" for yellow, "YR" for yellow red, etc.). The value notation reflects the lightness or darkness of the sample within the range of the

hue, with "0" being absolute black and "10" being absolute white. The chroma notation indicates the saturation of the sample, with "0" corresponding to a neutral color while higher numbers relate to higher degrees of intensity.[67] Three electronic readings were taken for each sample and the measurements averaged to provide a representative valuation of the color of each. Representative samples include assessments of the predominant color of the stucco, excluding any surface finishes.

Data and Observations

The data reported in Table 2 represents average color space evaluations for the entirety of the building as well as individual samples. Comprehensive color space evaluation data for individual samples is provided in *Appendix C: Colorimetry Data.*

Sample	Hue	Value	Chroma	Color
Aiken Rhett, 1830s Stucco (average)	**9.08YR-0.47Y**	**5.18**	**1.96**	**"Grayish yellowish brown"**
005.1 (average)	0.46Y	4.23	2.03	"Grayish yellowish brown"
101.4 (average)	0.1Y	5.3	1.87	"Grayish yellowish brown"
102.5 (average)	0.63Y	4.8	1.93	"Grayish yellowish brown"
203.3 (average)	9.33YR	4.0	1.9	"Grayish yellowish brown"
203.4 (average)	8.83YR	4.06	2.17	"Grayish yellowish brown"
206.2 (average)	0.67y	4.67	1.87	"Grayish yellowish brown"

Table 2. Comparative color space values for original stucco expressed as a function of hue, value and chroma in Munsell System of Color.

[67] Timothy M. Noble, J. Christopher Frey and Kristin Justham, Pennsylvania State Capitol Masonry Conservation Study (Zionsville, PA: unpublished, 1997), Appendix E: Colorimetry Data.

Conclusions

Despite having weathered somewhat differently in different micro-climates, the stucco possesses a relatively homogenous color. While colorimetry data indicates slightly different readings for the hue, value and chroma of each sample, all readings correspond to the color name "grayish yellowish brown" as defined by the Department of Commerce.[68] Unto itself and without the analysis of surface applications, this represents the natural color which results from the combination of white lime, gray-brown clay, red brick dust and clear, white and tan sand.

6.3.2 Texture

Rationale

The texture of a material is an important component of the impression which it creates. The interaction of light and shadow on the surface of a material is able to create subtleties and intricacies which contribute to the greater whole of an architectural experience.

Methodology

Aiken-Rhett specimens were compared with grit sandpaper samples to evaluate readily-available, benchmark texture references. Although this method of analysis is purely visual,

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[68] Munsell color data corresponds with color names as listed in Kenneth L. Kelly and Deane B. Judd, *Color: Universal Language and Dictionary of Names* (Washington, DC: United States of America Department of Commerce Sensory Environment Section, Center for Building Technology, National Bureau of Standards, 1976).

and somewhat subjective, it does offer a textural reference which will be easily understandable to architects, conservators and contractors alike.

Six samples of original stucco were compared against sandpapers of 220-grit, 120-grit, 80-grit, 50-grit and 36-grit and the results logged. Textural comparisons for individual samples are provided in Appendix A: Gravimetric and Calcimeter Analyses.

Data and Observations

The general surface textures of four samples (005.1, 101.4, 102.5, and 206.2) are most similar to that of 80-grit sandpaper, as reported in Table 3. The surface texture of two samples (203.3, 203.4) are more similar to that of 120-grit sandpaper.

Sample	Reference comparison
Aiken-Rhett 1830s Stucco (average)	**80-grit sandpaper**
Sample 005.1	80-grit sandpaper
Sample 101.4	80-grit sandpaper
Sample 102.5	80-grit sandpaper
Sample 203.3	120-grit sandpaper
Sample 203.4	120-grit sandpaper
Sample 206.2	80-grit sandpaper

Table 3. Comparative texture evaluations for original stucco.

Conclusions

Most of the samples examined are comparable to the texture of 80-grit sandpaper. Assuming that weathered surfaces and the rear surfaces of protected are representative, then, most of the exterior of the building may be said to have a texture similar to 80-grit sandpaper. Variations will occur where surface applications are intact, and surfaces are

notably smoother. Smoother surfaces also exist in areas which have been worked to a greater degree, including at corners where more binder has been brought to the surface with increased troweling (as represented by samples 203.3 and 203.4, the texture of such areas is closer to that of a finer, 120-grit sandpaper).

6.3.3 Density

Rationale

An examination of the density of the original material was conducted to determine the amount and weight of solid material which exists per unit space. This analysis was conducted in anticipation of using density as a comparative factor for potential replication materials.

Methodology

Standard procedure following Teutonico, "Exercise 13: Porosity in Solids: Hydrostatic Weighing," and RILEM Test I.2: "Bulk and Real Densities" was followed. Disks of original material were dried at 60°C and the mass measured before being immersed in water for a period of 72 hours. Each sample was weighed both hydrostatically (Figure 6.18) and on an electric scale. The real density of the material is expressed in kg/m^3 by the following calculation:

$$\text{Real Density} = (mass_{dry}/(mass_{dry} - mass_{hydrostatic})) \times 10^3$$

Experimentation and calculations were performed for five samples of original material (005.2, 101.4, 102.5, 203.3 and 203.4).

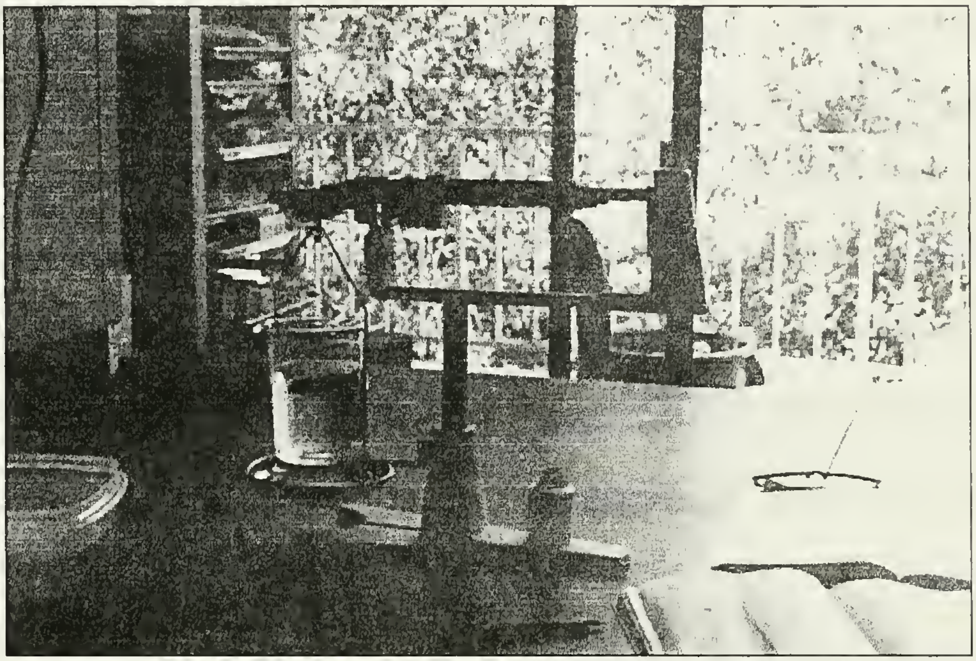

Figure 6.18. Measuring the density of original stucco based upon figures and calculations resulting from hydrostatic weighing.

Data and Observations

Data reported in Table 4 and calculations employed for statistical analysis are provided in *Appendix D: Density Data.*

Sample	$Mass_{dry}$ (g)	$Mass_{hydrostatic\ s}$ (g)	Real Density (kg/m^3)
Aiken-Rhett 1830s Stucco			**266.20 ± 18.98**
005.2	26.81	16.82	268.36
101.4	31.61	19.81	267.88
102.5	22.25	14.14	274.35
203.3	37.02	24.21	288.99
203.4	40.20	22.83	231.43

Table 4. Comparative real densities for original stucco.

Conclusions

The average density of the stucco is 266.20 ± 18.98 kg/m^3. The most significant deviations from the average occur in samples 203.3 and 203.4, which are the only samples analyzed with numbers significantly different from the rest. The respectively high and low densities exhibited by these samples suggests that the additional manipulation required to trowel corners into a smooth finish affects the density of the material. This conclusion is perhaps less important in the overall conservation scheme of Aiken-Rhett's stucco than is the fact that it illustrates the importance of sampling representative materials if accurate performance values and characteristics are to be obtained.

6.3.4 Porosity

Rationale

Examining of the porosity of a material such as stucco, which by intention is exposed to weathering, is useful to determine not only the deleterious and decompositional effects which weathering may have on a material over time, but also in evaluating the potential for a material to disintegrate further. Porosity is expressed as the percentage of pore space within a given sample. Empty space within a composite material such as stucco may occur as a result of air bubbles entrained during mixing or application to the building, cracking which may take place during cure, cracking which may occur during physical impact, or with the loss of material due to weathering over time.

Methodology

Standard procedure following Teutonico, "Exercise 13: Porosity in Solids: Hydrostatic Weighing," and RILEM Test I.2: "Bulk and Real Densities" as outlined *in Section 6.3.3: Density* was utilized. Measurement of porosity relies on the calculation of the total volumetric percentage of a sample which consists of empty space. Evaluation of porosity percentages may be made by comparing the apparent density of a given material with its actual, or "real" density, where:

Apparent Density = $(mass_{dry}/(mass_{saturation} - mass_{hydrostatic})) \times 10^3$
% Porosity = [1-(apparent density/real density)] x 100

Data and Observations

Data reported in Table 5 and calculations employed for statistical analysis are provided in *Appendix E: Porosity Data.*

Sample	Real Density (kg/m³)	Apparent Density (kg/m³)	Porosity (%)
Aiken-Rhett 1830s Stucco			**24.94 ± 2.80**
005.2	268.36	193.99	27.71
101.4	267.88	193.45	27.78
102.5	274.35	210.90	23.13
203.3	288.99	215.11	25.56
203.4	231.43	183.98	20.50

Table 5. Comparative porosities for original stucco expressed as a percentage of pore space within solid material.

Conclusions

The average porosity of the stucco is 24.94 ± 2.80%. Somewhat surprising is the fact that weathering appears to have little bearing on the overall porosity of a material, as evidenced by comparable values between severely weathered sample 005.2 and protected samples 101.4, 102.5 and 203.3. This suggests that, as of feldspathic portions of the aggregate erode and leave behind empty pore space, the resultant deteriorated surface may be so weakened that it washes away more easily than the solid material beneath. Thus, a more porous layer erodes more quickly to stable material and does not figure into the data reported in this section. The most significant deviations from the average occur with sample 203.4, which represents material exposed to the highest degree of tooling. As troweling manipulated the relative proportions of binder and aggregate in this sample by bringing more binder to the surface, a greater percentage of binder necessary to create a smooth finish also creates a more compact matrix with less aggregate which could erode into empty pore space.

6.3.5 Water Absorption Capacity

Rationale

An analysis of the ability of the original stucco to absorb liquid water was conducted to assess the potential of the material to transmit water and soluble salts. Generally, the more water a material is capable of absorbing, the more susceptible it may be to damage incurred as a result of freeze-thaw cycles or soluble salt crystallization.

Methodology

Standard procedure following Teutonico, "Exercise 13: Porosity in Solids: Hydrostatic Weighing," and RILEM Test I.2: "Bulk and Real Densities" as outlined in Section 6.3.3: Density and ASTM Designation C 97-83 "Standard Test Methods for Absorption and Bulk Specific Gravity of Dimension Stone" was utilized. Measurement of the Water Absorption Capacity (WAC) of a given material is expressed a the percentage of overall weight gained by a given sample after an extended period of total immersion until saturation is reached, where:

$$WAC (\%) = ((mass_{saturation} - mass_{dry})/(mass_{dry}))$$

Data and Observations

Data reported in Table 5 and calculations employed for statistical analysis are provided in *Appendix F: Water Absorption Capacity Data.*

Sample	$Mass_{dry}$ (g)	$Mass_{saturated}$ (g)	Change (g)	Water Absorption Capacity (%)
Aiken-Rhett 1830s Stucco				**12.47 ± 1.43**
005.2	26.81	30.64	+ 3.83	14.29
101.4	31.61	36.20	+ 4.54	14.08
102.5	22.25	24.69	+ 2.44	10.97
203.3	37.02	41.42	+ 4.40	11.89
203.4	40.20	44.68	+ 4.48	11.14

Table 6. Comparative water absorption capacities for original stucco expressed as a percentage of total weight in a saturated sample which is occupied by water.

Conclusions

The average water absorption capacity of the original stucco is 12.47 ± 1.43%. The data obtained suggests that weathering may have a slight impact on the material's ability to absorb water, as the WAC of Sample 005.2 represents a marked increase in absorption capacity compared with unweathered samples 102.5, 203.3 and 203.4. The comparatively high WAC of Sample 101.4 may or may not be an anomaly. Additional sampling and examination would be required to accurately assess the relative effect which weathering has on the ability of this material to take on additional liquid water

6.3.6 Water Vapor Transmission Rate

Rationale

It is a given that water, in the form of rainfall, runoff or rising damp will find a way to penetrate a building. Because it is applied as a sheltering material, stucco must be able to transmit water once absorbed either by it or by the brickwork beneath it. An analysis of the ability of the original stucco to transmit water vapor was conducted to determine the relative ability of the material to relinquish water in vapor form which might be absorbed by this or other building materials.

Methodology

Standard procedure following ASTM Designation E 96-80 "Standard Test Methods for Water Vapor Transmission" was modified to reflect smaller sample size. Disc-shaped

samples of original material approximately 42.5 mm in diameter and 13 mm thick were cleaned of all surface debris and sealed around the edge with electrical tape to create a vapor barrier. Taped samples were placed on the ledge of a water-filled 50 ml tri-cornered polypropylene test dish with a 42 mm reactive surface opening. Paraffin wax was applied around the top of the dish to create a seal between the electrical tape and the polypropylene cup, with care taken so as not to spill hot wax which might affect transmission qualities onto the surface of the sample. The wax was allowed to cure and the mass of the entire apparatus measured. The test apparatus was placed in a sealed observation chamber with Drierite (manufactured by W.A. Hammond Drierite Company, Xenia, OH) desiccating material below (Figure 6.19). As the desiccant drew water vapor through the material, periodic measurements (every 24 hours for the first 72 hours and each three days for the next 24 days) of mass were conducted to determine the loss of mass of each sample apparatus over time (Figure 6.20). Water vapor transmission rates were calculated for each sample in units ($g/h*m^2$). Measurements of temperature and relative humidity inside the chamber were also recorded.

An average water vapor transmission rate (WVTR) was calculated for the original stucco based on the performance of five samples (005.2, 101.4, 102.5, 203.3 and 206.2). A control specimen was also evaluated to measure the fluctuation in readings which is not attributed to effective transmission.

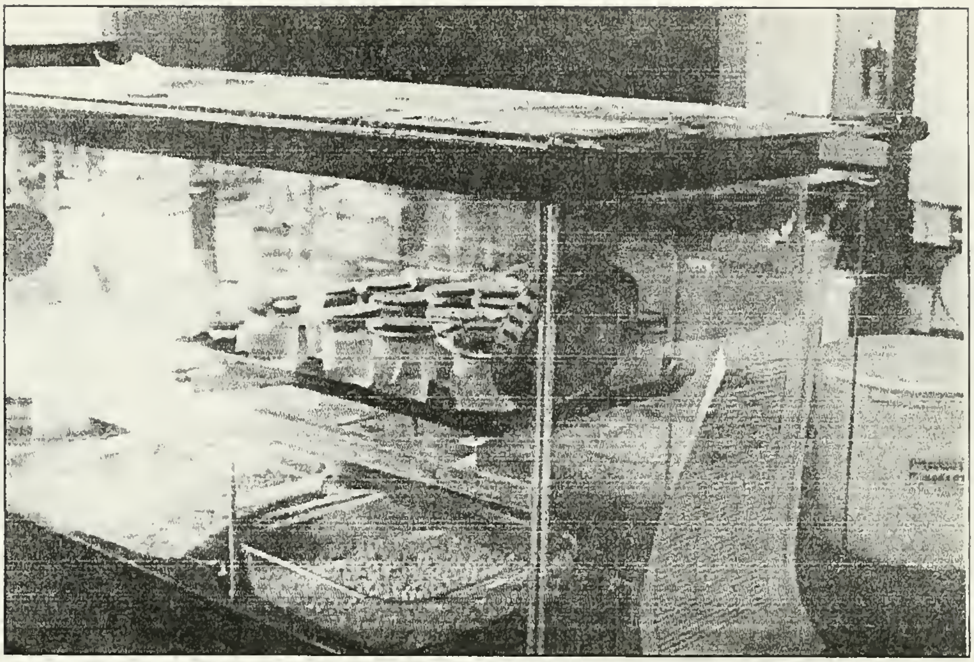

Figure 6.19. Samples of original stucco are placed in assemblies within a desiccant chamber.

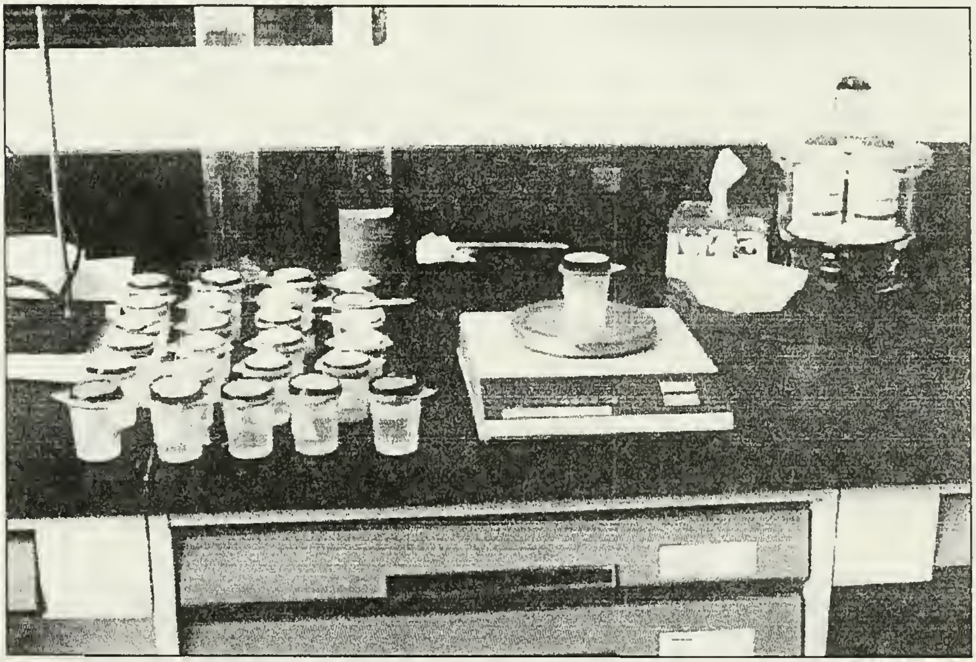

Figure 6.20. Regular measurements of the mass of assemblies are recorded.

Data and Observations

Data reported in Table 7 and calculations employed for statistical analysis are provided in Appendix G: Water Vapor Transmission Data.

Sample	Mass (g), $t_{0\ days}$	Mass (g), $t_{27\ days}$	Change (g)	WVTR (g/h*m^2)
Aiken-Rhett, 1830s Stucco				**0.244 ± 0.080**
005.2	78.94	70.33	- 8.61	0.316
101.4	85.23	83.00	- 2.23	0.082
102.5	68.82	62.50	- 6.3.2	0.232
203.3	80.63	73.05	- 7.58	0.279
206.3	73.19	64.74	- 8.45	0.310

Table 7. Comparative water vapor transmission rates (WVTRs) for original stucco expressed as a function of amount of water vapor passed through 42 mm-diameter specimens over a 27-day period.

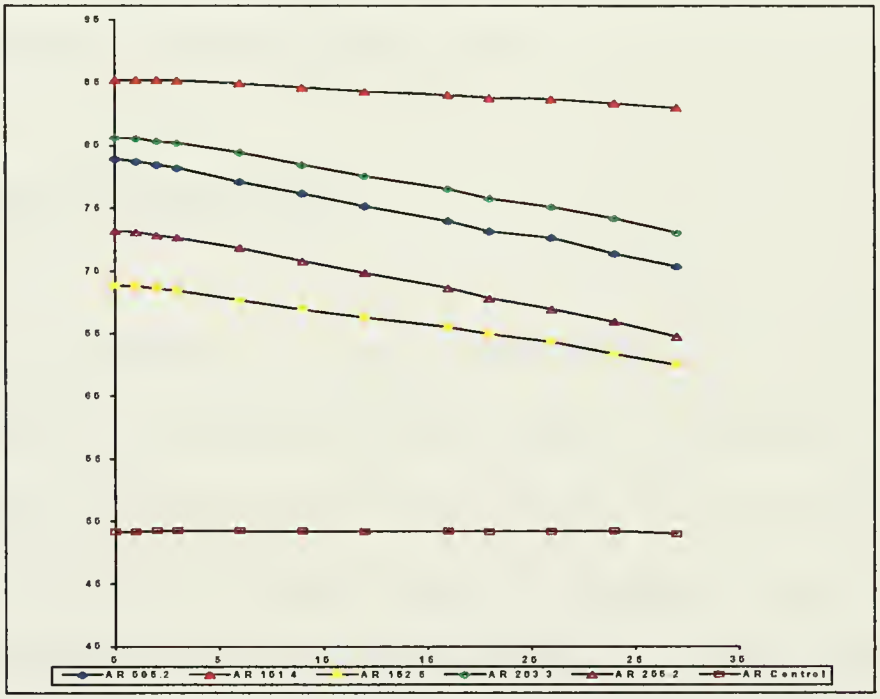

Chart 1. Comparative water vapor transmission rates (WVTRs) for original stucco expressed as a function of amount of water vapor passed through 42 mm-diameter specimens over a 27-day period. Y-axis values represent assembly mass (g) and X-axis values represent time (days).

Conclusions

The average water vapor transmission rate of the original stucco is 0.244 ± 0.080 g/h*m^2. Weathered stucco which has lost all traces of surface applications and has been subject to the loss of binding and aggregate material due to erosion (Samples 005.2 and 206.3) transmits water vapor more readily than does protected stucco which retains all or part of two layers of less permeable lime wash (Samples 101.4, 102.5 and 203.3). As lime washes applied to provide a smooth surface finish consist entirely of binder, it is to be expected that these layers would be and less permeable that the stucco below. Consequently, samples which possess lime washes also retain properties which slightly inhibit the release of water vapor through the material.

6.3.7 Evaporation Characteristics

Rationale

In addition to understanding other moisture-related properties such as how much water can be absorbed by and transmitted through a material, it is important to adequately understand the mechanisms of drying. If a material retains an excessive amount of water, it may be susceptible to deterioration resulting from freeze-thaw cycles and chemical reactions with water. On the other hand, if water evaporates too quickly, the material may be more susceptible to the crystallization of soluble salts at and beneath the surface which occurs with rapid wet-dry cycles. An examination of the rate at which water evaporates

from the original material was conducted to determine how it behaves during ambient conditions.

