Aiken-Rhett
Interior Plaster Blind Study

Prepared for:
Historic Charleston Foundation
40 East Bay Street
Charleston, SC 29401

Prepared By:
Meadors, Inc.
PO BOX 21758
CHARLESTON, SC 29413

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Table of Contents

Attention:
Will Hamilton
Properties Coordinator
Historic Charleston Foundation
40 East Bay Street
Charleston, SC 29401

Introduction

The following report identifies the findings regarding the interior plaster assessment of the Aiken-Rhett House in Charleston, SC. The findings described within this summary encompass the results of a blind study performed within the 2nd floor southeast and southwest bedchambers using tactile assessment methods and infrared analysis to assess the plaster. The results from traditional sounding methods are compared to results found using an infrared camera. This research project initially began as a quest to find a low cost, rapid, and non-destructive method of assessing interior plaster. This project is funded in part by a grant from the Cynthia Woods Mitchell Fund for Historic Preservation from the National Trust for Historic Preservation.

The observations and data in this study were recorded during site inspection and analysis performed by Meadors, Inc. in August and September of 2014. No selective demolition was performed during Meadors' evaluation of the structure. Upper portions of the building were accessed by a 10-ft ladder and moveable scaffolding that was erected in each room. A more detailed explanation of procedures can be found in the Methodology section within the report.

Project Narrative

The Aiken-Rhett House (c.1820) is considered one of the most intact urban townhouse complexes in Charleston. The structure has a high degree of historic integrity as many of the early finishes and furnishings remain throughout the house. The interior plaster at the Aiken-Rhett House museum is a major visible component of the structure and has been left largely untouched over the last two centuries. Recent deterioration of the plaster and complete failure of several sections of the ceiling have prompted the need for an interior assessment of the historic plaster throughout the house to identify areas that require repair. Traditional evaluation of historic plaster often requires the process of sounding, where a small tool is lightly tapped on the surface of the plaster in order to create an audible sound. Sounding is considered an accurate and effective method of investigating plaster as areas of detached plaster will sound noticeably different from areas where plaster is well adhered to the substrate. However, this method is particularly time consuming and potentially damaging, as a majority of the plaster surfaces including the ceilings must be physically touched to determine their respective conditions. This technique also has the potential to damage many of the well-preserved finishes found throughout the Aiken-Rhett House, including fragile wallpaper that remains in situ.

Thermography as a Non-Destructive Tool

Recent advances in the field of architectural conservation have led to a greater reliance on non-destructive testing to evaluate fragile historical material. In an effort to minimize contact with the plaster and the delicate and brittle finishes, such as the paint and wallpaper, the project focused on investigating the use of non-destructive infrared thermography (IRT) to evaluate the interior plaster. The use of non-destructive testing and in particular, infrared thermography to assess cultural heritage is a burgeoning area of research within the field of preservation. As thermographic cameras have become more cost effective and accurate, new and exciting uses for this technology have been discovered. Infrared assessment of plaster is one such area of research that has only recently been explored.

Previous Work

Infrared technology has been successfully applied to assess plaster in historic structures in many different historic sites. A 2011 study of the interior plaster walls on masonry at the Alamo was able to detect not only moisture within the plaster, but also “anomalies in wall composition, including voids, joints, or breaks in construction.” Thermographic tests were also used to evaluate exterior and interior renders of the 13th century Zica Monastery in Serbia following a 2010 earthquake. Their results successfully documented the condition of the building and confirmed the advantages of IR thermography when diagnosing cracking. Furthermore, the analysis helped indicate areas of the structure where more in-depth investigations were required (Ristic et al. 2013). Further research has indicated that thermal imaging may be able to indicate compositional changes within a lime plaster system and evaluate the efficacy of consolidation of such substrates (W.Bartz et al. 2012).

Active Thermography

When assessing materials such as historic plaster it is important to note that infrared thermography measures the surface radiation, which depends on several atmospheric conditions, including air temperature, relative humidity, sun exposure, and air movement. Passive thermography measures the plaster as is without artificial heating of the surface while active thermography uses an artificial heat source, most often an infrared lamp, to heat the surface to manipulate the temperatures of the wall and amplify the thermal differences among the construction materials. Based upon these principles, it is believed that voids within the plaster such as detachment or cracking will conduct heat differently than the surrounding materials, resulting in a varying temperature reading and a visible difference on the thermogram. Laboratory studies have illustrated this principle in plaster by burying pieces of cork and plastic bags filled with air to simulate air voids at different depths. Infrared analysis of these laboratory specimens was able to detect the location of each simulated void at 10mm and 20mm depths (Meola 2013).

Therefore, it is highly possible that an infrared analysis of the interior plaster of Aiken-Rhett can provide information relating to the different plaster conditions including detachment, cracking, and loss. However, as these studies indicate, climactic conditions affect thermal images and areas of interest must be tested extensively on site before any conclusions regarding condition can be made. Additional work must be undertaken to manipulate the thermal gradient through the wall and magnify the contrast between the studs, lath, thermal bridges, and cavities. Knowledge not only of the physics of thermography and the equipment, but also of the historical materials and construction methods is essential to this type of application.