Methodology

Five samples (005.2, 101.4, 102.5, 203.3 and 203.4) were immersed in water until reaching saturation after 72 hours, as outlined in *Section 6.3.3: Density*. Upon removal from immersion, the samples were weighed and placed on a metal rack in standard ambient conditions. The mass of each sample was measured at regular intervals of time (every 5 minutes for the first 15 minutes, every 15 minutes for the following 45 minutes and every hour for the following five hours) and recorded. Evaporation rates were evaluated as a percentage of the absorbed water lost over a 6-hour period in accordance with the following equation:

$$\% \text{ Evaporation}_{6hours} = [(\text{Mass}_{saturated} - \text{Mass}_{t=6hours})/(\text{Mass}_{saturated} - \text{Mass}_{dry})] \times 100$$

Data and Observations

Data reported in Table 8 and calculations employed for statistical analysis are provided in Appendix H: Evaporation Data.

Sample	$\text{Mass}_{saturated}$ (g)	$\text{Mass}_{t=6\ hours}$ (g)	Mass_{dry} (g)	Evaporation (%)
Aiken-Rhett, 1830s Stucco				**60.26 ± 10.03**
005.2	30.84	28.32	26.81	62.53
101.4	36.40	33.77	31.61	54.91
102.5	25.08	22.85	22.25	78.80
203.3	44.83	42.48	37.02	50.76
203.4	41.68	39.15	40.20	54.29

Table 8. Comparative evaporation rates for original stucco expressed as a function of amount of absorbed water released in conditions of natural circulation over a 6-hour period.

Conclusions

Over a 6-hour period, the original stucco loses 60.26 ± 10.03% of all water absorbed during saturation in ambient conditions. There is a rather wide variation of evaporation rates, which roughly correspond to the data presented in *Section 6.3.4: Porosity* . Generally, samples with higher percentages of porosity lose more absorbed water to natural evaporation than do less porous samples. There does not appear to be any direct correlation between the amount of water vapor a sample is able to transmit and the percentage of absorbed water which evaporates within a given amount of time.

6.3.8 Soluble Salt Analysis

Rationale

The presence of soluble salts within a masonry system indicates the possible presence of a potentially dangerous deterioration process. In the presence of moisture, as may be expected in Charleston, salts may solubilize and move throughout pore networks. With the evaporation of moisture, salts may recrystallize, expand, and cause problems such as efflorescence, cracking and spalling. Using simple microscopic and qualitative chemical analysis, this experiment determines whether potentially dangerous salts (sulfates, chlorides, carbonates) resulting from atmospheric, environmental or material transmission are present in the original stucco.

Methodology

Standard procedure following Teutonico, "Exercise 16: Qualitative Analysis of Water-Soluble Salts and Carbonates" was conducted on four representative samples of original stucco to determine whether water-soluble salts occurred with regularity within this building material. A few grams of each sample was ground into a fine homogenous powder with a mortar and pestle. Approximately half of each sample was placed in separate test tubes; the other half of each sample was saved for control/future testing. Approximately 5cc of deionized water was added to each test tube. The apparatus was shaken gently to dissolve soluble material. After a few minutes' wait, the insoluble portion of each sample was deposited at the bottom of each test tube. Because each resulting liquid was somewhat cloudy, each was filtered before analysis. The filtrates were transferred from each beaker to observation dishes. The following tests were performed:

Sulfates: 2 drops of dilute hydrochloric acid and a 10% solution of barium chloride were added and the results observed; a white precipitate of barium sulfate would indicate the presence of sulfates, according to the following reaction:

$$SO_4 + BaCl_2 \text{---->} BaSO_4 + 2Cl$$

Chlorides: 2 drops of dilute nitric acid and 2 drops of a solution of silver nitrate were added to the liquid; a resulting white-blue gelatinous precipitate of silver chloride would indicate the presence of chlorides, according to the following reaction:

$$Cl + AgNO_3 \text{---->} AgCl + NO_3$$

Insoluble material conserved in each test tube was tested for *carbonates* by adding 2 drops of concentrated hydrochloric acid; resulting bubbles of carbon dioxide gas would indicate the presence of carbonates, according to the following reaction:

$$CO_3 + 2HCl \text{---->} Cl_2 + H_2O + CO_2$$

Data and Observations

Tests for sulfates proved negative, as white precipitate did not appear during macroscopic or microscopic examination of liquid/chemical combination of any sample. Similarly, tests for chlorides proved negative, as no liquid/chemical combination produced signs of a white-blue gelatinous precipitate. The acid digestion test for carbonates proved positive, as a significant amount of carbon dioxide gas was discharged from the base of the test tube when hydrochloric acid was added to it. The reaction was a prolonged one, which appeared to dissolve much of the water-insoluble material.

Sample	Sulfates	Chlorides	Carbonates
101.5	-	-	+++
102.6	-	-	+++
102.7	-	-	+++
206.4	-	-	+++

Table 9. Results of a qualitative analysis to determine the presence of potentially damaging soluble salts in original stucco.
-: presence of the ion +/-: ion barely perceptible
+: presence of the ion ++: presence of the ion in notable quantity
+++: presence of the ion as a principal component

Conclusions

The results of sulfate and chloride tests were uniformly and overwhelmingly negative in multiple samples of a fairly uniform material. It is likely that Aiken-Rhett's stuccoes, as tested, suffer from no immediate danger of sulfate or chloride crystallization in both weathered and protected areas. Further testing may be advisable in regions which presently or in the future may display signs of surface efflorescence.

The carbon dioxide evolution which resulted with the addition of hydrochloric acid to the water-insoluble portion of the sample indicates the presence of carbonates. This is most likely due to the nature of the binder, which in this stucco is composed of calcium carbonate, (confirmation of calcium carbonate presence is indicated in *Section 6.1: Compositional Analysis*, *Appendix A: Gravimetric and Calcimeter Data and Appendix B: X-Ray Diffraction Data*).

7.0 Experimental Program

Modern stucco materials may, because of their physical and performance characteristics, be inappropriate for use on historic buildings such as Aiken-Rhett. As each building functions as a series of interrelated systems, it is important that any materials used to repair, replace, and or patch historic systems be compatible with original materials.

> In limited circumstances substitute materials that imitate historic materials may be used if the appearance and properties of the historic materials can be matched closely and no damage to the remaining historic fabric will result.
>
> ...substitute materials are being used more frequently than ever in preservation projects, and in many cases with positive results. They can be cost-effective, can permit the accurate visual duplication of historic materials, and last a reasonable time. Growing evidence indicates that with proper planning, careful specifications and supervision, substitute materials can be used successfully in the process of restoring the visual appearance of historic resources.[69]

The use of substitute materials on historic building exteriors in Charleston focuses primarily on lime- and cement-based composite materials:

> ...the distinction between the various mortars and stuccoes [of Charleston] 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.[70]

Most building owners and architects realize that repair of stucco is essential building maintenance which must be performed periodically. However, the opportunity to perform

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[69] Sharon C. Park, *Preservation Brief 16: The Use of Substitute Materials on Historic Building Exteriors* (Washington: U.S. Department of the Interior, National Park Service), 1.
[70] Fore and Pepi, 1

an in-depth analysis of *how* the original stucco performs in its present state as well as *how* substitute materials perform relative to that material is infrequently realized.

As a primary goal of this research is to establish a standardized methodology to evaluate stucco performance which is both economically feasible and insightful, this program employs standard performance tests which are easily duplicable in an analytical laboratory without a prohibitive amount of overhead. The experimental program which follows incorporates procedures employed by previous conservation studies in an attempt to assess certain performance characteristics of potential replication stuccoes versus the current performance characteristics of Aiken-Rhett's original stucco. Standards regarding the preparation of replication stuccoes including mixing, molding and cure borrows heavily from research which has assessed the performance characteristics of various lime-based materials (Carr 1995). Compositional analyses (Jedrzejewska 1960, Stewart and Moore 1982, Banta 1995) are somewhat academic as the nature of binders and aggregates used in these replication stuccoes are known entities. Much information may be obtained by simple macroscopic comparison of replication and historic materials (Ciach and Penkala 1984); it follows that assessments of color and texture responsible for creating the aesthetic impact of the original stucco are critical in selecting a compatible replication stucco. As one of the primary functions of stucco is its ability to repel and release moisture, and to resist water-borne and water-related deteriorative elements, this program examines assessments of density, porosity, water absorption capacity, water vapor

transmission, and evaporation characteristics as well as resistance to attack by soluble salts (Ciach and Penkala 1984, Teutonico 1988, Jacob and Weiss 1989, Carr 1995) of replication stuccoes versus the original. Evaluation of cure time is a widely employed test for mortars applied in modified form to the replication stuccoes examined herein (Carr 1995).

7.1 Selection of Replication Mixes

7.1.1 Selection of Replication Materials

Five replication stuccoes were selected for laboratory examination throughout the experimental program. Four mixes (RS 1, RS 2, RS 4 and RS 5) employed 2:5 binder:aggregate ratios with the binding material variable from set to set, while one (RS 3) is a pre-mixed commercial composite material which does not require the addition of binder or aggregate. These materials provide a range of binding materials which have traditionally been used for mortars and stuccoes in historically-sensitive settings. The aggregate employed as the constant is "tan sand" from Hubbard Sand and Gravel, New York, chosen as a standard reference material which approximates many physical characteristics of sand used in the original stucco, including color, texture and particle size. This is a slightly clayey sand, which is viewed as an appropriate component given that the original stucco employed a clay extender in a significantly higher concentration.[71]

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[71] The presence of small amounts of clay, varying from 0-10% is both common and acceptable according to Lea, 558. The clays adhering to individual aggregate grains in this sand are extremely surfacial,

RS 1 consists of 2 parts Riverton Hydrated Hydraulic Lime (RHHL) and 5 parts Hubbard Sand and Gravel tan sand. As a binder which sets by chemical reaction, Riverton was selected because its hydraulic set properties were viewed as a desirable characteristic in a humid environment such as Charleston. Additionally, it was felt that the warm gray color of the powdered material prior to mix might be compatible with the gray shades of the original stucco.

RS 2 consists of Corson Type S Hydrated Lime and 5 parts Hubbard Sand and Gravel tan sand. This is a dolomitic lime consisting of calcium magnesium carbonate (Ca, $Mg(CO_3)$). Although elemental analysis provided no evidence that the original stucco consisted of dolomitic lime, it was deemed important to establish benchmark comparative data for the dolomitic lime commonly used in the U.S.

RS 3 consists of Jahn M60 Restoration Stucco with no color manipulation. Because a replication material must be not only physico-chemically compatible with the original stucco but must also be relatively easy to obtain, mix and apply, this mix was examined as a commercially-available, one-part homogenous material which might be suitable were ease of application and material uniformity deemed primary goals.

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providing clear particles with a slight degree of cloudiness. In its raw state, this sand does not possess significant quantities of clay lumps.

RS 4 consists of 2 parts High Calcium Lime Putty and 5 parts Hubbard Sand and Gravel tan sand. Because slaked lime putty was commonly used in 19th century Charleston, this mix was examined as a formula whose consistency upon cure might be more compatible with the original stucco than other materials.

RS 5 consists of 1 part Keystone Portland Cement, 1 part Tarmac America High Calcium Chemical Hydrated Lime and 5 parts Hubbard Sand and Gravel tan sand. As many contemporary masonry formulas call for the use of a lime-cement mix, the combination of these materials was examined to evaluate their actual compatibility in an historic setting.

7.1.2 Rationale for Volumetric Mixes

The replication stuccoes (RS) chosen for examination are based in part on information obtained by the compositional analysis of original stucco in its current state *(Appendix A: Gravimetric and Calcimeter Analysis)* and an examination of proportions used in historic formulations, the idea being that like materials applied in proportions similar to those of the original might form a replication material which is able to approximate the current values of the original.[72] Standard gravimetric analysis does not provide data sufficient to determine the proportional relationships of the original components, and calcimeter

[72] Fore and Pepi indicate the risk of directly translating volumetric mixes from historic materials into modern formulations by observing that many would, in fact, be considered unworkable (8).

analysis which provides more data in a more useful manner was not available at the time of mix formulation. Therefore, the determination of the volumetric relationships of components for replication mixes relied on formulas published in academic literature which might be frequently specified for similar materials in similar situations. Throughout history, plasterers have applied stucco mixes consisting of 1 part binder to 2 or 3 parts aggregate, or 2 parts binder to 5 parts aggregate.[73] Scholars have recommended 1:3 and 2:5 mixes for the restoration of external renders with cementitious components.[74] Based upon historical research, a 2:5 binder:aggregate volumetric ratio was chosen for all replication formulas.

With the exception of RS 3, the replication stuccoes selected consist of one constant and one variable, the constant being the aggregate used in the same volumetric proportion within each mix and the variable being the binder type. By manipulating only the binder, theoretically, it is possible to examine the different physical characteristics which different binding materials impart. Furthermore, by comparing the physical and performance characteristics which result from different binding materials with the physical and performance characteristics of the original stucco in its present state, it is possible to select

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[73] Vitruvius. translated by Morgan, 45. Formulas were subject to variation based on time, location, availability of material and architectural heritage.

[74] Ashurst and Ashurst, 19-24. This source recommends the use of a 1:3 mix (1:1:6 lime:cement:sand) for the restoration of rough undercoats based on Roman and Portland cement binders which might be comparable to Aiken-Rhett's original. Also recommended are 1:1:6 mixes for the restoration of cement compound renders and 2:5 hydraulic lime:sand mixes for lime stuccoes.

which replication stucco of those examined may be most compatible with extant historic fabric.

7.2 Formulation

Following the formulas noted in *Section 7.1.1: Selection of Replication Materials*, all materials were measured dry, combined with water and mixed mechanically in accordance with "ASTM C 305: Test Method for Mechanical Mixing of Hydraulic Cement Pastes and Mortars of Plastic Consistency (Figures 7.1 and 7.2)."

Immediately after mixing, samples were placed in mold types according to the parameters of standardized tests to which they would be subjected to after cure. Samples slated for examinations of color, texture, density, porosity, water absorption capacity, water vapor transmission and evaporation rates were prepared in cylindrical PVC molds which, prior to molding were greased lightly with Vaseline petroleum jelly to act as a releasing agent. PVC molds were 42 mm in interior diameter and cut to a thickness of 13mm to approximate the standard dimensions of samples of the original stucco removed from the building. Greased molds were placed onto bricks to approximate a surface to which stucco is applied on a building. Workable replication material was placed into molds with a spatula, lightly tamped to ensure that the mold was filled, and struck once across the top surface of the mold to remove excess material. Molded samples were placed in an observation chamber, covered with a permeable cheesecloth, allowed to cure for 1-4 days

before demolding, and allowed to cure for an additional 31 days prior to undergoing laboratory experimentation.

Samples slated for examinations of resistance to attack by soluble salts were prepared in 2” wooden cube molds which, prior to molding were covered with aluminum foil and greased lightly with Vaseline petroleum jelly to act as a releasing agent. Greased molds were placed onto bricks to approximate a surface to which stucco is applied on a building. Workable replication material was placed into cube molds with a spatula, lightly tamped to ensure that the mold was filled, and struck once across the top surface of the mold to remove excess material. Molded samples were placed in an observation chamber, covered with a permeable cheesecloth, allowed to cure for one day before demolding, and allowed to cure for an additional 34 days prior to undergoing laboratory experimentation.

Samples slated for examinations of cure time were prepared in conical molds which, prior to molding were greased lightly with Vaseline petroleum jelly to act as a releasing agent. Greased molds were placed onto an impermeable plastic sheet to avoid variable set manipulation which might occur as a result of variations in brick surfaces. Workable replication material was placed into these molds with a spatula, lightly tamped to ensure that the mold was filled, and struck once across the top surface of the mold to remove excess material. Molded samples were placed in an observation chamber, covered with

plastic wrap to limit vapor transmission, allowed to cure for two hours before demolding, and measured periodically with a Vicat needle apparatus as outlined in *Section 7.3.9: Set.*

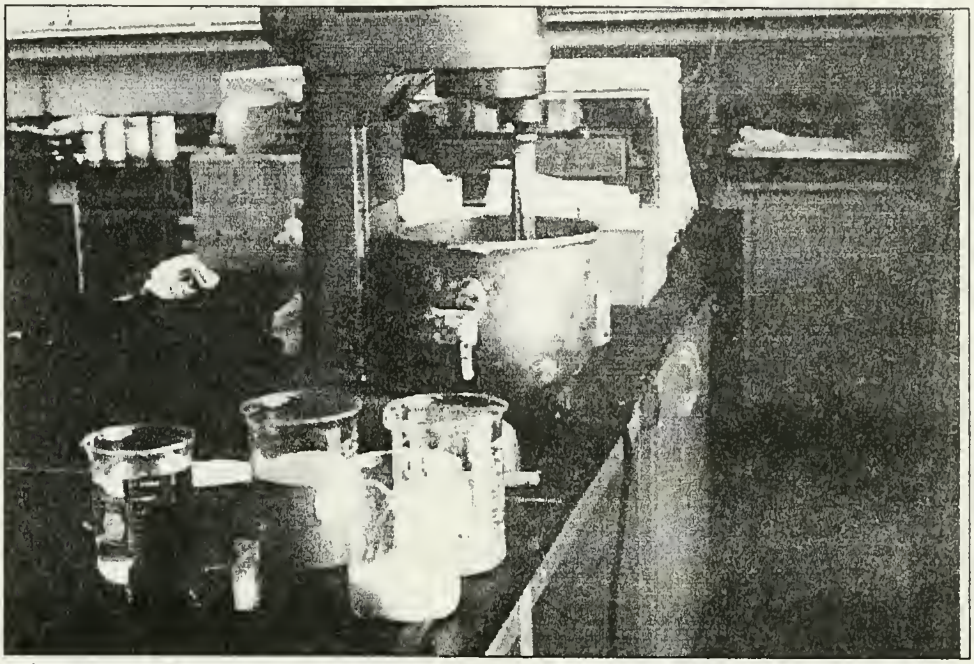

Figure 7.1. Preparation for mixing replication materials included measuring materials in dry volumetric proportions of 2 parts binder to 5 parts aggregate.

Figure 7.2. Mechanical mixing performed.

7.3 Presentation and Analysis of Critical Performance Data

7.3.1 Color

Rationale

To some extent, many of the materials used to repair cracks and patches in the 1830s stucco coat may be viewed as aesthetic failures which display very little, if any, sympathy to the color and texture of the original *(Section 4.2.1: Functional)*.

Most of Aiken-Rhett's stucco coat was applied in the 1830s, in an attempt to cover up alterations to exterior brickwork which corresponded with the re-arranging of interior space and re-location of the primary entrance from the south facade to the west facade. In this sense, one of the most important functions of this material is the aesthetic impact created by its color, texture and finishing pattern.[75]

Structural alterations which necessitated the use of stucco in the first place have begun to fail, compromising the integrity of the stucco envelope in the process. Now, and in future maintenance or restoration campaigns, the replacement of original stucco which has been lost over time will be a necessity. In addition to approximating important performance qualities relating to permeability and water absorption, it is critical that replacement

[75] It should be noted that the original and subsequent surface finishes applied to the stucco created different colors and textures than currently exist.

material respect the important visual qualities of the original by matching the color of the original material as closely as possible.

Methodology

Fifteen samples (three samples for each of the five replication formulas) of replication material were analyzed for color using a Minolta Chroma Meter in accordance with the procedure outlined in *Section 6.3.1: Color.* Color space data for replication materials was compared with data obtained for the original material and evaluated.

Data and Observations

The data presented in Table 10 represents average color space evaluations for each of the replication materials as compared with the original stucco. Comprehensive color space evaluation data for individual replication samples is provided in *Appendix C: Colorimetry Data.*

Sample	Hue	Value	Chroma	Color
Aiken Rhett, 1830s stucco (average)	**9.08YR-0.47Y**	**5.18**	**1.96**	**"Grayish yellowish brown"**
RS 1, Riverton HHL	0.96Y	6.57	2.37	"Light grayish yellowish brown"
RS 2, Corson Type "S"	1.3Y	6.1	1.97	"Light olive brown"
RS 3, Jahn M60	1.9Y	7.3	0.53	"Light gray"
RS 4, High Ca Lime Putty	1.57y	6.9	1.87	"Yellowish gray"
RS 5, Gray Port/Hi Ca Lime	0.96Y	6.93	2.17	"Light grayish yellowish brown"

Table 10. Comparative color space values for original stucco and Replication Stuccoes 1-5 expressed as a function of hue, value and chroma in Munsell System of Color.

Conclusions

A major goal of the formulation of replication mixes was to approximate the color of the original stucco as closely as possible without the addition of pigments. None of the replication stuccoes selected for testing exactly matched the color of Aiken-Rhett's 1830 stucco after nearly a century-and-a-half of weathering. However, the "Light grayish yellowish brown" of two mixes (RS 1 and RS 5) approximates the "Grayish yellowish brown" of the original reasonably well. Color space measurements of two mixes (RS 2 and RS 4) were too light, and are unacceptable in comparison with the original. The standard color of one mix (RS 3) is unacceptable as is, with the note that the manufacturer assures that this material may be pigmented to match any existing original stucco.

7.3.2 Texture

Rationale

Recognizing that the texture of the original stucco plays a role in its overall aesthetic impression, it is important that any replication stucco not fundamentally distract from the impression created by extant historic fabric by possessing a radically different surface appearance.

Methodology

Replication stuccoes were compared with sandpaper samples in accordance with procedures outlined in *Section 6.3.2: Texture.* The textures of all replication stuccoes were compared with data obtained for the original stucco and evaluated.

Two samples of each replication stucco were compared against sandpapers of 220-grit, 120-grit, 80-grit, 50-grit and 36-grit and the results logged. Textural comparisons for individual samples are provided in *Appendix A: Gravimetric and Calcimeter Analyses.*

Data and Observations

The data presented in Table 11 represents average evaluations of texture for each of the replication materials as compared with the original stucco. Comprehensive texture evaluation data for individual replication samples is provided in *Appendix A: Gravimetric and Calcimeter Analyses.*

Sample	Reference comparison
Aiken-Rhett 1830s Stucco (average)	**80-grit sandpaper**
RS 1, Riverton HHL	50-grit sandpaper
RS 2, Corson Type "S"	50-grit sandpaper
RS 3, Jahn M60	120-grit sandpaper
RS 4, High Calcium Lime Putty	50-grit sandpaper
RS 5, Gray Port/High Ca Lime	50-grit sandpaper

Table 11. Comparative texture evaluations for Replication Stuccoes 1-5.

Conclusions

Replication Stuccoes RS 1, RS 2, RS 4 and RS 5, based on different binders with the same aggregate, all possess similar texture when mixed, molded and troweled in the same manner, indicating that the texture of stucco depends largely on the particle shape and size of the aggregate. Other factors which will affect the texture of the material include the degree of troweling and the volumetric relationship between the binder and the aggregate. In comparison with the 80-grit texture of the historic stucco, the 50-grit texture of RS 1, RS 2, RS 4 and RS 5 is acceptable with modification. As tested, RS 1, RS 2, RS 4 and RS 5 are rougher than the original stuccoes, but with a higher degree of troweling during application may more closely approximate the texture of the original. Because the texture of these replication stuccoes as tested may be manipulated to approximate the original stucco, they are treatments which successfully fulfill the important aesthetic function of texture in relation to the original stuccos. The aggregate used for RS 3 is an extremely fine, homogenous material consisting largely of synthetic hollow spheres which creates a much finer texture. The extremely fine texture of RS 3 is unacceptable in this particular application, with the note that this mix may be custom-formulated to more closely match the texture of the original material.

7.3.3 Density

Rationale

Ideally, the replication material selected for use along with Aiken-Rhett's original stucco will possess a density similar to that of the original in its present state. If a material is significantly more dense than the original, it may perform differently over time.

Methodology

Experimentation and calculations of density for fifteen samples (three samples for each of the five formulas) of replication stuccoes were completed in accordance with the procedure outlined in *Section 6.3.3: Density*. The densities of replication materials were compared with data obtained for the original material and evaluated.

Data and Observations

The data presented in Table 12 represents average calculations of the density of the replication stuccoes as compared with the original stucco. Comprehensive data on the density of individual replication samples is provided in *Appendix D: Density Data.*

Sample	Density (kg/m^3)
Aiken-Rhett 1830s Stucco	**266.20 ± 18.98**
RS 1, Riverton HHL	256.3.8 ± 8.64
RS 2, Corson Type "S"	253.02 ± 2.97
RS 3, Jahn M60	118.11 ± 1.26
RS 4, High Calcium Lime Putty	250.13 ± 2.91
RS 5, Gray Port/High Ca Lime	261.78 ± 5.10

Table 12. Comparative real densities for original stucco and Replication Stuccoes 1-5.

Conclusions

Using the volume and type of aggregate as a control, slight variations in density are produced by different binders. Variations in density are extremely slight between RS 1, RS 2, RS 4 and RS 5, although hydraulic binders (RS 1 and RS 5) are apparently more dense than straight lime mixes tested (RS 2 and RS 4). RS 3 is notably less dense than the original stucco *and* all other replication stuccoes tested. This is most likely a function of the microballoons included in the aggregate, which, because their cores are void, possess a degree of density significantly lower than the solid aggregate used in the other replication stuccoes.

Density values of 256.3.8 ± 8.64 kg/m^3 for RS 1, 253.02 ± 2.97 kg/m^3 for RS 2, 250.13 ± 2.91 kg/m^3 for RS 4 and 261.78 ± 5.10 kg/m^3 for RS 5 all fall within the range of 266.20 ± 18.98 kg/m^3 calculated for the original stucco, and, consequently constitute acceptable laboratory replications. RS 3, because its levels of variance do not fall within those of the original stucco and is unacceptable in this application. In reality, however, whether replication material possesses a density similar to historic fabric is somewhat academic, as performance values over time will be much more critical in assessing whether indeed the density of a replication material affects its ability to perform in harmony with the original stucco.

7.3.4 Porosity

Rationale

Porous materials are capable of absorbing water into empty spaces, which, in stucco may range in size from large to microscopic. Because a primary function of stucco is its ability to isolate liquid water from a masonry substrate, an assessment of the percentage of space which might potentially be occupied by water may provide insight into its potential lifespan and resistance to water-related deterioration. Theoretically, a replication stucco should possess a degree of porosity and permeability similar to that of the original in its current state. If a replication is significantly more porous, it may deteriorate too rapidly to be considered a successful treatment. If a replication is significantly less porous, it may disrupt overall water absorption patterns by re-directing water onto the more porous original material adjacent to it.

Methodology

Experimentation and calculations of porosity for fifteen samples (three samples for each of the five formulas) of replication stucco were completed in accordance with the procedure outlined in *Section 6.3.4: Porosity*. The porosities of replication materials were compared with data obtained for the original material and evaluated.

Data and Observations

The data presented in Table 13 represents average calculations of the porosity of replication stuccoes as compared with the original stucco. Comprehensive data on the porosity of individual replication samples is provided in *Appendix E: Porosity Data.*

Sample	Porosity (%)
Aiken-Rhett 1830s Stucco	**24.94 ± 2.80**
RS 1, Riverton HHL	19.35 ± 0.31
RS 2, Corson Type "S"	22.34 ± 0.68
RS 3, Jahn M60	17.59 ± 0.24
RS 4, High Calcium Lime Putty	25.46 ± 0.82
RS 5, Gray Port/High Ca Lime	21.60 ± 0.24

Table 13. Comparative porosities for original material and Replication Stuccoes 1-5 expressed as a percentage of pore space within solid material.

Conclusions

Of the five mixed tested, only RS 2 (22.34 ± 0.68%) and RS 4 (25.46 ± 0.82) possess degrees of porosity which lie within the values and levels of variation of the 24.94 ± 2.80% of the original stucco. RS 1 (19.35 ± 0.31%), RS 3 (17.59 ± 0.24%) and RS 5 (21.60 ± 0.24%) were slightly to moderately less porous than the original stucco.

Because much of the porosity within the original stucco may be attributed to the voids created by the alteration and subsequent washing out of feldspars, it is unreasonable to expect that the combination of sound, solid materials within a composite matrix will successfully duplicate degrees of porosity which occur only with the weathering of a material over time. It will be crucial either to monitor the performance of replication

materials next to original stuccoes over time to determine whether the lower degree of porosity of the former has a negative effect on the weathering of the latter or to develop additional formulas which more closely approximate the current degree of porosity of the original stuccoes.

7.3.5 Water Absorption Capacity

Rationale

The ability of a composite material to absorb liquid water is a function of the nature of its constituent parts, its degree of porosity, and the size, shape and distribution of empty pore space within the material. By evaluating the percent of weight gain attributed to water absorption under extreme conditions, it is possible to assess whether a replication stucco may behave in a manner similar to the original. An assessment of the ability of each replication stucco to absorb water was conducted and compared with that of the original stucco to evaluate potential compatibility. By providing a measure of a replication material's ability to absorb water, this test also provides comparative, indirect data on material durability.

Methodology

Experimentation and calculations of the water absorption capacity for fifteen samples (three samples for each of the five formulas) of replication stucco were completed in accordance with the procedure outlined *in Section 6.3.5: Water Absorption Capacity.* The

water absorption capacity values of each replication stucco was compared with data obtained for the original and evaluated.

Data and Observations

The data presented in Table 14 represents average calculations of the water absorption capacity of replication materials as compared with the historic stucco. Comprehensive data on the water absorption capacity of individual replication samples is provided in *Appendix F: Water Absorption Capacity Data.*

Sample	Water Absorption Capacity (%)
Aiken-Rhett 1830s Stucco	**12.47 ± 1.43**
RS 1, Riverton HHL	9.61 ± 0.02
RS 2, Corson Type "S"	11.26 ±0.22
RS 3, Jahn M60	18.07 ± 0.48
RS 4, High Calcium Lime Putty	13.68 ± 0.47
RS 5, Gray Port/High Ca Lime	10.53 ± 0.22

Table 14. Comparative water absorption capacities for original stucco and Replication Stuccoes 1-5 expressed as a percentage of total weight in a saturated sample which is occupied by water.

Conclusions

Of the five mixed tested, only RS 2 (11.26 ±0.22%) and RS 4 (13.68 ± 0.47%) possess degrees of water absorption capacity which lie within the values and levels of variation of the 12.47 ± 1.43% of the historic stucco. RS 1 (9.61 ± 0.02%) and RS 5 (10.53 ± 0.22%), are slightly less porous, and, consequently, able to absorb slightly less water than the original stucco. RS 3 absorbed the highest percentage of its weight in water (18.07 ± 0.48%).

Non-hydraulic lime-based mixes represented by RS 2 and RS 4 absorb water in a manner most similar to that of the original stucco. Because they are slightly less porous, hydraulic-based RS 1 and RS 5 absorb a slightly lower percentage of water. RS 3, despite its relatively low porosity, absorbs a significantly higher percentage of its dry weight in water than do the other mixes; this is attributable to the fact that the relatively low beginning mass of the material is significantly affected by the absorption of water.

Although examining the ability of a replication material to absorb water is useful in predicting the potential susceptibility of that material to water-related deterioration, the values obtained during this examination must be viewed in conjunction with other values, such as the ability of the material to transmit water vapor and the rate at which the material releases liquid water (evaluations of these performance characteristics are provided in *Section 7.3.6: Water Vapor Transmission and Section 7.3.7: Evaporation Characteristics*). Consequently, assessments of the acceptability of values for the water absorption capacity of different replication stuccoes are impractical without additional data.

7.3.6 Water Vapor Transmission

Rationale

It is crucial that any stucco, whether it be the original or a replication stucco, be able to transmit water in the form of vapor. As outlined in *Section 6.3.6: Water Vapor Transmission* , it must function as a sacrificial material which protects masonry elements below. To be considered acceptable, a replication stucco must have a similar or increased ability to release water vapor compared to the original so as not to redirect moisture or water vapor trapped behind it to surrounding original stucco, thus increasing the risk of water-related deterioration to historically important material.

Methodology

Experimentation and calculations of the water vapor transmission rates for fifteen samples (three samples for each of the five formulas) of replication stuccoes were completed in accordance with the procedure outlined in *Section 6.3.6: Water Vapor Transmission*. The WVTR of each replication material was compared with data obtained for the original material and evaluated.

Data and Observations

The data presented in Table 15 represents average WVTRs of replication stuccoes as compared with the original stucco, while WVTRs are expressed graphically in Charts 2-6.

Comprehensive data on the WVTRs of individual replication samples is provided in Appendix G: Water Vapor Transmission Data.

Sample	WVTR (g/h*m^2)
Aiken-Rhett, 1830s Stucco	**0.244 ± 0.080**
RS 1. Riverton HHL	0.407 ± 0.102
RS 2. Corson Type "S"	0.416 ± 0.039
RS 3. Jahn M60	0.278 ± 0.022
RS 4. High Calcium Lime Putty	0.496 ± 0.089
RS 5. Gray Portland/High Ca Lime	0.239 ± 0.032

Table 15. Comparative water vapor transmission rates (WVTRs) for original stucco and Replication Stuccoes 1-5 expressed as a function of amount of water vapor passed through 42 mm-diameter specimens over a 27-day period.

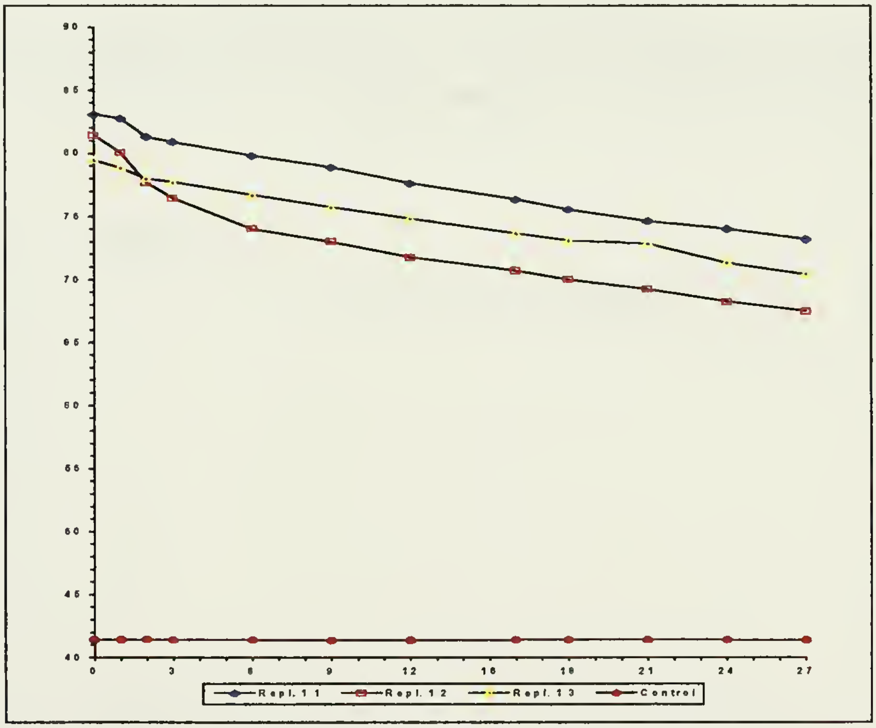

Chart 2. Comparative water vapor transmission rates (WVTRs) for Replication Stucco 1, Riverton HHL, expressed as a function of amount of water vapor passed through 42 mm-diameter specimens over a 27-day period. Y-axis values represent assembly mass (g) and X-axis values represent time (days).

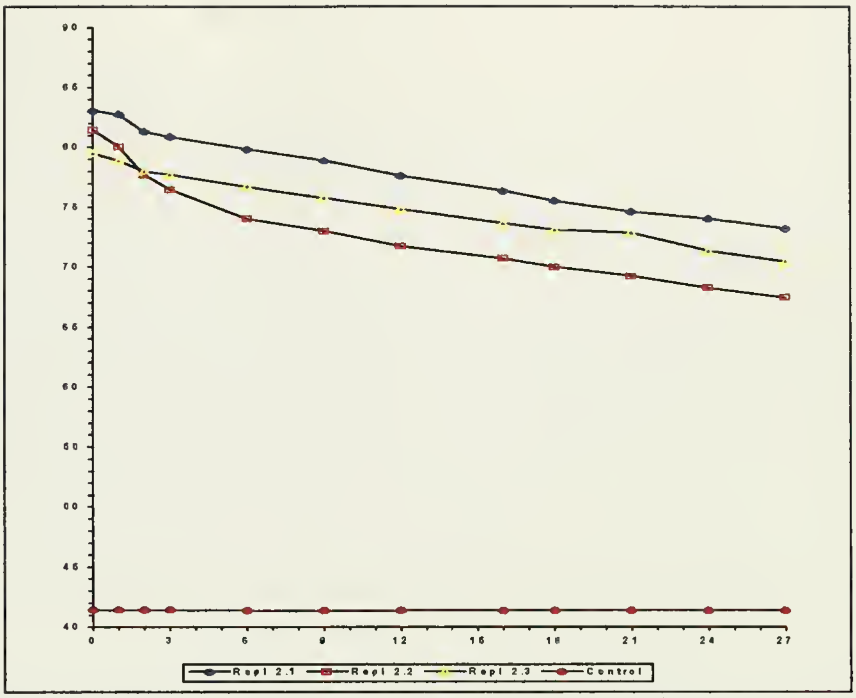

Chart 3. Comparative water vapor transmission rates (WVTRs) for Replication Stucco 2, Corson Type "S", expressed as a function of amount of water vapor passed through 42 mm-diameter specimens over a 27-day period. Y-axis values represent assembly mass (g) and X-axis values represent time (days).

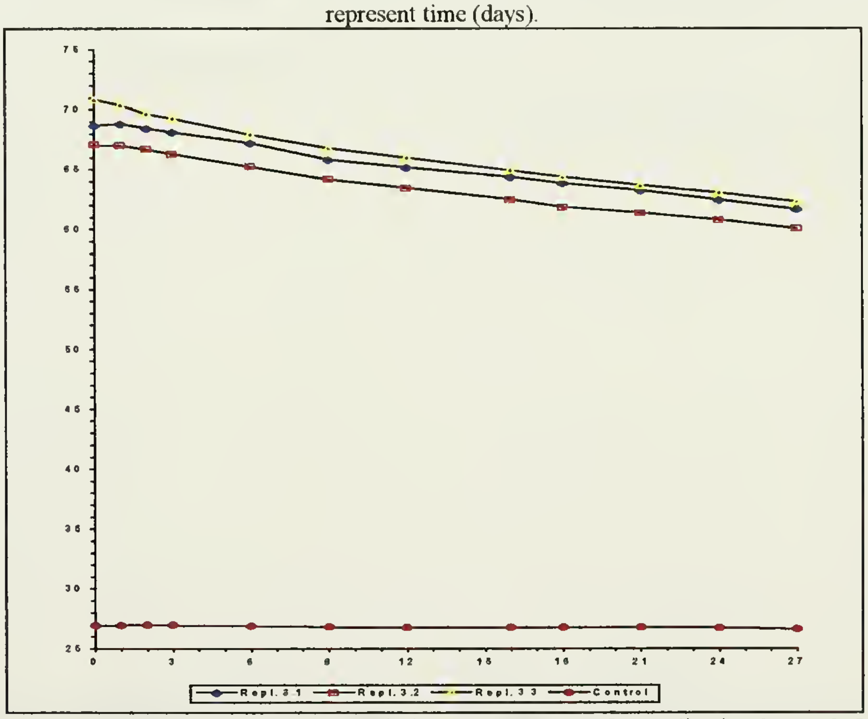

Chart 4. Comparative water vapor transmission rates (WVTRs) for Replication Stucco 3, Jahn M60, expressed as a function of amount of water vapor passed through 42 mm-diameter specimens over a 27-day period Y-axis values represent assembly mass (g) and X-axis values represent time (days).

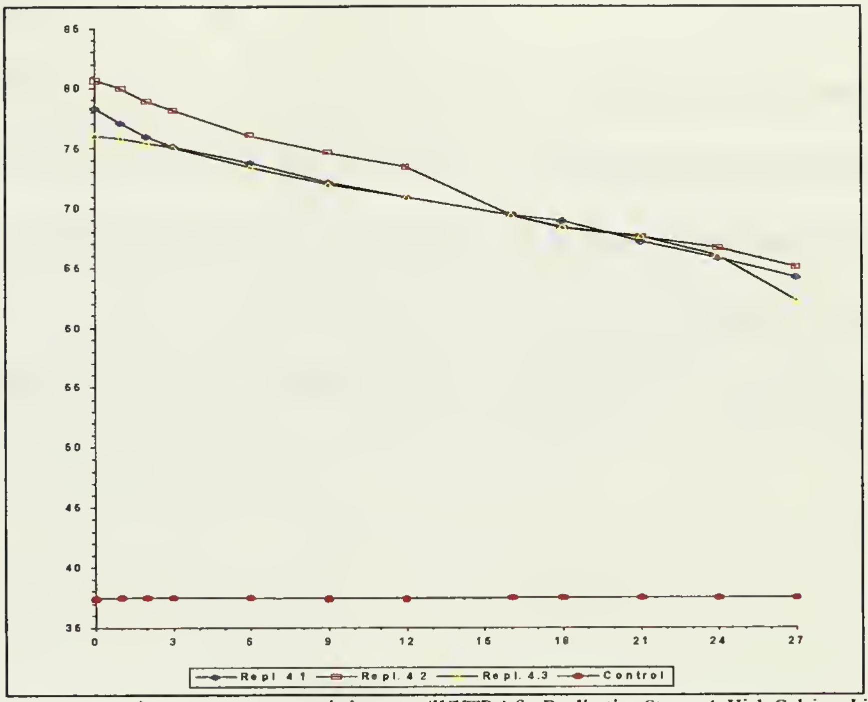

Chart 5. Comparative water vapor transmission rates (WVTRs) for Replication Stucco 4, High Calcium Lime Putty, expressed as a function of amount of water vapor passed through 42 mm-diameter specimens over a 27-day period. Y-axis values represent assembly mass (g) and X-axis values represent time (days).

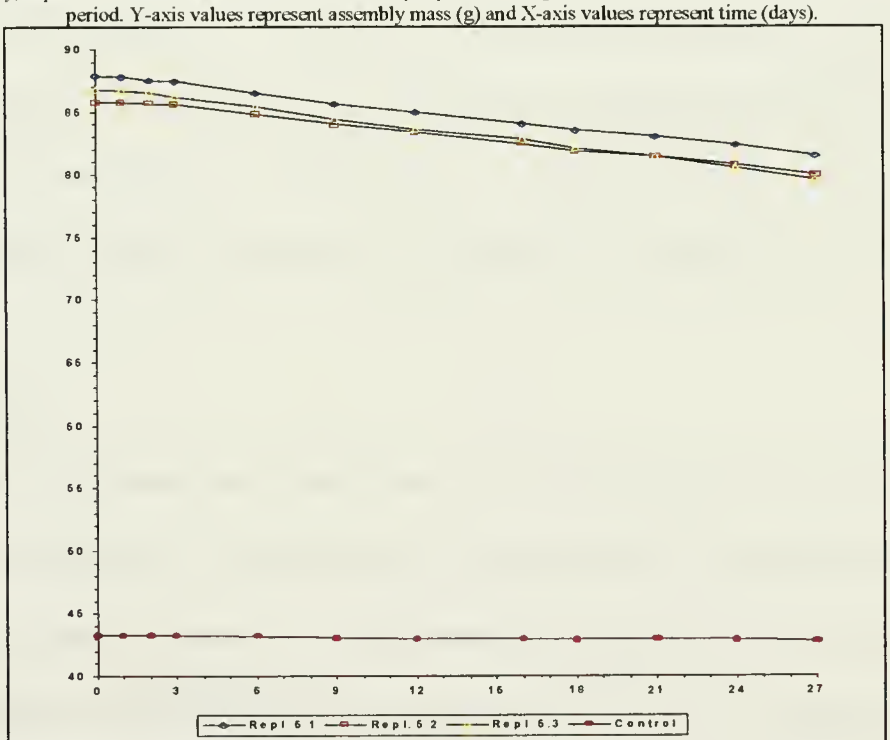

Chart 6. Comparative water vapor transmission rates (WVTRs) for Replication Stucco 5, Gray Portland Cement/High Calcium Hydrated Lime, expressed as a function of amount of water vapor passed through 42 mm-diameter specimens over a 27-day period. Y-axis values represent assembly mass (g) and X-axis values represent time (days).

Conclusions

Each of the five replication stuccoes tested exhibited the ability to transmit water vapor at or above the rate of 0.244 ± 0.080 $g/h*m^2$ for the original stucco, thus constitute potentially acceptable treatments. The WVTRs of lime-based stuccoes, 0.407 ± 0.102 $g/h*m^2$ for RS 1, 0.416 ± 0.039 $g/h*m^2$ for RS 2, and 0.496 ± 0.089 $g/h*m^2$ for RS 4, are notably higher than those of cementitious-based materials 0.278 ± 0.022 $g/h*m^2$ for RS 3 and 0.239 ± 0.032 $g/h*m^2$ for RS 5.

7.3.7 Evaporation Characteristics

Rationale

As outlined in *Section 6.3.7: Evaporation Characteristics*, the rate at which stucco releases moisture is an important value. Theoretically, replication stuccoes should release water at the same rate as or quicker than the original stucco so that water does not become trapped within the newer material and spread to the original stucco.

Methodology

Examination of the evaporation characteristics for fifteen samples (three samples for each of the five formulas) of replication stucco was completed in accordance with the procedure outlined in *Section 6.3.7: Evaporation Characteristics*. The evaporation rate for each replication stucco was compared with data obtained for the original stucco and evaluated.

Data and Observations

The data presented in Table 16 represents average evaporation rates for each replication stucco as compared with the original. Comprehensive data on the evaporation rates of individual replication samples is provided in *Appendix H: Evaporation Data.*

Sample	Evaporation (%)
Aiken-Rhett, 1830s Stucco	**60.26 ± 10.03**
RS 1, Riverton HHL	71.52 ± 1.64
RS 2, Corson Type "S"	71.14 ± 3.40
RS 3, Jahn M60	55.27 ± 6.43
RS 4, High Calcium Lime Putty	66.41 ± 7.43
RS 5, Gray Portland/High Ca Lime	47.84 ± 1.94

Table 16. Comparative evaporation rates for original stucco and Replication Stuccoes 1-5 expressed as a function of amount of absorbed water released in conditions of natural circulation over a 6-hour period.

Conclusions

Four of the five replication stuccoes (RS 1, RS 2, RS 3 and RS 4) exhibited evaporation rates within the variance of the original stucco, which loses 60.26 ± 10.03% of water absorbed during saturation over a six-hour period, and may be deemed acceptable. The significantly lower rate of evaporation exhibited by RS 5, which lie outside the variation of the original stucco, is not within the limits of the original.

Lime-based replication stuccoes, represented by a 71.52 ± 1.64% loss for RS 1, 71.14 ± 3.40% loss for RS 2, and 66.41 ± 7.43% loss for RS 4 released water at a substantially higher rate than did cementitious-based replication stuccoes RS 3, which lost 55.27 ± 6.43% and RS 5, which lost 47.84 ± 1.94% of its water weight over a comparable period

of time. This indicates that, regardless of factors such as porosity, water is released more easily from lime-based composite mixes than from their cementitious counterparts.

7.3.8 Salt Resistance

Rationale

Although no soluble salts were detected during analysis of several samples of original stucco as outlined in *Section 6.3.8: Soluble Salt Analysis,* each replication stucco was subjected to an intense cycle of immersion in a 10-14% solution of sodium sulfate and rapid drying to simulate the effects of aggressive salt crystallization. By measuring each sample after each wet-dry cycle visually and mechanically, it is possible to evaluate which replication stuccoes may be best able to resist deterioration caused by the crystallization of soluble salts beneath the surface.

Methodology

Standardized procedure modifying Teutonico, "Exercise 15 Salt Crystallization," and British Research Establishment Report, Crystallization Test modified by Carr 1995, was utilized. Control and experimental cubes measuring 2" on each side were dried in an oven at 60°C for 24 hours allowed to cool, and their masses measured. "Crystallization" samples were immersed in a 10 % solution of sodium sulfate decahydrate for 2 hours (Figure 7.3), dried in the oven at 60°C for 24 hours allowed to cool, their masses measured, and state of deterioration noted. This procedure was repeated for 10 cycles.

After determining that a 10% solution was insufficient, "crystallization" samples were immersed in a 14 % solution of sodium sulfate decahydrate for 2 hours, dried in the oven at 60°C for 24 hours allowed to cool, their masses measured, and state of deterioration noted. This procedure was repeated for 8 cycles.[76]

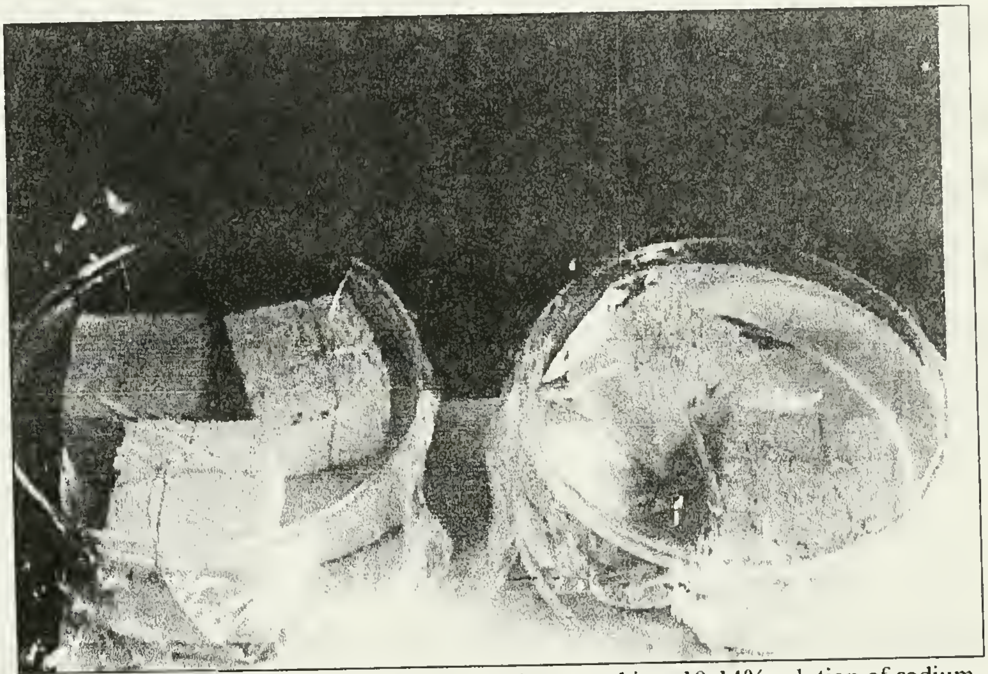

Figure 7.3. Cubes of replication stuccoes are immersed in a 10-14% solution of sodium sulfate, dried and observed. This process approximates the accelerated effects of salt crystallization within porous building materials.

[76] Teutonico's test recommends a 14% solution for "porous building materials" which may include stone, mortars, plasters and stuccoes. Carr's experimentation recorded results for two tests, one run at 10% and one at 14% for lime-based facsimile materials. Because the replication stucco cubes experienced a minimal amount of cure time prior to immersion, it was felt that a 10% solution of sodium sulfate would be sufficient to accelerate deterioration of replication samples.

Data and Observations

Each replication stucco displayed an increase in mass gradually (Figures 7.4-7.6) as soluble salts were absorbed into pore networks. Each sample displayed minor efflorescence at the corners by cycle 8. More significant crystallization occurred at the corners of RS 1 and RS 5 by cycle 11, and RS 2 and RS 4 by cycle 12. Macroscopic deterioration of RS 2, including cracking, delamination and a significant material loss occurred by cycle 15 and 16, after which the immersion-dry cycle was halted for this sample. Macroscopic deterioration of RS 4 began during cycle 16 and continued through cycle 18. Macroscopic deterioration of RS 1 began during cycle 17 and continued through cycle 18 (Figure 7.6). Samples RS 3 and RS 5 did not exhibit serious evidence of deterioration such as material loss or structural disintegration during the course of this experiment.

Data presented in Table 17 displays the change in mass which may be attributed to the crystallization of soluble salts in RS 1, RS 2, RS 3, RS 4 and RS 5 throughout the course of this experiment.

Cycle	RS 1.5	RS 2.5	RS 3.5	RS 4.5	RS 5.5
0	253.23 (0.00/0.00)	247.42 (0.00/0.00)	147.76 (0.00/0.00)	248.32 (0.00/0.00)	305.17 (0.00/0.00)
1	255.77 (+1.00/+1.00%)	249.59 (+0.88/+0.88%)	149.30 (+1.04/+1.04%)	250.84 (+1.01/+1.01%)	308.10 (+0.96/+0.96%)
2	257.42 (+0.65/+1.65%)	251.55 (+0.79/+1.67)	151.13 (+1.23/+2.28%)	253.03 (+0.87/+1.89%)	313.40 (+1.72/+2.70%)
3	259.48 (+0.80/+2.47%)	253.04 (+0.59/+2.27)	152.19 (+0.70/+3.00%)	255.00 (+0.78/+2.69%)	315.17 (+0.56/+3.28%)
4	261.50 (+0.78/+3.27%)	254.04 (+0.40/+2.68%)	153.90 (+1.12/+4.16%)	256.28 (+0.50/+3.21%)	319.27 (+1.27/+4.62%)
5	262.19 (+0.26/+3.53%)	255.06 (+0.40/+3.09%)	154.14 (0.16/+4.32%)	257.44 (+0.45/+3.67%)	314.29 (-1.56/+2.99%)
6	263.80 (+0.61/+4.17%)	256.23 (+0.46/+3.56%	155.48 (+0.87/+4.55%)	258.63 (+0.46/+4.15%)	316..47 (+0.69/+3.70%)
7	265.71 (+0.72/+4.93%)	257.40 (+0.46/+4.03%)	157.13 (+1.06/+6.3.4%)	258.99 (+0.14/+4.30%)	318.56 (+0.66/+4.39%)
8	267.49 (+0.67/+5.63%)	258.66 (+0.49/+4.54%)	158.26 (+0.72/+7.11%)	260.11 (+0.43/+4.75%)	320.83 (+0.71/+5.13%)
9	269.48 (+0.74/+6.42%)	260.03 (+0.53/+5.10%)	160.48 (+1.40/+8.61%)	262.20 (+0.80/+5.59)	323.31 (+0.77/+5.94%)
10	270.09 (+0.23/+6.66%)	261.57 (+0.59/+5.72%)	162.16 (+1.05/+9.75%)	263.04 (+0.32/5.93%)	324.04 (+0.23/+6.18%)
11	269.88 (-0.08/+6.58%)	259.13 (-0.93/+4.73%)	160.99 (-0.72/+8.95%)	261.77 (-0.48/+5.42%)	323.06 (-0.30/+5.86%)
12	272.29 (+0.89/+7.53%)	261.58 (+0.95/+5.72%)	162.91 (+1.19/+10.25%)	264.88 (+1.19/+6.67%)	329.16 (+1.89/+7.86%)
13	274.29 (+0.73/+8.32%)	264.02 (+0.93/+6.71%)	164.71 (+1.10/+11.47%)	267.79 (+1.10/+7.84%)	330.95 (+0.54/+8.45%)
14	276.03 (+0.63/+9.00%)	265.90 (+0.71/+7.47%)	165.92 (+0.73/+12.29%)	269.98 (+0.82/+8.72%)	332.93 (+0.60/+9.10%)
15	277.73 (+0.62/+9.67%)	180.35 (-32.17/-27.10%)	166.84 (+0.55/12.91)	269.11 (-0.32/+8.37%)	334.90 (+0.59/+9.74)
16	280.50 (+1.00/+10.77%)	145.63 (-19.25/-41.14%)	169.78 (+1.76/+14.90)	269.41 (+0.11/+8.49%)	338.87 (+1.18/+11.04)
17	260.21 (-7.23/+2.76%)	--	170.14 (+0.21/+15.15%)	228.83 (-15.06/-7.85%)	340.89 (+0.60/+11.70)
18	202.59 (-22.14/-20.00%)	--	172.03 (+1.11/+16.43)	206.3.1 (-9.84/-16.92%)	342.56 (0.49/+12.25%)

Table 17. Comparative changes in mass due to crystallization of soluble salts for Replication Stuccoes 1-5 expressed in true mass, change in mass from previous cycle, and change in mass from original mass.

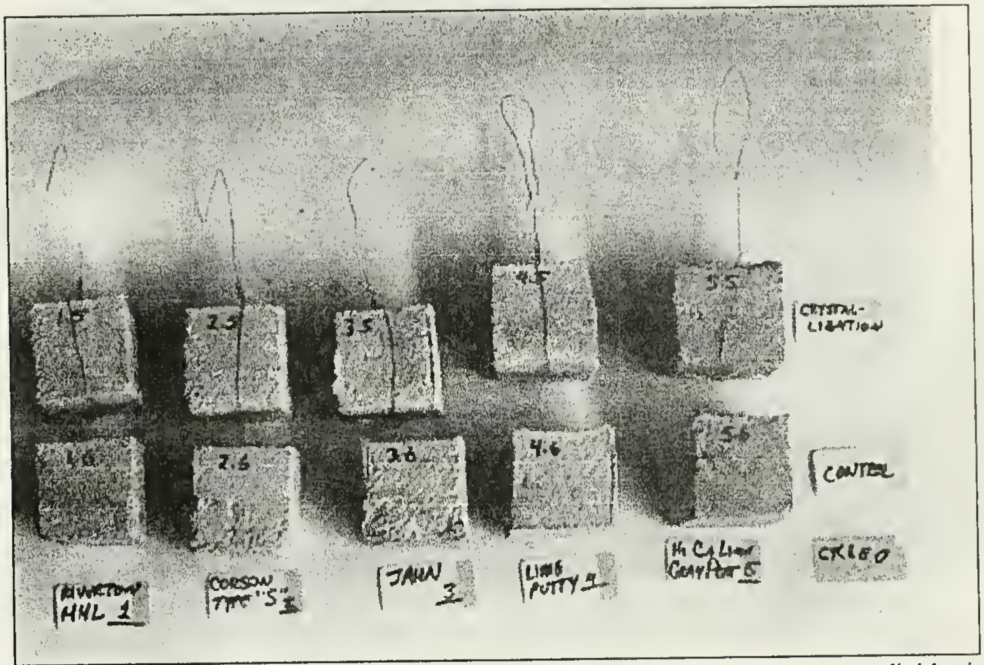

Figure 7.4. Prior to immersion in sodium sulfate solution, replication stuccoes are divides into "crystallization" samples to undergo immersion and "control" samples which represent the stuccoes in their unweathered state. Control samples on bottom, RS 1-5 left to right.

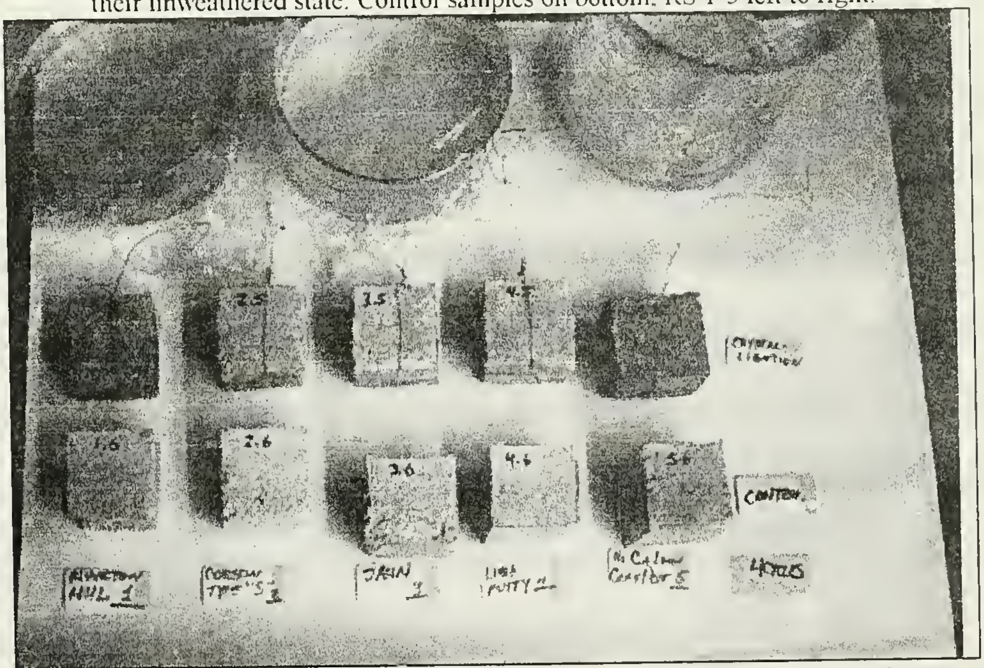

Figure 7.5. Minor areas of efflorescence are the only signs of deterioration after 4 immersion-drying cycles at 10%; the solution was increased to 14% after 10 cycles. Control samples on bottom, RS 1-5 left to right.

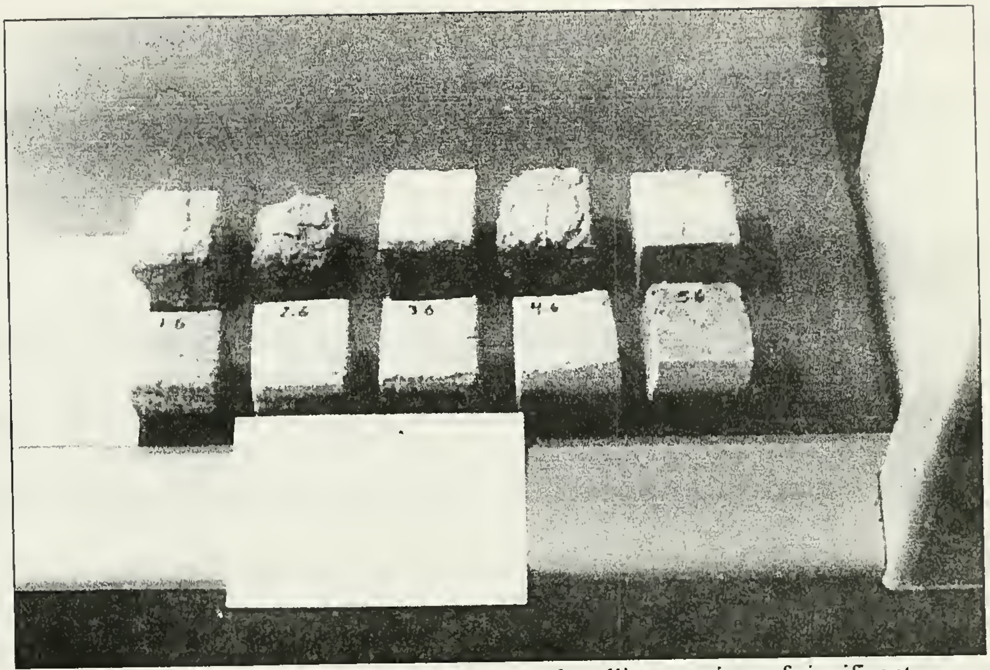

Figure 7.6. Major areas of efflorescence and spalling are signs of significant deterioration after 10 cycles at 10% and 8 cycles at 14%. Control samples on bottom, RS 1-5 left to right.

Conclusions

The absorption of soluble salts in solution and subsequent crystallization in accelerated wet-dry conditions is an indirect measurement of the strength and durability of comparable materials which has different effects on different composite mixes. As the binder is the only variable between RS 1, RS 2, RS 4 and RS 5, this experiment provides the opportunity to assess the performance of different binding materials in conditions of extreme salinity. RS 2 was the first replication stucco to exhibit significant deterioration, followed in order by RS 4 and RS 1, indicating that materials based on dolomitic lime will be more susceptible to deterioration by salt crystallization than will those based on high calcium lime putty than will those based on hydrated hydraulic lime. The relative stability

of RS 3 and RS 5 indicates that cementitious replication materials display a susceptibility to absorbing soluble salts but a lesser susceptibility to structural deterioration due to crystallization.

While this experiment provides useful information regarding which of the binders examined create composite materials which naturally possess the greatest resistance to deterioration catalyzed by soluble salt attack, in the absence of data on the original stucco, it does not provide information about which level of resistance is most appropriate for application at Aiken-Rhett. However, as a high degree of resistance to deterioration is a desirable quality, RS 3 and RS 5 constitute the most acceptable replication stuccoes examined, followed respectively by RS 1, RS 4 and RS 2.

7.3.9 Set

Rationale

Ideally, the replication formula selected for use on Aiken-Rhett will be able to set in a humid environment. Theoretically, hydraulic binders which cure by chemical set are preferable to non-hydraulic binders in such situations. An analysis of rate of cure was conducted to determine which replication stuccoes were most likely to cure quickly in a humid environment.

Methodology

Immediately after mixing, replication formulas were deposited into an impermeable conical ring sealed from below by an impermeable plastic plate and placed into a moist cabinet sealed off from air circulation (Figure 7.8). As non-hydraulic lime-based materials are not likely to cure quickly when surrounded by impermeable materials, all samples were removed from the conical mold two hours after initially being placed in the mold. The samples were penetrated with the Vicat needle at regular intervals and the results recorded in accordance with ASTM C 191-82: "Test Method for Time of Setting of Hydraulic Cement by Vicat Needle (Figure 7.8). Mixes were determined to have an "initial set" when the tip of the Vicat needle was able to penetrate less than 15 mm beneath the surface. A "final set" indicating complete cure was determined when the needle was not able to penetrate the surface.

Many standardized tests have been designed to evaluate the set rate of hydraulic materials which do not require exposure to carbon dioxide to cure. Consequently, the permeability of the mold into which a workable hydraulic material is placed, as well as the exposure of the material to free-flowing air are not necessarily issues. While hydraulic materials would be expected to cure surrounded by an impermeable plastic mold in a moist cabinet, the same cannot be said of non-hydraulic lime-based materials exposed to the same conditions. In recognition of the fact that this study was to examine comparative performance

characteristics of hydraulic and non-hydraulic lime-based materials against one another, the standardized test consulted was modified to speed up set time of all materials by removing samples from the conical mold two hours after being applied.

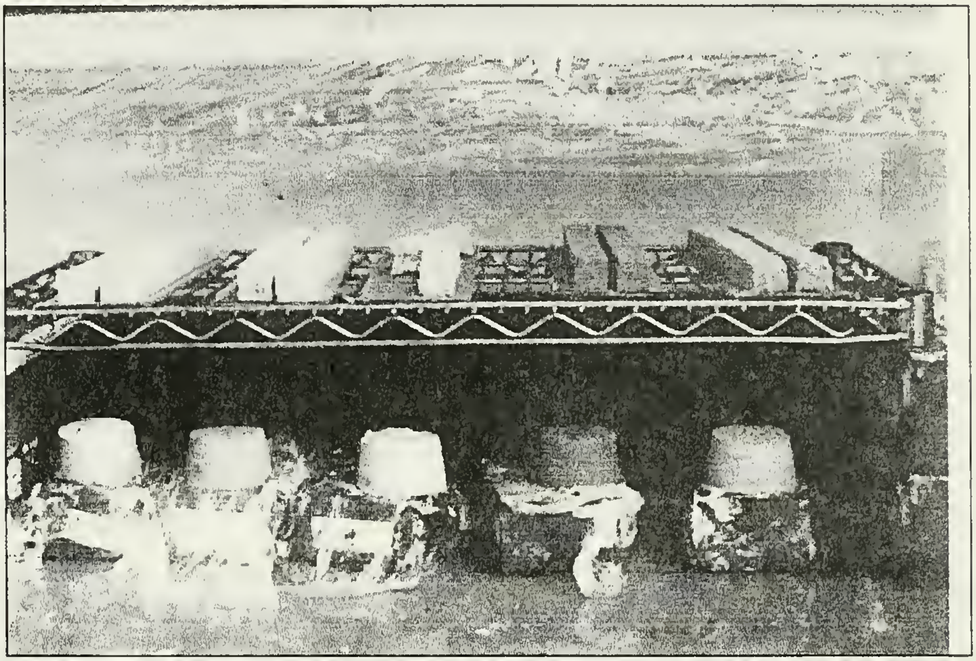

Figure 7.7. After mixing, and between measurements of cure, samples were kept in a moist cabinet sealed from air circulation.

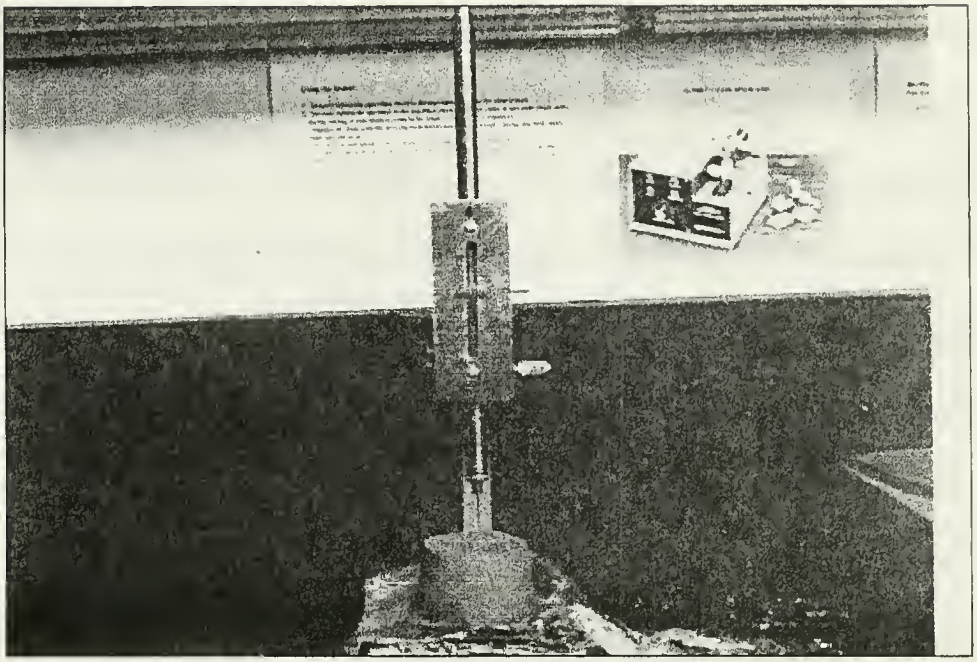

Figure 7.8. Penetration of demolded replication stucco sample with Vicat needle apparatus.

Data and Observations

A minimal amount of physical deformation occurred as samples were removed from the conical Vicat ring specified by applicable standards. Though samples were sealed from air circulation, regular measurements of temperature and humidity inside the observation cabinet would have been information useful for the interpretation of data.

Results of this modified test provide valuable comparative data for the manner in which different binders will cure in humid conditions. The data collected indicates that hydraulic binders (represented by RS 1, RS 3 and RS 5) set much more quickly than do non-hydraulic binders. Two mixes examined performed comparably, experiencing initial and final sets within a short period of time after de-molding. RS 5 cured most rapidly,

experiencing an initial set within 3 hours and a final set within 4 hours. RS 1 experienced an initial set within 4 hours and a final set within 6 hours. RS 3 experienced both an initial and final set within 18 hours. Non-hydraulic, lime-based mixes took significantly longer to experience initial and final sets than their hydraulic counterparts. RS 2 experienced initial set after 48 hours and final set after 60 hours. RS 4 was the slowest of all potential formulas to cure, with an initial set after 192 hours and a final set after 240 hours.

Table 18 reports data on the penetration of the Vicat needle into all replication stuccoes, where a lower degree of penetration is indicative of set.

Time	**RS 1 Riverton HHL**	**RS 2 Corson Type "S"**	**RS 3 Jahn M60**	**RS 4 High Calcium Lime Putty**	**RS 5 Gray Portland/ High Ca Lime**
0 Hrs..	39 mm	39 mm	39 mm	39 mm	39 mm
1 Hrs.	39 mm	39 mm	39 mm	39 mm	30 mm
2 Hrs.	35 mm	39 mm	39 mm	39 mm	25 mm
3 Hrs.	24 mm	39 mm	39 mm	39 mm	5 mm
4 Hrs.	1 mm	39 mm	39 mm	39 mm	0 mm
6 Hrs.	0 mm	39 mm	37 mm	39 mm	
18 Hrs.		39 mm	0 mm	39 mm	
30 Hrs.		30 mm		39 mm	
36 Hrs.		25 mm		39 mm	
48 Hrs.		5 mm		39 mm	
60 Hrs.		0 mm		39 mm	
72 Hrs.				39 mm	
84 Hrs.				39 mm	
96 Hrs.				37 mm	
120 Hrs.				36 mm	
144 Hrs.				32 mm	
168 Hrs.				20 mm	
192 Hrs.				15 mm	
216 Hrs.				5 mm	
240 Hrs.				0 mm	

Table 18. Comparative rate of set for Replication Stuccoes 1-5 expressed as depth of Vicat needle penetration from time of de-molding of samples.

Conclusions

The analysis of data obtained from this examination represents the balance of a worst-case scenario for the curing of several potential mixes and the realization that appropriate standards may be unable to accurately examine the cure time of non-hydraulic lime-based materials. By isolating samples in an observation chamber with high humidity and no air circulation, data suggests that hydraulic binders which set chemically are preferable to non-hydraulic binders where quick cure in a humid environment is desirable. Removing all samples from impermeable rings shortly after molding recognizes the fact that non-hydraulic lime-based materials will require an even lengthier amount of time to set than data obtained herein indicates.

Rapid set, provided that it is not accompanied by microcracking, excessive shrinkage or surface crazing, is a desirable quality for any replication stucco selected for use at Aiken-Rhett. Notably, those formulas which incorporate hydraulic binders (RS 1, RS 3 and RS 5) constitute acceptable materials as each set within 18 hours from application.[77] Because

[77] It should be noted that, as tested, the conical rings used to mold replication mixes into standard forms, at 40 mm, are significantly thicker than any on-site applications will be (approximately 13 mm). The results as indicated in these tests represent laboratory data which is useful for comparing potential materials in like situations, but do not represent actual curing times which might be expected when actually applied to the building. When applied in thinner applications to porous brick surfaces rather

of the time required to cure the non-hydraulic binders (RS 2 and RS 4) examined was dramatically longer, these materials were judged to be comparatively less acceptable.

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than impermeable plastic plates, and exposed to environmental air circulation, mixes are likely to cure more quickly than in the laboratory setting as examined.

8.0 Conclusions

Performance data for all replication stuccoes, reported in *Chapter 7: Experimental Program*, when compared to performance data for the original aged stucco, reported in *Chapter 6: Characterization of 1830s Stucco,* indicates that while none of the composite mixes examined exactly duplicates all current physical and performance properties of stucco applied to Aiken-Rhett's walls in the 1830s, certain replication stuccoes with different binders do approximate critical properties reasonably well.

If the fact that no replication stucco will exactly duplicate all properties and characteristics of the original, the questions "How close is good enough?" and "Are there properties and performance values which must be different from those of the original material?" must be asked. Given the fact that the original stucco has weathered for more than 150 years, it is unreasonable to expect that any *new* material would behave exactly like the historic material. Therefore, it is crucial to prioritize among the properties examined which are the most crucial by providing a material which is stable unto itself and sensitive to the continued existence of the original. It is assumed that each of the recommended formulas is, to a degree, reversible inasmuch as it may be removed from the substrate if necessary. It is also assumed that, because their constituents are similar to the original stucco (a binder based on calcium carbonate, impurities which impart hydraulic qualities, and similar aggregate mixed in appropriate volumetric ratios) that they represent potentially sympathetic mixes from the material standpoint. There are other properties and

performance characteristics worthy of examination which have not been covered by this research, including the adhesive strength of the bond between replication mixes and the substrate, the strength of the bond between replication mixes and the original material, both as compared with the strength of the bond between the original material and the substrate. Also worthwhile is an examination of the weathering characteristics of each replication mix relative to those of the original; such may be evident from extended exposure and monitoring of field mock-ups over a period of several years, or may be approximated with parallel runs of accelerated laboratory weathering.

As noted frequently throughout this document, the visual qualities imparted by Aiken-Rhett's original stucco are of utmost importance. It is essential, therefore, that any replication stucco applied during regular maintenance or during future campaigns be sympathetic to the original in both color and texture. Performance assessments for potential acceptability of treatments examined herein are summarized below and outlined in Tables 18 and 19.

As *preservation and maintenance of extant historic fabric* as opposed to restoration is the driving conservation philosophy at this property, it is not possible to dismiss the inherent color and texture of replication stuccoes by arguing that they will eventually be covered with surface finished to replicate those which existed during the property's period of significance. As examined, RS 1 and RS 5 are most similar in color to that of the original

and constitute potentially acceptable replication stuccoes; these formulas may require slight modification pending the outcome of additional on-site testing. RS 3 may constitute an acceptable color match only with the addition of pigments which may be completed by the manufacturer. RS 2 and RS 4, because they are dissimilar to the color of the original, are the least acceptable of all treatments examined based on this particular criteria. Recognizing that the natural texture created by the volumetric combination of binder and aggregate is critical to the visual impact which a stucco creates, RS 1, RS 2, RS 4 and RS 5 were found to be acceptable, with a note that additional troweling not completed in the laboratory will be necessary to approximate the texture of the original.

The most critical performance properties examined herein are those which relate to the ability of stucco to keep water away from the brick walls beneath. Generally, all replication stuccoes tested behaved similarly to the original stucco with respect to qualities of water absorption capacity, water vapor transmission and evaporation characteristics, and thus constitute potentially acceptable treatments. Of the materials tested, lime-based replication stuccoes RS 1, RS 2 and RS 4 behave most like the original material, while cementitious stuccoes RS 3 and RS 5 are somewhat less similar.

An assessment of the amount of time which will be required to cure any replication stucco is fairly important, as humid conditions which prevail in Charleston during much of the year may hamper the ability of a material to become stable before it is subjected to an

intense weathering environment. Hydraulic replication stuccoes RS 1, RS 3 and RS 5 all cured in humid conditions within a 24 hour period. This indicates, theoretically, that during maintenance campaigns, plasterers can apply these mixes within relatively short spans of time which are expected to be without rainfall with some degree of certainty that they will cure rapidly. The five-day cure span of RS 2 and ten-day span of RS 4 may create unacceptable cure demands in Charleston, where high humidity is complemented by frequent and sporadic rainstorms.

Properties such as density and porosity are important inasmuch as they relate to other performance characteristics, but ought not to be used as factors which would justify or prohibit the use of a replication stucco in close proximity to valuable historic fabric. In this sense, the "acceptable" values of RS 1, RS 2, RS 4 and RS 5 and "unacceptable" values of RS 3 are somewhat academic in their relation to viability as potentially successful stucco treatments at Aiken-Rhett.

While it is important that any replication stucco applied to Aiken-Rhett display both a sensitivity to valuable original fabric, it is also somewhat important that replication materials display stability unto themselves. The abilities to resist deterioration due to the crystallization of soluble salts exhibited by RS 1, RS 3 and RS 5 are superior to those exhibited by RS 2 and RS 4, but the absence of soluble salts in the original material after 150 years of weathering indicates that most of Aiken-Rhett's stucco, in its present state

and present microclimate, is not at a substantial risk of deterioration by soluble salt crystallization in the first place.

In light of the data presented in previous chapters and conclusions reached herein, RS 1 and RS 5 are replication stuccoes which most closely approximate the original stucco in color, texture, water absorption capacity, water vapor transmission, evaporation characteristics, density and porosity while providing acceptable resistance to deterioration due to salt crystallization and require minimal time to set. Neither RS 1 or RS 5 were found to contain significant concentrations of soluble sulfate or chloride salts (see *Appendix J: Soluble Salt Analysis for Selected Replication Stuccoes)*, suggesting that neither mix threatens to introduce soluble salts into the building system. RS 2, primarily because of its slow cure, color and low resistance to salt-related deterioration, does not constitute an acceptable treatment. RS 3, by virtue of its color and texture, capacity to absorb water and density does not constitute an acceptable treatment without significant modification. RS 4, because of its prohibitively slow set, color and low resistance to salt crystallization, does not constitute an acceptable treatment.

Replication	Color	Texture	Density	Porosity	WAC	WVT	Evaporation	Salt Resistance	Set
RS 1: Riverton HHL (2:5)	Similar, needs slight modification	Similar with additional troweling	Similar- within variation of original	Dissimilar- slightly lower than variation of original	Dissimilar- slightly lower than variation of original	Similar- within variation of original	Similar- within variation of original	Somewhat resistant	Rapid
RS 2: Corson Type "S" (2:5)	Dissimilar- too light	Similar with additional troweling	Similar- within variation of original	Similar- within variation of original	Similar- within variation of original	Dissimilar- slightly higher than variation of original	Similar- within variation of original	Least Resistant	Slow
RS 3: Jahn M60 (mfr. mix)	Dissimilar- too light as tested, mfr. modification possible	Dissimilar- but may be modified by mfr.	Dissimilar- lower than variation of original	Dissimilar- lower than variation of original	Dissimilar- higher than variation of original	Similar- within variation of original	Similar- within variation of original	Most Resistant	Rapid
RS 4: High Ca Lime Putty (2:5)	Dissimilar- too light	Similar with additional troweling	Similar- within variation of original	Similar- within variation of original	Similar- within variation of original	Dissimilar- slightly higher than variation of original	Similar- within variation of original	Least Resistant	Extremely Slow
RS 5: Gray Port/Hi Ca Lime (2:5)	Similar, needs slight modification	Similar with additional troweling	Similar- within variation of original	Dissimilar- slightly lower than variation of original	Dissimilar- slightly lower than variation of original	Similar- within variation of original	Dissimilar- slightly more rapid than variation of original	Most resistant	Rapid

Table 19. Basic assessments of physical and performance characteristics of Replication Stuccoes 1-5 versus the physical and performance characteristics of the original stucco.

Replication	Color	Texture	Density	Porosity	WAC	WVT	Evaporation	Salt Resistance	Cure
RS 1: Riverton HHL (2:5)	Acceptable, with slight modification	Acceptable with additional troweling	Acceptable	Borderline Acceptable	Borderline Acceptable	Acceptable	Acceptable	Acceptable	Acceptable
RS 2: Corson Type "S" (2:5)	Unacceptable without major modification	Acceptable with additional troweling	Acceptable	Acceptable	Acceptable	Borderline Acceptable	Acceptable	Unacceptable	Unacceptable
RS 3: Jahn M60 (mfr. mix)	Unacceptable without major modification	Unacceptable *as is*	Unacceptable but not as critical as other properties	Borderline Acceptable	Unacceptable	Acceptable	Acceptable	Acceptable	Acceptable
RS 4: High Ca Lime Putty (2:5)	Unacceptable without major modification	Acceptable with additional troweling	Acceptable	Acceptable	Acceptable	Borderline Acceptable	Acceptable	Unacceptable	Unacceptable
RS 5: Gray Port/Hi Ca Lime (2:5)	Acceptable, with slight modification	Acceptable with additional troweling	Acceptable	Borderline Acceptable	Borderline Acceptable	Acceptable	Borderline Acceptable	Acceptable	Acceptable

Table 20. Qualified assessments of physical and performance characteristics of Replication Stuccoes 1-5 versus the physical and performance characteristics of the original stucco.

9.0 Recommendations

9.1 Recommendations for Treatment

Pursuant to the physical investigations and data presented in *Chapter 6: Characterization of 1830s Stucco* and *Chapter 7: Experimental Program*, and summaries provided in *Chapter 8: Conclusions*, it is recommended that Historic Charleston conduct an on-site testing program to evaluate the compatibility of RS 1 and RS 5 against the performance of the original to assess whether these formulas, which performed similarly in laboratory examinations, perform similarly in an actual weathering environment. Application should be conducted and analyzed periodically over a period of 6-12 months on multiple areas of the building which represent different microclimates. The suitability of different areas for testing should follow a brief site survey to determine which areas would be most acceptable and out of view. Replication stuccoes should be applied and cured in accordance with standard practice employed by Historic Charleston masonry professionals. It should be noted that the hydraulic nature of each recommended replication stucco, because of their rapid set, will behave differently than traditional lime-based materials. Lime-cement blends such as RS 5 have gained widespread acceptance in recent years for restoration purposes, but it should be noted that excessively dry setting

conditions may compromise the performance values imparted by the cement, and that excessively wet setting conditions may affect the setting of the lime fraction.[78]

The experimental program employed for this study utilized a sand from New York which closely approximated the color, particle size distribution, particle shape and consistency of the original. Ideally, however, Historic Charleston will be able to use a *local* sand with characteristics similar to those of the original. This will require an examination of sands available through local masonry suppliers to determine an acceptable substitution for the sand employed during this examination. It is recommended that Historic Charleston Foundation select a sand with a grain size distribution which approximates that employed in this experimental program:

Tray Number	Passage (%)
>20	74.61 ± 2.14
40	30.91 ± 3.63
60	8.17 ± 3.32
80	6.86 ± 2.90
100	6.14 ± 2.76
<100	-

Table 21. Recommended grain size distribution for replication sands, based on Hubbard Sand and Gravel "tan sand" as outlined above.

[78] S. Peroni, C. Tersigni, G. Torraca, S. Cerea, M. Forti, F. Guidobaldi, P. Rossa-Doria, A. DeRege, D. Picchi, F.J. Pietrafitta, G. Benedetti, "Lime-Based Mortars for the Repair of Ancient Masonry and Possible Substitutes" (Rome: ICCROM, 1981) 63.

9.2 Recommendations for Further Study

Though the characterization and experimental program included in this research identify a potentially compatible material solution for historic stuccoes at the Aiken-Rhett House, there are lingering material and research deficiencies which, if addressed in the future, might provide information critical to the sensitive treatment of historic stuccoes throughout Charleston and beyond.

Foremost is the need for a basic catalog of materials such as sands and binders which are locally available for replication stuccoes. Historic Charleston is uniquely poised as a respected preservation organization which regularly provides advice and input to homeowners and contractors alike on the sensitive treatment of historic materials which contribute to the experience which Charleston seeks to protect. In this sense, should Historic Charleston compile a large inventory of sand types available throughout the Carolinas, classified according to color, particle shape and size and mineralogical constituents, it could function as an information clearinghouse capable of providing accurate, reliable and easily-accessible data on a material critical to the preservation of Charleston stucco.

There is a significant clay component to the hard brown stuccoes applied at Aiken-Rhett, Market Hall and elsewhere in Charleston which is not represented in any of the replication stuccoes examined during this research. A materials testing program which more precisely examines the composition of the original stucco is important, and could provide useful information on stuccoes which appear on other buildings throughout Charleston. There is an outstanding opportunity to further examine the nature of the binder, to determine whether these stuccoes contain hydraulic lime or natural cement. Specifically, a testing program should be designed which characterizes the hydraulic components of the original material, and establishes benchmark reference information on the degree of hydraulicity of the original. While experimental standards for the analysis of historic mortars, plasters and stuccoes do exist, they are somewhat deficient. Though they recognize significant binder: aggregate combinations (lime:sand, lime:cement:sand, cement:sand, etc.), they fail to recognize the wide variation of volumetric formulas which have historically been employed throughout the centuries. It is highly advisable that, as replication materials with known volumetric ratios are created, that samples be archived and eventually analyzed quantitatively and qualitatively to establish reference data for future comparisons.

The role of commercially-available pigments, accepted by many as a necessity in replicating historic stuccoes with modern materials, was not covered in this research.

Should RS 1 and RS 5 fail to approximate the exact color of the original stucco during on-site testing and examination, artificially-pigmented materials will be necessary. Given the benchmark data established by this research, it would be valuable to examine whether commercially-available pigments, mixed at different concentrations to create different shades, significantly affect physical and performance qualities which have already been discussed.

This research was conducted prior to the start of maintenance campaigns which will seek to address the structural failure of Aiken-Rhett's bearing masonry system. In the future, should original stuçco need to be sacrificed as a casualty of structural stabilization, Historic Charleston will be able to initiate a program of additional testing on material which must be removed without worries of excessive sampling. Because of concerns that additional sampling might remove an excessive amount of historic material, performance properties such as the bond strength between original stucco and the brickwork beneath, and the potential bond strength between the original and replication stuccoes were not examined. As structural stabilization starts, Historic Charleston may have the opportunity to retain, catalog and analyze additional historic fabric which could provide valuable practical and educational information on the continued performance of an historic material within an historically-sensitive situation.

APPENDICES

APPENDIX A: Gravimetric and Calcimeter Analyses

GRADUATE PROGRAM IN HISTORIC PRESERVATION
UNIVERSITY OF PENNSYLVANIA
ARCHITECTURAL CONSERVATION LABORATORY

Owner: Historic Charleston Foundation

Sample Number: 005.1	**Date Sampled:** January, 1997
Sample Location: Rear Courtyard, Ground level	**Date Analyzed:** March 23, 1997

Mortar Type (Description): Aiken-Rhett Stucco-1830s

Mortar Analysis:

This mortar sample was analyzed in accordance with practice outlined by Jeanne Marie Teutonico, "Mortar Analysis: A Simple Method", *A Laboratory Manual for Architectural Conservators, 1988.* The sample was crushed with a mortar and pestle and reacted with hydrochloric acid (HCl). Analysis of weight loss as a result of reaction provides data for percentage of sample composed of lime ($CaCO_3$), and percentage aggregate. When data is coordinated with real densities of respective materials, a volume mix which approximates the original mix may be obtained. Though not definitive, apparent densities calculated for original materials are: High Calcium Lime Putty/$CaCO_3$ (1.244 g/mL), Aiken-Rhett sand (1.60 g/mL), Aiken-Rhett fines (0.52 g/mL). Note that this study assumes the original material employed slaked high-calcium lime in the mix; volumetric analyses would be radically different if hydrated lime were used as the volumes calculated are in line with historic stucco formulas.

Color: Munsell 0.46Y 4.23/2.03 "Grayish yellowish brown"	**Initial Mass (M_o):** 38.93 g	**Texture:** 80 grit sandpaper
Acid-Soluble Mass: 17.08 g	**Sand Mass:** 15.74 g	**Fines Mass:** 6.11 g
$CaCO_3$ (wt. %): 43.87	**Sand (wt %):** 40.43	**Fines (wt. %):** 15.69
$CaCO_3$ (vol. %): 38.80	**Sand (vol. %):** 28.20	**Fines (vol. %):** 33.00

Binder Analysis:

Lime composed primarily of $CaCO_3$. Evidence that lime may have come from the burning of sea shells exists in the form of shell fragments found undissolved in aggregate.

Aggregate Analysis:

Well-graded sand composed mainly of quartz and feldspar, with crushed shells added for texture or as unburned component of binder. As most grains are subrounded, this is most likely a river or ocean sand. Addition of brick dust may indicate that masons intended for a hydraulic set due to high humidity of climate. Significant clay portion found in the form of fines indicates either an attempt to pigment or extend the lime-sand mix. Aggregate breakdown is 40% subrounded, cloudy feldspar, 30% subangular to subrounded, clear quartz, 25% angular feldspar with iron streaks, 4% amorphous, red brick dust, 1% crushed white shell.

Sieve Data:

Tray Number	Mass Retained (g)	Mass Retained (%)	Passage (%)
8	0.01	0.06	99.94
16	2.44	15.50	84.44
30	5.70	36.22	48.22
50	2.00	12.71	35.51
100	4.64	29.47	6.04
200	0.61	3.88	2.16
Pan	0.34	2.16	0.00

Fines Analysis:

For volume analysis, fines were included as aggregate. Clays used as a pigment or extender, indicated as alumino-silicates by X-Ray Diffraction. Significant concentration of quartz (SiO_2) also indicated by X-Ray Diffraction analysis from crushing of sample or as extremely fine aggregate.

Conclusions:

Binder: Aggregate ratio of 1:2 is possible. Extensive loss of material over time makes determination of exact original mix difficult.

GRADUATE PROGRAM IN HISTORIC PRESERVATION
UNIVERSITY OF PENNSYLVANIA
ARCHITECTURAL CONSERVATION LABORATORY

Owner: Historic Charleston Foundation

Sample Number: 101.3	**Date Sampled:** January, 1997
Sample Location: First Floor Piazza, South wall	**Date Analyzed:** March 23, 1997

Mortar Type (Description): Aiken-Rhett Stucco-1830s

Mortar Analysis:
This mortar sample was analyzed in accordance with practice outlined by Jeanne Marie Teutonico, "Mortar Analysis: A Simple Method", *A Laboratory Manual for Architecturol Conservators, 1988.* The sample was crushed with a mortar and pestle and reacted with hydrochloric acid (HCl). Analysis of weight loss as a result of reaction provides data for percentage of sample composed of lime ($CaCO_3$), and percentage aggregate. When data is coordinated with real densities of respective materials, a volume mix which approximates the original mix may be obtained. Though not definitive, apparent densities calculated for original materials are: High Calcium Lime Putty/$CaCO_3$ (1.244 g/mL), Aiken-Rhett sand (1.60 g/mL), Aiken-Rhett fines (0.52 g/mL). Note that this study assumes the original material employed slaked high-calcium lime in the mix; volumetric analyses would be radically different if hydrated lime were used as the volumes calculated are in line with historic stucco formulas.

Color: Munsell 0.1Y 5.3/1.87 "Grayish yellowish brown"	**Initial Mass (M_o):** 22.61 g	**Texture:** 80 grit sandpaper
Acid-Soluble Mass: 7.84 g	**Sand Mass:** 11.93 g	**Fines Mass:** 2.84 g
$CaCO_3$ (wt. %): 34.67	**Sand (wt %):** 52.76	**Fines (wt. %):** 12.56
$CaCO_3$ (vol. %): 32.80	**Sand (vol. %):** 38.75	**Fines (vol. %):** 28.36

Binder Analysis:
Lime composed primarily of $CaCO_3$. Evidence that lime may have come from the burning of sea shells exists in the form of shell fragments found undissolved in aggregate.

Aggregate Analysis:
Well-graded sand composed mainly of quartz and feldspar, with crushed shells added for texture or as unburned component of binder. As most grains are subrounded, this is most likely a river or ocean sand. Addition of brick dust may indicate that masons intended for a hydraulic set due to high humidity of climate. Significant clay portion found in the form of fines indicates either an attempt to pigment or extend the lime-sand mix. Aggregate breakdown is 40% subrounded, cloudy feldspar, 30% subangular to subrounded, clear quartz, 25% angular feldspar with iron streaks, 4% amorphous, red brick dust, 1% crushed white shell.

Sieve Data:

Tray Number	Mass Retained (g)	Mass Retained (%)	Passage (%)
8	0.00	0.00	100.00
16	1.82	15.26	84.74
30	5.73	48.03	36.71
50	3.35	28.08	8.63
100	0.57	4.77	3.86
200	0.18	1.51	2.35
Pan	0.28	2.35	0.00

Fines Analysis:
For volume analysis, fines were included as aggregate. Clays used as a pigment or extender, indicated as alumino-silicates by X-Ray Diffraction. Significant concentration of quartz (SiO_2) also indicated by X-Ray Diffraction analysis from crushing of sample or as extremely fine aggregate.

Conclusions:
Binder: Aggregate ratio of 1:3 or 2:5 is possible based on volumetric analysis.

GRADUATE PROGRAM IN HISTORIC PRESERVATION
UNIVERSITY OF PENNSYLVANIA
ARCHITECTURAL CONSERVATION LABORATORY

Owner: Historic Charleston Foundation

Sample Number: 102.3	**Date Sampled:** January, 1997
Sample Location: First Floor Piazza, East Wall	**Date Analyzed:** March 23, 1997

Mortar Type (Description): Aiken-Rhett Stucco-1830s

Mortar Analysis:

This mortar sample was analyzed in accordance with practice outlined by Jeanne Marie Teutonico, "Mortar Analysis: A Simple Method", *A Laboratory Manual for Architectural Conservators, 1988.* The sample was crushed with a mortar and pestle and reacted with hydrochloric acid (HCl). Analysis of weight loss as a result of reaction provides data for percentage of sample composed of lime ($CaCO_3$), and percentage aggregate. When data is coordinated with real densities of respective materials, a volume mix which approximates the original mix may be obtained. Though not definitive, apparent densities calculated for original materials are: High Calcium Lime Putty/$CaCO_3$ (1.244 g/mL), Aiken-Rhett sand (1.60 g/mL), Aiken-Rhett fines (0.52 g/mL). Note that this study assumes the original material employed slaked high-calcium lime in the mix; volumetric analyses would be radically different if hydrated lime were used as the volumes calculated are in line with historic stucco formulas.

Color: Munsell 0.63Y 4.8/1.93 "Grayish yellowish brown"	**Initial Mass (M_o):** 53.03 g	**Texture:** 80 grit sandpaper
Acid-Soluble Mass: 15.43 g	**Sand Mass:** 30.59 g	**Fines Mass:** 7.01 g
$CaCO_3$ (wt. %): 29.10	**Sand (wt %):** 57.68	**Fines (wt. %):** 13.22
$CaCO_3$ (vol. %): 27.66	**Sand (vol. %):** 42.47	**Fines (vol. %):** 29.87

Binder Analysis:

Lime composed primarily of $CaCO_3$. Evidence that lime may have come from the burning of sea shells exists in the form of shell fragments found undissolved in aggregate.

Aggregate Analysis:

Well-graded sand composed mainly of quartz and feldspar, with crushed shells added for texture or as unburned component of binder. As most grains are subrounded, this is most likely a river or ocean sand. Addition of brick dust may indicate that masons intended for a hydraulic set due to high humidity of climate. Significant clay portion found in the form of fines indicates either an attempt to pigment or extend the lime-sand mix. Aggregate breakdown is 40% subrounded, cloudy feldspar, 30% subangular to subrounded, clear quartz, 25% angular feldspar with iron streaks, 4% amorphous, red brick dust, 1% crushed white shell.

Sieve Data:

Tray Number	Mass Retained (g)	Mass Retained (%)	Passage (%)
8	0.06	0.20	99.80
16	4.16	13.60	86.20
30	13.53	44.24	41.96
50	10.22	33.40	8.56
100	1.92	6.27	2.29
200	0.59	1.93	0.36
Pan	0.11	0.36	0.00

Fines Analysis:

For volume analysis, fines were included as aggregate. Clays used as a pigment or extender, indicated as alumino-silicates by X-Ray Diffraction. Significant concentration of quartz (SiO_2) also indicated by X-Ray Diffraction analysis from crushing of sample or as extremely fine aggregate.

Conclusions:

Binder: Aggregate ratio of 1:3 or 2:5 is possible. As sample is sheltered, this may fairly well represent original mix and constituents.

Graduate Program in Historic Preservation
University of Pennsylvania
Architectural Conservation Laboratory

Owner: Historic Charleston Foundation

Sample Number: 102.4	**Date Sampled:** January, 1997
Sample Location: First Floor Piazza, East Wall	**Date Analyzed:** March 23, 1997

Mortar Type (Description): Aiken-Rhett Stucco-1830s

Mortar Analysis:

This mortar sample was analyzed in accordance with practice outlined by Jeanne Marie Teutonico, "Mortar Analysis: A Simple Method", *A Laboratory Manual for Architectural Conservators, 1988.* The sample was crushed with a mortar and pestle and reacted with hydrochloric acid (HCl). Analysis of weight loss as a result of reaction provides data for percentage of sample composed of lime ($CaCO_3$), and percentage aggregate. When data is coordinated with real densities of respective materials, a volume mix which approximates the original mix may be obtained. Though not definitive, apparent densities calculated for original materials are: High Calcium Lime Putty/$CaCO_3$ (1.244 g/mL), Aiken-Rhett sand (1.60 g/mL), Aiken-Rhett fines (0.52 g/mL). Note that this study assumes the original material employed slaked high-calcium lime in the mix; volumetric analyses would be radically different if hydrated lime were used as the volumes calculated are in line with historic stucco formulas.

Color: Munsell 0.63Y 4.8/1.93 "Grayish yellowish brown"	**Initial Mass (M_o):** 59.98 g	**Texture:** 80 grit sandpaper
Acid-Soluble Mass: 13.98 g	**Sand Mass:** 33.53 g	**Fines Mass:** 13.54 g
$CaCO_3$ (wt. %): 23.31	**Sand (wt %):** 55.90	**Fines (wt. %):** 22.57
$CaCO_3$ (vol. %): 19.38	**Sand (vol. %):** 36.00	**Fines (vol. %):** 44.60

Binder Analysis:

Lime composed primarily of $CaCO_3$. Evidence that lime may have come from the burning of sea shells exists in the form of shell fragments found undissolved in aggregate.

Aggregate Analysis:

Well-graded sand composed mainly of quartz and feldspar, with crushed shells added for texture or as unburned component of binder. As most grains are subrounded, this is most likely a river or ocean sand. Addition of brick dust may indicate that masons intended for a hydraulic set due to high humidity of climate. Significant clay portion found in the form of fines indicates either an attempt to pigment or extend the lime-sand mix. Aggregate breakdown is 40% subrounded, cloudy feldspar, 30% subangular to subrounded, clear quartz, 25% angular feldspar with iron streaks, 4% amorphous, red brick dust, 1% crushed white shell.

Sieve Data:

Tray Number	Mass Retained (g)	Mass Retained (%)	Passage (%)
8	0.05	0.15	99.85
16	3.41	10.17	89.68
30	12.92	38.53	51.15
50	11.50	34.30	16.85
100	3.56	10.62	6.23
200	1.92	5.72	0.51
Pan	0.17	0.51	0.00

Fines Analysis:

For volume analysis, fines were included as aggregate. Clays used as a pigment or extender, indicated as alumino-silicates by X-Ray Diffraction. Significant concentration of quartz (SiO_2) also indicated by X-Ray Diffraction analysis from crushing of sample or as extremely fine aggregate.

Conclusions:

Binder: Aggregate ratio of 1:4 is possible.

GRADUATE PROGRAM IN HISTORIC PRESERVATION UNIVERSITY OF PENNSYLVANIA ANALYSIS PERFORMED AT NOBLE PRESERVATION SERVICES, INC.	
Client: Historic Charleston Foundation	
Sample Number: 102.10	**Date Sampled:** January, 1997
Sample Location: First Floor Piazza, East wall	**Date Analyzed:** September 15, 1997
Mortar Type (Description): Aiken-Rhett Stucco-1830s	

Calcimeter Analysis:

This mortar sample was analyzed in accordance with practice outlined by Hanna Jedrzejewska, *Studies in Conservation, 1960.* The sample was crushed and reacted in the calcimeter with hydrochloric acid (HCl). Analysis of carbon dioxide (CO_2) displacement as a result of reaction provides data for percentage of sample composed of lime ($CaCO_3$), percentage of soluble non-carbonates and percentage aggregate. When data is coordinated with real densities of respective materials, a volume mix which approximates the original mix may be obtained. Though not definitive, apparent densities calculated for original materials are: High Calcium Lime Putty/$CaCO_3$ (1.244 g/mL), Aiken-Rhett sand (1.60 g/mL), Aiken-Rhett fines (0.52 g/mL). Note that this study assumes the original material employed slaked high-calcium lime in the mix; volumetric analyses would be radically different if hydrated lime were used as the volumes calculated are in line with historic stucco formulas.

Color: Munsell 0.63Y 4.8/1.93 "Grayish yellowish brown"	**Initial Mass (M_o):** 0.50 g **Final Mass (M_f):** 0.31 g	**Texture:** 80 grit sandpaper
Initial H_2O: 37.2 mL	**Final H_2O:** 56.0 mL	**CO_2 Displacement:** 18.8 mL
$CaCO_3$ (%): 16.80	**Solubles (%):** 21.20	**Aggregate (%):** 62.00

Binder Analysis:

Hydraulic lime composed primarily of $CaCO_3$ and solubles. Evidence that lime may have come from the burning of sea shells exists in the form of shell fragments found undissolved in aggregate.

Aggregate Analysis:

Well-graded sand composed mainly of quartz and feldspar, with crushed shells added for texture or as unburned component of binder. As most grains are subrounded, this is most likely a river or ocean sand. Addition of brick dust may indicate that masons intended for a hydraulic set due to high humidity of climate. Significant clay portion found in the form of fines indicates either an attempt to pigment or extend the lime-sand mix. Aggregate breakdown is 40% subrounded, cloudy feldspar, 30% subangular to subrounded, clear quartz, 25% angular feldspar with iron streaks, 4% amorphous, red brick dust, 1% crushed white shell.

Sieve Data:

Tray Number	Mass Retained (g)	Mass Retained (%)	Passage (%)
>20	.08	25.00	75.00
40	.14	43.75	31.25
60	.05	15.63	15.62
80	.01	3.13	12.49
100	.00	0.00	12.49
<100	.04	12.49	0.00

Fines Analysis:

Clays used as a pigment or extender, indicated as alumino-silicates by X-Ray Diffraction. Significant concentration of quartz (SiO_2) also indicated by X-Ray Diffraction analysis from crushing of sample or as extremely fine aggregate.

Conclusions:

Binder:aggregate ratio of 1:2 or 2:5 is possible given resultant calculations. Significant amount of soluble materials in binder may indicate presence of soluble silicates or impurities in lime.

Graduate Program in Historic Preservation University of Pennsylvania Analysis performed at Noble Preservation Services, Inc.	
Client: Historic Charleston Foundation	
Sample Number: 102.11	**Date Sampled:** January, 1997
Sample Location: First Floor Piazza, East wall	**Date Analyzed:** September 15, 1997
Mortar Type (Description): Aiken-Rhett Stucco-1830s	

Calcimeter Analysis:

This mortar sample was analyzed in accordance with practice outlined by Hanna Jedrzejewska, *Studies in Conservation, 1960.* The sample was crushed and reacted in the calcimeter with hydrochloric acid (HCl). Analysis of carbon dioxide (CO_2) displacement as a result of reaction provides data for percentage of sample composed of lime ($CaCO_3$), percentage of soluble non-carbonates and percentage aggregate. When data is coordinated with real densities of respective materials, a volume mix which approximates the original mix may be obtained. Though not definitive, apparent densities calculated for original materials are: High Calcium Lime Putty/$CaCO_3$ (1.244 g/mL), Aiken-Rhett sand (1.60 g/mL), Aiken-Rhett fines (0.52 g/mL). Note that this study assumes the original material employed slaked high-calcium lime in the mix; volumetric analyses would be radically different if hydrated lime were used as the volumes calculated are in line with historic stucco formulas.

Color: Munsell 0.63Y 4.8/1.93 "Grayish yellowish brown"	**Initial Mass (M_o):** 0.50 g **Final Mass (M_f):** 0.27 g	**Texture:** 80 grit sandpaper
Initial H_2O: 41.6 mL	**Final H_2O:** 59.4 mL	**CO_2 Displacement:** 17.8 mL
$CaCO_3$ (%): 15.90	**Solubles (%):** 30.10	**Aggregate (%):** 54.00

Binder Analysis:

Hydraulic lime composed primarily of $CaCO_3$ and solubles. Evidence that lime may have come from the burning of sea shells exists in the form of shell fragments found undissolved in aggregate.

Aggregate Analysis:

Well-graded sand composed mainly of quartz and feldspar, with crushed shells added for texture or as unburned component of binder. As most grains are subrounded, this is most likely a river or ocean sand. Addition of brick dust may indicate that masons intended for a hydraulic set due to high humidity of climate. Significant clay portion found in the form of fines indicates either an attempt to pigment or extend the lime-sand mix. Aggregate breakdown is 40% subrounded, cloudy feldspar, 30% subangular to subrounded, clear quartz, 25% angular feldspar with iron streaks, 4% amorphous, red brick dust, 1% crushed white shell.

Sieve Data:

Tray Number	Mass Retained (g)	Mass Retained (%)	Passage (%)
>20	.08	29.63	70.37
40	.14	51.85	18.52
60	.04	14.81	3.71
80	.00	0.00	3.71
100	.00	0.00	3.71
<100	.01	3.70	0.01

Fines Analysis:

Clays used as a pigment or extender, indicated as alumino-silicates by X-Ray Diffraction. Significant concentration of quartz (SiO_2) also indicated by X-Ray Diffraction analysis from crushing of sample or as extremely fine aggregate.

Conclusions:

Binder:aggregate ratio of 1:2 is possible given resultant calculations. Significant amount of soluble materials in binder may indicate presence of soluble silicates or impurities in lime.

GRADUATE PROGRAM IN HISTORIC PRESERVATION
UNIVERSITY OF PENNSYLVANIA
ANALYSIS PERFORMED AT NOBLE PRESERVATION SERVICES, INC.

Client: Historic Charleston Foundation

Sample Number: 203.5	**Date Sampled:** January, 1997
Sample Location: Second Floor Piazza, South wall, corner	**Date Analyzed:** September 15, 1997

Mortar Type (Description): Aiken-Rhett Stucco-1830s

Calcimeter Analysis:

This mortar sample was analyzed in accordance with practice outlined by Hanna Jedrzejewska, *Studies in Conservation, 1960.* The sample was crushed and reacted in the calcimeter with hydrochloric acid (HCl). Analysis of carbon dioxide (CO_2) displacement as a result of reaction provides data for percentage of sample composed of lime ($CaCO_3$), percentage of soluble non-carbonates and percentage aggregate. When data is coordinated with real densities of respective materials, a volume mix which approximates the original mix may be obtained. Though not definitive, apparent densities calculated for original materials are: High Calcium Lime Putty/$CaCO_3$ (1.244 g/mL), Aiken-Rhett sand (1.60 g/mL), Aiken-Rhett fines (0.52 g/mL). Note that this study assumes the original material employed slaked high-calcium lime in the mix; volumetric analyses would be radically different if hydrated lime were used as the volumes calculated are in line with historic stucco formulas.

Color: Munsell 8.83YR 4.06/2.17 "Grayish yellowish brown"	**Initial Mass (M_o):** 0.50 g **Final Mass (M_f):** 0.21 g	**Texture:** 120 grit sandpaper
Initial H_2O: 40.0 mL	**Final H_2O:** 73.6 mL	**CO_2 Displacement:** 33.6 mL
$CaCO_3$ (%): 30.02	**Solubles (%):** 27.98	**Aggregate (%):** 42.00

Binder Analysis:

Hydraulic lime composed primarily of $CaCO_3$ and solubles. Evidence that lime may have come from the burning of sea shells exists in the form of shell fragments found undissolved in aggregate. Percentage of binder is unusually high, as masons used more lime around corners to provide for crisp edges.

Aggregate Analysis:

Well-graded sand composed mainly of quartz and feldspar, with crushed shells added for texture or as unburned component of binder. As most grains are subrounded, this is most likely a river or ocean sand. Addition of brick dust may indicate that masons intended for a hydraulic set due to high humidity of climate. Significant clay portion found in the form of fines indicates either an attempt to pigment or extend the lime-sand mix. Aggregate breakdown is 40% subangular to subrounded, clear quartz, 25% subrounded, cloudy feldspar, 20% angular quartz/feldspar with iron streaks, 10% amorphous, red brick dust, 5% crushed white shell.

Sieve Data:

Tray Number	Mass Retained (g)	Mass Retained (%)	Passage (%)
>20	.04	22.22	77.78
40	.08	44.44	33.34
60	.04	22.22	11.12
80	.02	11.11	0.01
100	.00	0.00	0.01
<100	.00	0.00	0.01

Fines Analysis:

Clays used as a pigment or extender, indicated as alumino-silicates by X-Ray Diffraction. Significant concentration of quartz (SiO_2) also indicated by X-Ray Diffraction analysis from crushing of sample or as extremely fine aggregate.

Conclusions:

Binder:aggregate ratio of 1:1 reflects the nature of the sample, which was taken from a the corner of a doorway. It is highly possible that here, were crisp edges and a smooth finish were desired, plasterers specifically tailored, altered or modified the mix by troweling, to include less aggregate and more binder.

GRADUATE PROGRAM IN HISTORIC PRESERVATION
UNIVERSITY OF PENNSYLVANIA
ANALYSIS PERFORMED AT NOBLE PRESERVATION SERVICES, INC.

Client: Historic Charleston Foundation	
Sample Number: 203.6	**Date Sampled:** January, 1997
Sample Location: Second Floor Piazza, South wall, corner	**Date Analyzed:** September 15, 1997
Mortar Type (Description): Aiken-Rhett Stucco-1830s	

Calcimeter Analysis:

This mortar sample was analyzed in accordance with practice outlined by Hanna Jedrzejewska, *Studies in Conservation, 1960.* The sample was crushed and reacted in the calcimeter with hydrochloric acid (HCl). Analysis of carbon dioxide (CO_2) displacement as a result of reaction provides data for percentage of sample composed of lime ($CaCO_3$), percentage of soluble non-carbonates and percentage aggregate. When data is coordinated with real densities of respective materials, a volume mix which approximates the original mix may be obtained. Though not definitive, apparent densities calculated for original materials are: High Calcium Lime Putty/$CaCO_3$ (1.244 g/mL), Aiken-Rhett sand (1.60 g/mL), Aiken-Rhett fines (0.52 g/mL). Note that this study assumes the original material employed slaked high-calcium lime in the mix; volumetric analyses would be radically different if hydrated lime were used as the volumes calculated are in line with historic stucco formulas.

Color: Munsell 8.83YR 4.06/2.17 "Grayish yellowish brown"	**Initial Mass (M_o):** 0.50 g **Final Mass (M_f):** 0.16 g	**Texture:** 120 grit sandpaper
Initial H_2O: 43.2 mL	**Final H_2O:** 68.8 mL	**CO_2 Displacement:** 34.6 mL
$CaCO_3$ (%): 30.91	**Solubles (%):** 37.09	**Aggregate (%):** 32.00

Binder Analysis:

Hydraulic lime composed primarily of $CaCO_3$ and solubles. Evidence that lime may have come from the burning of sea shells exists in the form of shell fragments found undissolved in aggregate. Percentage of binder is unusually high, as masons used more lime around corners to provide for crisp edges.

Aggregate Analysis:

Well-graded sand composed mainly of quartz and feldspar, with crushed shells added for texture or as unburned component of binder. As most grains are subrounded, this is most likely a river or ocean sand. Addition of brick dust may indicate that masons intended for a hydraulic set due to high humidity of climate. Significant clay portion found in the form of fines indicates either an attempt to pigment or extend the lime-sand mix. Aggregate breakdown is 40% subangular to subrounded, clear quartz, 25% subrounded, cloudy feldspar, 20% angular quartz/feldspar with iron streaks, 10% amorphous, red brick dust, 5% crushed white shell.

Sieve Data:

Tray Number	Mass Retained (g)	Mass Retained (%)	Passage (%)
>20	.02	12.50	87.50
40	.07	43.75	43.75
60	.04	25.00	18.75
80	.01	6.25	12.50
100	.00	0.00	12.50
<100	.02	12.50	0.00

Fines Analysis:

Clays used as a pigment or extender, indicated as alumino-silicates by X-Ray Diffraction. Significant concentration of quartz (SiO_2) also indicated by X-Ray Diffraction analysis from crushing of sample or as extremely fine aggregate.

Conclusions:

Binder:aggregate ratio of 1:1 reflects the nature of the sample, which was taken from a the corner of a doorway. It is highly possible that here, were crisp edges and a smooth finish were desired, plasterers specifically tailored, altered or modified the mix by troweling, to include less aggregate and more binder.

GRADUATE PROGRAM IN HISTORIC PRESERVATION
UNIVERSITY OF PENNSYLVANIA
ARCHITECTURAL CONSERVATION LABORATORY

Owner: Historic Charleston Foundation

Sample Number: 206.2	**Date Sampled:** January, 1997
Sample Location: Second Floor, Art Gallery	**Date Analyzed:** March 23, 1997

Mortar Type (Description): Aiken-Rhett Stucco-1830s

Mortar Analysis:

This mortar sample was analyzed in accordance with practice outlined by Jeanne Marie Teutonico, "Mortar Analysis: A Simple Method", *A Laboratory Manual for Architectural Conservators, 1988.* The sample was crushed with a mortar and pestle and reacted with hydrochloric acid (HCl). Analysis of weight loss as a result of reaction provides data for percentage of sample composed of lime ($CaCO_3$), and percentage aggregate. When data is coordinated with real densities of respective materials, a volume mix which approximates the original mix may be obtained. Though not definitive, apparent densities calculated for original materials are: High Calcium Lime Putty/$CaCO_3$ (1.244 g/mL), Aiken-Rhett sand (1.60 g/mL), Aiken-Rhett fines (0.52 g/mL). Note that this study assumes the original material employed slaked high-calcium lime in the mix; volumetric analyses would be radically different if hydrated lime were used as the volumes calculated are in line with historic stucco formulas.

Color: Munsell 0.67Y 4.67/1.87 "Grayish yellowish brown"	**Initial Mass (M_o):** 41.10 g	**Texture:** 80 grit sandpaper
Acid-Soluble Mass: 14.43 g	**Sand Mass:** 20.31 g	**Fines Mass:** 6.26 g
$CaCO_3$ (wt. %): 35.11	**Sand (wt %):** 49.42	**Fines (wt. %):** 15.23
$CaCO_3$ (vol. %): 35.20	**Sand (vol. %):** 49.29	**Fines (vol. %):** 15.27

Binder Analysis:

Lime composed primarily of $CaCO_3$. Evidence that lime may have come from the burning of sea shells exists in the form of shell fragments found undissolved in aggregate.

Aggregate Analysis:

Well-graded sand composed mainly of quartz and feldspar, with crushed shells added for texture or as unburned component of binder. As most grains are subrounded, this is most likely a river or ocean sand. Addition of brick dust may indicate that masons intended for a hydraulic set due to high humidity of climate. Significant clay portion found in the form of fines indicates either an attempt to pigment or extend the lime-sand mix. Aggregate breakdown is 40% subrounded, cloudy feldspar, 30% subangular to subrounded, clear quartz, 25% angular feldspar with iron streaks, 4% amorphous, red brick dust, 1% crushed white shell.

Sieve Data:

Tray Number	Mass Retained (g)	Mass Retained (%)	Passage (%)
8	0.03	0.14	99.86
16	4.01	19.75	80.11
30	8.55	42.10	38.01
50	5.70	28.06	9.95
100	1.38	6.80	3.15
200	0.48	2.36	0.79
Pan	0.16	0.79	0.00

Fines Analysis:

For volume analysis, fines were included as aggregate. Clays used as a pigment or extender, indicated as alumino-silicates by X-Ray Diffraction. Significant concentration of quartz (SiO_2) also indicated by X-Ray Diffraction analysis from crushing of sample or as extremely fine aggregate.

Conclusions:

Binder: Aggregate ratio of 1:3 or 2:5 is possible. Erosion of aggregate makes higher aggregate concentration than indicated above likely.

APPENDIX B: X-Ray Diffraction Data

Fine particulates separated from original stucco samples were analyzed with X-Ray Diffraction at the University of Pennsylvania Laboratory for Research on the Structure of Matter. Fines were analyzed for raw samples (Z08615 and Z08491) as well as those which had undergone calcium carbonate digestion with dilute hydrochloric acid (Z08614 and Z08489). Two ranges were examined to characterize crystalline portions of the material, 5-65 degrees at 1 degree per minute and 5-95 degrees at 3 degrees per minute.

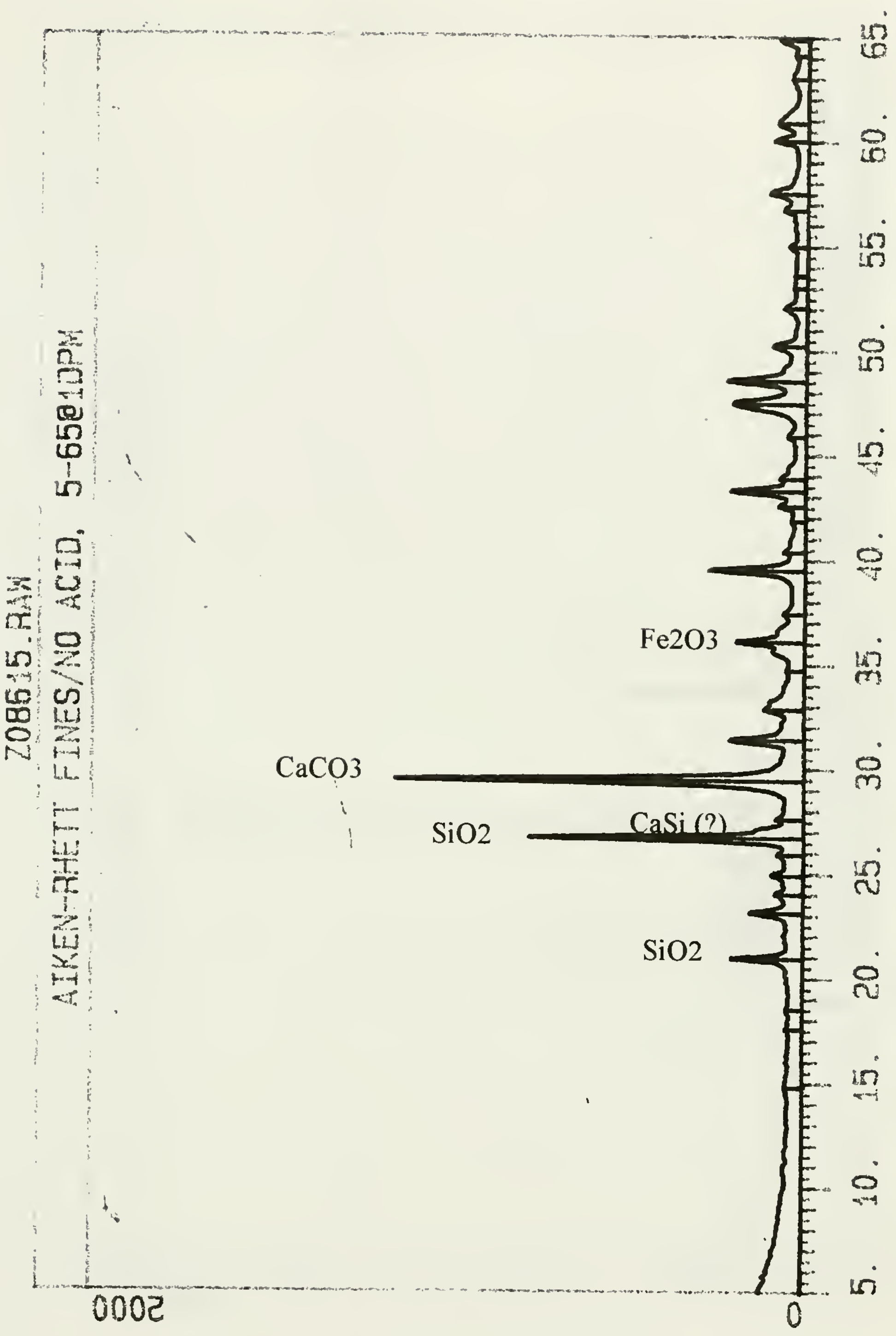
As anticipated, unreacted samples displayed evidence of a calcium carbonate binder (calcite), quartz (silicon dioxide) from crushed aggregate, and iron oxides (magnetite) which are either pigments or mineral components of clays.

Reacted samples displayed evidence of quartz from crushed aggregate, and iron oxides which are either pigments or mineral impurities from the addition of clays, but no bicarbonates (which had been removed by a reaction with hydrochloric acid).

Evidence of complex soluble silicates which would indicate the presence of hydraulic components in the original stucco were inconclusive as potential diffraction spectra coincide with other elements which are more predominant in the mix.

This method of examination is unable to detect the presence of clays which form a considerable portion of the original stucco. In an effort to confirm that clays are not easily detectable, spectra for Kaolinite-Montmorillonite, Illite-montmorillonite and Iron Oxide/Magnetite were examined to no avail.

Element *PC-PDF Number*	*Peak #1 (Intensity)*	*Peak #2 (Intensity)*	*Peak #3 (Intensity)*	*Range Z08614/Acid-Digested*	*Range Z08615/No Acid Digestion*
Calcium Carbonate # 29-305	29.777 (100)	39.783 (20)	48.213 (18)	No evidence of primary peak.; acid digestion of calcium carbonate. Unlikely.	Peaks @ 29.489, 39.559, 48.592. Highly likely.
Silicon Oxide, Quartz, low # 5-0490D	26.644 (100)	20.835 (35)	59.983 (15)	Strong evidence of primary, secondary and tertiary peaks. Likely.	Strong evidence of primary, secondary and tertiary peaks. Likely.
Calcium Magnesium Carbonate # 36-426	30.939 (100)	41.128 (19)	44.950 (10)	No evidence of primary peak. Unlikely.	No evidence of primary peak. Unlikely.
Aluminum Silicate # 44-27	40.267 (100)	46.662 (64)	44.964 (21)	No evidence of primary peak. Unlikely.	No evidence of primary peak. Unlikely.
Aluminum Silicate Hydrate # 10-478	9.897 (100)	26.111 (80)	36.497 (60)	Peaks very difficult to read due to amorphism and absorption into other peaks. Inconclusive.	Peaks very difficult to read due to amorphism and absorption into other peaks. Inconclusive.
Chlorite-vermiculite-montmorrilonite #39-381	25.428 (100)	19.982 (50)	11.483 (50)	Peaks very difficult to read due to amorphism and absorption into other peaks. Inconclusive.	Peaks very difficult to read due to amorphism and absorption into other peaks. Inconclusive.
Kaolinite-Montmorillonite #29-1490	12.215 (100)	20.591 (65)	25.064 (65)	Peaks very difficult to read due to amorphism and absorption into other peaks. Inconclusive.	Peaks very difficult to read due to amorphism and absorption into other peaks. Inconclusive.
Illite-montmorillonite #35-652	26.750 (100)	9.302 (90)	7.010 (70)	Peaks very difficult to read due to amorphism and absorption into other peaks. Inconclusive.	Peaks very difficult to read due to amorphism and absorption into other peaks. Inconclusive.
Iron Oxide/Magnetite # 19-624	35.423 (100)	62.516 (40)	30.095 (30)	Strong evidence of primary peak. Likely.	Strong evidence of primary peak. Likely.
Calcium Silicate # 31-300	27.551 (100)	27.690 (100)	46.035 (100)	Possible evidence of primary peaks. Difficult to read with low intensity. Possible, but inconclusive.	Possible evidence of primary peaks. Difficult to read with low intensity. Inconclusive.


Z08615.RAW
AIKEN-RHETT FINES/NO ACID, 5-65@1DPM
2000
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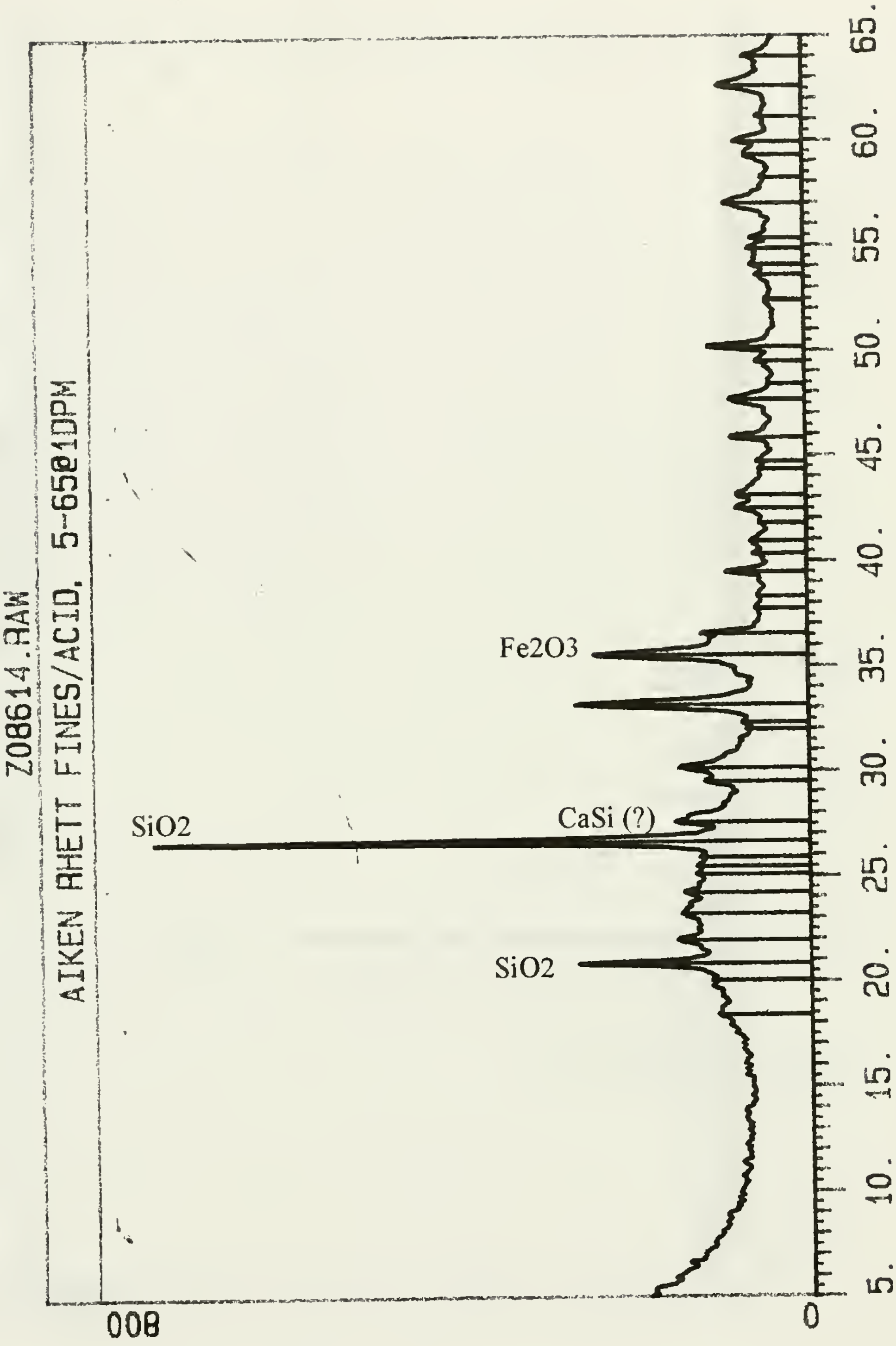
CaCO3
SiO2
CaSi (?)
SiO2
Fe2O3
5. 10. 15. 20. 25. 30. 35. 40. 45. 50. 55. 60. 65.


Z08614.RAW
AIKEN RHETT FINES/ACID. 5-65@1DPM
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Fe2O3
CaSi (?)
SiO2
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0
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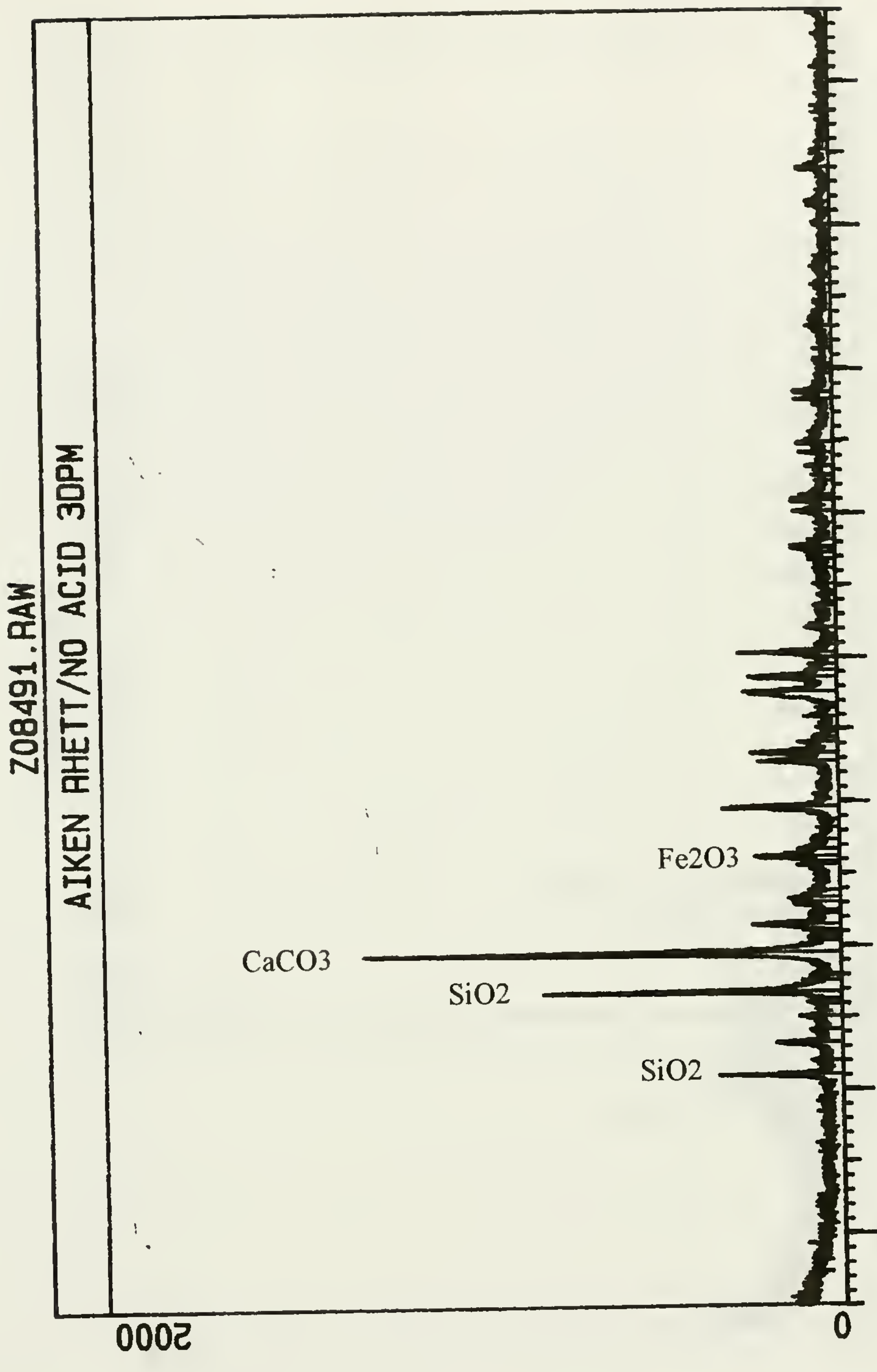
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AIKEN RHETT/NO ACID 3DPM
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0
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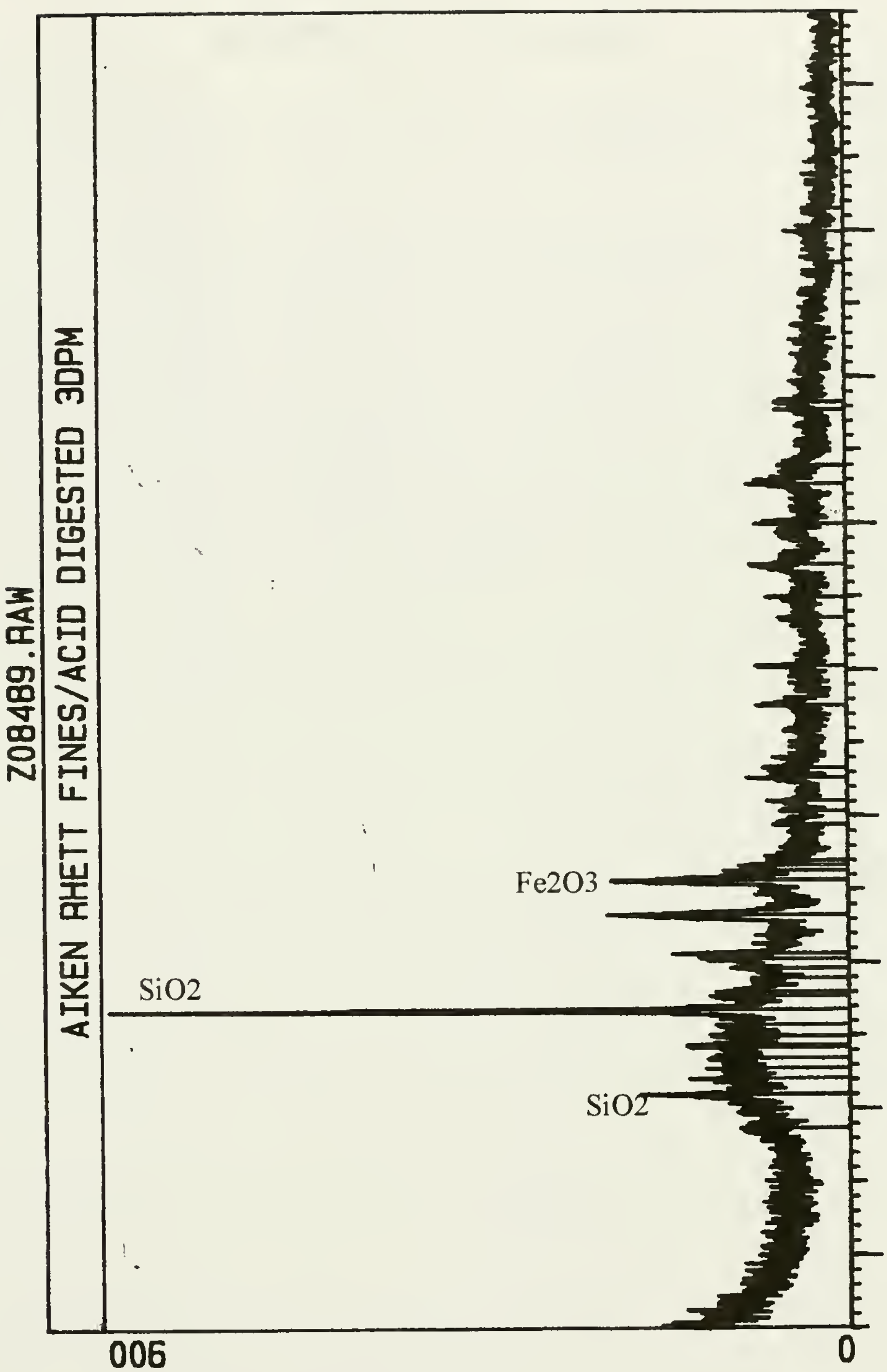
SiO2
Fe2O3
10.
20.
30.
40.
50.
60.
70.
80.
90.


Z08489.RAW
AIKEN RHETT FINES/ACID DIGESTED 3DPM
SiO2
Fe2O3
SiO2
900
0
10.
20.
30.
40.
50.
60.
70.
80.
90.

APPENDIX C: Colorimetry Data

Aiken Rhett, 1830s Stucco (average)		**9.08YR-0.47Y**	**5.18**	**1.96**	**"Grayish yellowish brown"**
005.1 (average)		**0.46Y**	**4.23**	**2.03**	**"Grayish yellowish brown"**
005.1	1	0.1Y	3.6	1.9	
	2	0.1Y	4.7	2.4	
	3	1.2Y	4.4	1.8	
101.4 (average)		**0.1Y**	**5.3**	**1.87**	**"Grayish yellowish brown"**
101.4	1	0.1Y	4.7	1.9	
	2	0.1Y	5.3	1.9	
	3	0.1Y	5.6	1.8	
102.5 (average)		**0.63Y**	**4.8**	**1.93**	**"Grayish yellowish brown"**
102.5	1	0.6Y	4.9	1.9	
	2	0.8Y	5.0	2.0	
	3	0.5Y	4.5	1.9	
203.3 (average)		**9.33YR**	**4.0**	**1.9**	**"Grayish yellowish brown"**
203.3	1	9.4YR	3.5	1.7	
	2	9.3YR	3.9	1.9	
	3	9.3YR	4.6	2.1	
203.4 (average)		**8.83YR**	**4.06**	**2.17**	**"Grayish yellowish brown"**
203.4	1	8.5YR	3.5	2.1	
	2	8.8YR	3.9	2.0	
	3	9.2YR	4.8	2.4	
206.2 (average)		**0.67y**	**4.67**	**1.87**	**"Grayish yellowish brown"**
206.2	1	1.1Y	4.7	1.8	
	2	0.5Y	4.5	1.8	
	3	0.1Y	6.9	2.8	
Repl. Set 1, Riverton HHL		**0.96Y**	**6.57**	**2.37**	**"Light grayish yellowish brown"**
1.1		0.6Y	6.6	2.6	
1.2		1.4Y	6.5	2.2	
1.3		0.9Y	6.6	2.3	
Repl. Set 2, Corson Type "S"		**1.3Y**	**6.1**	**1.97**	**"Light olive brown**
2.1	1	0.1Y	7.1	2.3	
2.2	2	2.2Y	6.5	2.0	
2.3	3	1.6Y	4.7	1.6	
Repl. Set 3, Jahn M60		**1.9Y**	**7.3**	**0.53**	**"Light gray"**
3.1		0.1Y	7.4	0.5	
3.2		2.3Y	7.4	0.5	
3.3		3.3Y	7.1	0.6	
Repl. Set 4, High Ca Lime Putty		**1.57y**	**6.9**	**1.87**	**"Yellowish gray"**
4.2		1.5Y	6.9	1.7	
4.3		3.0Y	6.2	1.8	
4.4		0.2Y	7.6	2.1	
Repl. Set 5, Gray Port/Hi Ca Lime		**0.96Y**	**6.93**	**2.17**	**"Light grayish yellowish brown"**
5.1		0.1Y	6.7	2.4	
5.2		1.4Y	7.0	2.1	
5.3		1.4Y	7.1	2.0	

APPENDIX D: Density Data

Data which follows consists of comparative data for the real densities of Aiken-Rhett 1830s stucco and potential replication materials. Figures used to determine mean values and standard deviations follow.

Sample	$Mass_{dry}$ (g)	$Mass_{hydrostatic s}$ (g)	Real Density (kg/m^3)
Aiken-Rhett 1830s Stucco			**266.20 ± 18.98**
005.2	26.81	16.82	268.36
101.4	31.61	19.81	267.88
102.5	22.25	14.14	274.35
203.3	37.02	24.21	288.99
203.4	40.20	22.83	231.43
Repl. Set 1, Riverton HHL			**256.38 ± 8.64**
1.1	30.75	19.18	265.77
1.2	28.49	17.30	254.60
1.3	28.36	16.96	248.77
Repl. Set 2, Corson Type "S"			**253.02 ± 2.97**
2.1	32.44	19.72	255.03
2.2	28.29	17.08	254.41
2.3	32.15	19.27	249.61
Repl. Set 3, Jahn M60			**118.11 ± 1.26**
3.1	17.87	2.92	119.53
3.2	16.96	2.48	117.13
3.3	17.38	2.61	117.67
Repl. Set 4, High Calcium Lime Putty			**250.13 ± 2.91**
4.2	29.17	17.44	248.68
4.3	23.01	13.74	248.22
4.4	27.35	16.65	253.48
Repl. Set 5, Gray Portland/High Ca Lime			**261.78 ± 5.10**
5.1	31.56	19.69	265.88
5.2	33.52	20.43	256.07
5.3	34.98	21.70	263.40

APPENDIX E: Porosity Data

Sample	Real Density (kg/m^3)	Apparent Density (kg/m^3)	Porosity (%)
Aiken-Rhett 1830s Stucco			24.94 ± 2.80
005.2	268.36	193.99	27.71
101.4	267.88	193.45	27.78
102.5	274.35	210.90	23.13
203.3	288.99	215.11	25.56
203.4	231.43	183.98	20.50
Repl. Set 1, Riverton HHL			**19.35 ± 0.31**
1.1	265.77	210.76	19.44
1.2	254.60	205.11	19.44
1.3	248.77	201.13	19.15
Repl. Set 2, Corson Type "S"			**22.34 ± 0.68**
2.1	255.03	197.32	22.62
2.2	254.41	196.32	22.83
2.3	249.61	195.80	21.56
Repl. Set 3, Jahn M60			**17.59 ± 0.24**
3.1	119.53	98.84	17.31
3.2	117.13	96.36	17.73
3.3	117.67	96.82	17.72
Repl. Set 4, High Calcium Lime Putty			**25.46 ± 0.82**
4.2	248.68	185.32	25.48
4.3	248.22	187.07	24.64
4.4	253.48	186.89	26.27
Repl. Set 5, Gray Portland/High Ca Lime			**21.60 ± 0.24**
5.1	265.88	208.87	21.44
5.2	256.07	201.08	21.47
5.3	263.40	205.76	21.88

APPENDIX F: Water Absorption Capacity Data

Sample	$Mass_{dry}$ (g)	$Mass_{saturated}$ (g)	Change (g)	Water Absorption Capacity (%)
Aiken-Rhett 1830s Stucco				**12.47 ± 1.43**
005.2	26.81	30.64	+ 3.83	14.29
101.4	31.61	36.15	+ 4.54	14.08
102.5	22.25	24.69	+ 2.44	10.97
203.3	37.02	41.42	+ 4.40	11.89
203.4	40.20	44.68	+ 4.48	11.14
Repl. Set 1, Riverton HHL				**9.61 ± 0.02**
1.1	30.75	33.77	+ 3.02	9.82
1.2	28.49	31.19	+ 2.70	9.48
1.3	28.36	31.06	+ 2.70	9.52
Repl. Set 2, Corson Type "S"				**11.26 ±0.22**
2.1	32.44	36.16	+ 3.72	11.47
2.2	28.29	31.49	+ 3.20	11.31
2.3	32.15	35.69	+ 3.54	11.01
Repl. Set 3, Jahn M60				**18.07 ± 0.48**
3.1	17.87	21.00	+ 3.13	17.52
3.2	16.96	20.08	+ 3.12	18.40
3.3	17.38	20.56	+ 3.18	18.30
Repl. Set 4, High Calcium Lime Putty				**13.68 ± 0.47**
4.2	29.17	33.18	+ 4.01	13.75
4.3	23.01	26.04	+ 3.03	13.17
4.4	27.35	31.21	+ 3.86	14.11
Repl. Set 5, Gray Portland/High Ca Lime				**10.53 ± 0.22**
5.1	31.56	34.80	+ 3.24	10.27
5.2	33.52	37.10	+ 3.58	10.68
5.3	34.98	38.70	+ 3.72	10.63

Sample Aiken-Rhett Set 1 1830s Stucco	72-hour water absorption capacity (%)	Deviation from Mean[1]	Square Deviation	Mean, Standard Deviation 12.47 ± 1.43
005.2	14.29	+ 1.82	3.31	
101.4	14.08	+ 1.61	2.59	
102.5	10.97	- 1.50	2.25	
203.3	11.89	- 0.58	0.34	
203.4	11.14	- 1.33	1.77	
Replication Set 1 Riverton HHL				**9.61 ± 0.02**
1.1	9.82	+ 0.21	0.04	
1.2	9.48	- 0.13	0.02	
1.3	9.52	- 0.09	0.01	
Replication Set 2 Corson Type "S"				**11.26 ±0.22**
2.1	11.47	+ 0.21	0.04	
2.2	11.31	+ 0.05	0.00	
2.3	11.01	- 0.25	0.06	
Replication Set 3 Jahn M60				**18.07 ± 0.48**
3.1	17.52	- 0.55	0.30	
3.2	18.40	+ 0.33	0.11	
3.3	18.30	+ 0.23	0.05	
Replication Set 4 High Calcium Lime Putty				**13.68 ± 0.47**
4.2	13.75	+ 0.07	0.00	
4.3	13.17	- 0.51	0.26	
4.4	14.11	+ 0.43	0.18	
Replication Set 5 Gray Port/High Ca Lime				**10.53 ± 0.22**
5.1	10.27	- 0.26	0.07	
5.2	10.68	+ 0.15	0.02	
5.3	10.63	+ 0.10	0.01	

APPENDIX G: Water Vapor Transmission Data

Sample	Mass (g), $t_{0\ days}$	Mass (g), $t_{27\ days}$	Change (g)	WVTR (g/h*m^2)
Aiken-Rhett, 1830s Stucco				**0.244 ± 0.080**
005.2	78.94	70.33	- 8.61	0.316
101.4	85.23	83.00	- 2.23	0.082
102.5	68.82	62.50	- 6.32	0.232
203.3	80.63	73.05	- 7.58	0.279
206.3	73.19	64.74	- 8.45	0.310
Repl. Set 1, Riverton HHL				**0.407 ± 0.102**
1.1	83.07	73.20	- 9.87	0.363
1.2	81.44	67.45	- 14.29	0.525
1.3	79.49	70.40	- 9.09	0.334
Repl. Set 2, Corson Type "S"				**0.416 ± 0.039**
2.1	82.98	70.50	- 12.48	0.459
2.2	77.58	66.96	- 10.62	0.390
2.3	83.74	72.90	- 10.84	0.398
Repl. Set 3, Jahn M60				**0.278 ± 0.022**
3.1	68.68	61.65	- 7.04	0.259
3.2	67.08	60.04	- 7.04	0.259
3.3	70.84	62.26	- 8.58	0.315
Repl. Set 4, High Calcium Lime Putty				**0.496 ± 0.089**
4.1	78.31	64.22	- 14.09	0.518
4.2	80.68	65.05	- 15.63	0.574
4.3	76.05	65.24	- 10.81	0.397
Repl. Set 5, Gray Portland/High Ca Lime				**0.239 ± 0.032**
5.1	87.87	81.44	- 6.43	0.236
5.2	85.79	79.96	- 5.83	0.214
5.3	86.77	79.52	- 7.25	0.266

Sample	0 days RH=50 T=21	1 day RH= 50 T=20	2 days RH=65 T=25	3 days RH=70 T=26	6 days RH=60 T=28	9 days RH=65 T=25	12 days RH=60 T=27	16 days RH=70 T=16	18 days RH=60 T=28	21 days RH=70 T=25	24 days RH=60 T=25	27 days RH=40 T=25	Loss
Aiken-Rhett Set 1 1830s Stucco									WVTR = 0.244 ± 0.080 g/h/m^2				
005.2	78.94	78.73	78.49	78.23	77.12	76.19	75.17	73.97	73.16	72.64	71.36	70.33	- 8.61
101.4	85.23	85.22	85.23	85.20	84.97	84.64	84.31	84.02	83.79	83.70	83.38	83.00	- 2.23
102.5	68.82	68.77	68.62	68.42	67.66	66.96	66.27	65.48	64.93	64.35	63.34	62.5	- 6.32
203.3	80.63	80.57	80.35	80.20	79.46	78.49	77.56	76.54	75.78	75.11	74.19	73.05	- 7.58
206.3	73.19	73.10	72.83	72.64	71.84	70.78	69.83	68.64	67.81	66.93	65.94	64.74	- 8.45
Control	49.17	49.19	49.28	49.28	49.28	49.21	49.18	49.23	49.19	49.18	49.21	48.99	- 0.18
Replication Set 1, Riverton HHL									WVTR = 0.407 ± 0.102 g/h/m^2				
1.1	83.07	82.77	81.33	80.90	79.82	78.90	77.62	76.35	75.55	74.63	74.02	73.20	- 9.87
1.2	81.44	80.06	77.68	76.45	74.03	73.00	71.74	70.70	70.00	69.22	68.23	67.45	- 14.29
1.3	79.49	78.88	78.00	77.71	76.71	75.74	74.83	73.65	73.08	72.84	71.32	70.40	- 9.09
Control	41.42	41.43	41.45	41.45	41.41	41.40	41.35	41.38	41.39	41.39	41.39	41.37	- 0.05
Replication Set 2, Corson Type "S"									WVTR = 0.416 ± 0.039 g/h/m^2				
2.1	82.98	82.25	80.47	79.75	78.56	77.38	76.26	74.93	74.09	73.08	71.75	70.50	- 12.48
2.2	77.58	77.33	76.23	75.82	74.29	73.17	72.12	71.00	70.05	69.28	68.12	66.96	- 10.62
2.3	83.74	83.38	82.29	81.75	80.09	78.86	77.92	76.71	75.82	74.99	74.01	72.90	- 10.84
Control	38.94	38.93	38.96	38.96	38.94	38.92	38.92	38.96	38.93	38.95	38.97	38.95	+ 0.01
Replication Set 3, Jahn M60"									WVTR = 0.278 ± 0.022 g/h/m^2				
3.1	68.68	68.82	68.42	68.11	67.21	65.81	65.16	64.38	63.84	63.24	62.43	61.65	- 7.04
3.2	67.08	67.02	66.68	66.28	65.24	64.16	63.46	62.50	61.83	61.35	60.78	60.04	- 7.04
3.3	70.84	70.39	69.64	69.38	67.92	66.76	66.00	64.92	64.34	63.68	63.04	62.26	- 8.58
Control	26.93	26.96	26.97	26.98	26.92	26.82	26.76	26.79	26.76	26.78	26.75	26.60	- 0.33
Replication Set 4, High Calcium Lime Putty"									WVTR = 0.496 ± 0.089 g/h/m^2				
4.1	78.31	77.12	75.98	75.11	73.78	72.13	70.87	69.38	68.45	67.20	65.77	64.22	- 14.09
4.2	80.68	80.01	78.91	78.20	76.02	74.63	73.40	69.35	68.33	67.55	66.64	65.05	- 15.63
4.3	76.05	75.81	75.46	75.09	73.38	71.96	70.87	69.37	68.41	67.60	66.58	65.24	- 10.81
Control	37.44	37.49	37.47	37.48	37.47	37.45	37.45	37.45	37.48	37.47	37.49	37.49	+ 0.05
Replication Set 5, High Calcium/Grey Port land									WVTR = 0.239 ± 0.032 g/h/m^2				
5.1	87.87	87.84	87.55	87.42	86.49	85.64	84.97	84.05	83.51	82.98	82.35	81.44	- 6.43
5.2	85.79	85.79	85.72	85.65	84.80	84.01	83.38	82.42	81.84	81.43	80.77	79.96	- 5.83
5.3	86.77	86.73	86.54	86.20	85.40	84.37	83.62	82.75	82.09	81.41	80.50	79.52	- 7.25
Control	43.29	43.28	43.29	43.31	43.22	43.09	43.01	43.01	42.92	42.97	42.94	42.96	- 0.33

APPENDIX H: Evaporation Data

Sample	6 hours Evaporation	Deviation from Mean	Square Deviation	Mean, Standard Deviation
Aiken-Rhett Set 1 1830s Stucco				60.26 ± 10.03
005.2	62.53	- 2.27	5.15	
101.4	54.91	- 5.35	28.62	
102.5	78.80	+ 18.54	343.73	
203.3	50.76	- 9.50	90.25	
203.4	54.29	- 5.97	35.64	
Replication Set 1 Riverton HHL				71.52 ± 1.64
1.1	69.72	- 1.8	3.24	
1.2	71.92	+ 0.40	0.16	
1.3	72.92	+1.40	1.96	
Replication Set 2 Corson Type "S"				71.14 ± 3.40
2.1	67.01	- 4.13	17.06	
2.2	77.88	+ 6.74	45.43	
2.3	68.53	-2.61	6.81	
Replication Set 3 Jahn M60				55.27 ± 6.43
3.1	52.07	- 3.20	10.24	
3.2	51.07	-4.20	17.64	
3.3	62.67	+ 7.40	54.76	
Replication Set 4 High Calcium Lime Putty				66.41 ± 7.43
4.2	61.19	- 5.22	27.25	
4.3	74.92	+ 8.51	72.42	
4.4	63.13	- 3.28	10.76	
Replication Set 5 Gray Port/High Ca Lime				47.84 ± 1.94
5.1	49.85	+ 2.01	4.04	
5.2	47.70	- 0.13	0.02	
5.3	45.97	- 1.87	3.50	

APPENDIX I: Sampling

Sample Number	*Location*	*Examinations*
005.1	Ground level, North Facade, Courtyard, Main Residence	Color space measurement Texture
005.2	"	Density Porosity Water Absorption Capacity Water vapor transmission Evaporation
101.1	1st Floor Piazza, South Facade, Main Residence	Thin-section polarized light microscopy
101.2	"	Reflected light microscopy
101.3	"	Gravimetric analysis
101.4	"	Color space measurement Texture Density Porosity Water Absorption Capacity Water vapor transmission Evaporation
101.5	"	Soluble salt analysis
102.1	1st Floor Piazza, East Facade, Main Residence	Thin-section polarized light microscopy
102.2	"	Reflected light microscopy
102.3	"	Gravimetric analysis Water absorption capacity
102.4	"	Gravimetric analysis X-Ray Diffractometry
102.5	"	Color space measurement Texture Density Porosity Water Absorption Capacity Water vapor transmission Evaporation
102.6	"	Soluble salt analysis
102.7	"	Soluble salt analysis
102.8	"	Water absorption capacity X-Ray Diffractometry
102.9	"	Thin-section microscopy (stained)

203.1	2nd Floor Piazza, South Facade, 1830s Wing	Thin-section polarized light microscopy
203.2	"	Gravimetric analysis
203.3	"	Color space measurement Texture Density Porosity Water Absorption Capacity Water vapor transmission Evaporation
203.4	"	Color space measurement Texture Density Porosity Water Absorption Capacity Evaporation
206.1	2nd Floor, West Facade, Above Art Gallery, Main Residence	Thin-section polarized light microscopy
206.2	"	Color space measurement Texture Gravimetric analysis
206.3	"	Water vapor transmission
206.4	"	Soluble salt analysis
206.5	"	Thin-section microscopy
206.6	"	Reflected light microscopy

APPENDIX J: Soluble Salt Analysis for Selected Replication Stuccoes

Though most of the original stucco displays no evidence of soluble salt contamination or salt-related deterioration, it is important that newer materials designed to enhance the longevity of the original do not introduce potentially hazardous materials to the system. After determining that the performance characteristics of RS 1 (Riverton Hydrated Hydraulic Lime) and RS 5 (Gray Portland Cement and High Calcium Lime) were the most suitable formulations of those examined, two samples of each were examined for the presence of soluble salts.

Methodology
Standard procedure following Teutonico, "Exercise 16: Qualitative Analysis of Water-Soluble Salts and Carbonates" as outlined in *Section 6.38: Soluble Salt Analysis* was conducted on two representative samples of RS 1 and two representative samples of RS 5 to determine whether water-soluble salts might occur naturally in either.

Data and Observations

Sample	Sulfates	Chlorides	Carbonates
RS1.1	-	-	+++
RS1.2	-	-	+++
RS5.2	-	-	+++
RS5.3	-	+/- to - (2x)	+++

Results of a qualitative analysis to determine the presence of potentially damaging soluble salts in RS 1 and RS 5.
-: presence of the ion +/-: ion barely perceptible
+: presence of the ion ++: presence of the ion in notable quantity
+++: presence of the ion as a principal component

Conclusions
Within the parameters of this test, RS 1 displayed no evidence of soluble sulfate or chloride salts, suggesting that, when applied, this formula will not impart soluble salts into Aiken-Rhett's system. Results for RS 5 were similar, displaying no evidence of soluble sulfate salts, and no evidence of chloride salts in one sample. However, the test detected what may be an extremely slight concentration of chlorides in one of two runs completed on RS 5.3. The presence of a barely-detectable concentration of chlorides may be cause for concern. It is recommended that, as Historic Charleston constructs mock-ups of these replication mixes (which may employ both different sands and a different brand of cement), soluble salt analyses of material applied on-site be conducted on which practical recommendations may be based.

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