Infrared technology is particularly valuable for Aiken-Rhett as it has the ability to quickly assess large areas of plaster without the need to physically sound the material, reducing the potential of damage and loss of the fragile material. We believe this is the most responsible approach to evaluate the condition of the plaster in a historic structure of this significance. In addition, this method of assessment will be much more cost effective than tactile methods and the technology can be shared with the larger preservation community.

DETERIORATION MECHANISMS & EXISTING CONDITIONS

Deterioration mechanisms

The plaster walls and ceiling in both the southwest and southeast chambers presently display several types of deterioration including cracking, detachment, and complete loss. Materials analysis of the plaster was not performed during the course of this analysis, but due to the age of the building, the plaster is believed to be lime based. The flat plaster in both the southwest and southeast rooms was applied as a three coat system and attached to timber studs with wood lath. Hand split wood lath is visible in one location in the southwest chamber where there has been complete plaster loss. Decorative plaster work such as the cornices were likely run in place using lime plaster possibly gauged with gypsum.

Cracking is one of the most common forms of deterioration in historic plasters. Areas of detachment within the stucco system are often associated with increased bulging of the plaster surface and cracking as the plaster begins to separates from the lath. The frequency and convergence of cracking can also help indicate areas of detachment. The cause for such detachment is due to a variety of reasons including failure between the individual layers, loss of the plaster key, moisture intrusion, or movement of the support system over time. Due to the numerous causes of failure, inspection and monitoring are often required to determine the exact causes of detachment.

Since 2009, Historic Charleston Foundation has conducted an annual crack study within each interior room to document changes in the plaster over time. Cracks are assessed visually to note the location and any changes from the previous data. Cracks measuring at least 1/16th of an inch are recorded and measurements are taken each year to indicate the size of major cracks and location of these cracks on the walls and ceilings.

In addition to the existing crack study, visual examination of photographs taken by the Historic American Building Survey (HABS) in 1979 serve as an excellent reference for estimating the rate of deterioration within the southwest and southeast chambers of the Aiken-Rhett House. Although those images can not adequately document plaster detachment, comparison between these images and current day photographs can indicate increased activity in terms of crack growth and movement.

Figure 1: Southwest chamber, north wall ca. 1979.

Figure 2: Southwest chamber, north wall ca. 2014.

Figure 3: Southwest chamber, east wall ca. 1979.

Figure 4: Southwest chamber, east wall ca. 2014.

Figure 5: Southeast chamber, north wall ca. 1979.

Figure 6: Southeast chamber, north wall ca. 2014.

SOUTHWEST CHAMBER

Analysis of an image taken of the north wall in the southwest bedchamber (Room 202) shows that extensive cracking of the plaster existed in 1979 (**Figure 1**). Comparison of these cracks with a current image indicates little to no growth of a majority of the visible cracks over the last 35 years **(Figure 2)**. There does not appear to be any new crack formation on this wall, but two cracks appear to have worsened over time. One crack, directly over the doorway into the northwest dressing room (Room 201) appears to have increased in severity during this time with noticeable vertical separation. Additionally, there appears to be greater separation in the ceiling crack directly over the closet door. The most dramatic change between these two images is the deterioration of the finishes on the woodwork and the removal of the plaster and wallpaper along the casing bead at the fireplace.

An alternative view taken in 1979 of the east wall within this bed chamber reveals a similar situation (**Figure 3**). Over the last 35 years, there has been further deterioration of the historic wallpaper, but little to no change in the plaster in this location **(Figure 4**). On the southeast corner, on both sides of the doorway, the wallpaper obscured the presence of cracks in 1979. Areas visible in the original photograph do not appear to have worsened over time.

The HCF crack study conducted within this room is reflective of current conditions, with a majority of cracks increasing in width over the last 5 years.

SOUTHEAST CHAMBER

One image of the north wall in the southeast chamber was taken during the documentation in 1979 allowing for only one comparison with current conditions. The plaster at this location in 1979 has little visible cracking as it is obscured by wallpaper (**Figure 5**). At this time, the wallpaper along the ceiling was beginning to deteriorate while the remaining paper on the walls appears to be in good condition. Comparison with the 2014 image shows there has been increased deterioration of the wall paper as several sheets have begun to detach at the ends and corners (**Figure 6**). One crack visible on the ceiling above the casing bead on the fireplace appears to have increased in separation over the last 35 years. Cracking present within the cornice does not appear to have increased during this time.

The HCF crack study conducted within this room is reflective of current conditions. However, as noted in the document, much of the current cracking is obscured by the wallpaper and there is little data on the growth of these cracks over time.

Figure 7: Southeast chamber, facing north: Stabilization installed in 2014 over existing cracks. The battens in this room span the full width of the ceiling.

Figure 8: Southwest chamber, facing northwest: Stabilization installed in 2014. The battens in this room only partially span the ceiling.

Stabilization

In order to address potential life safety issues, Historic Charleston Foundation has installed several 1x4 wood battens over the ceiling cracks within both bedrooms (**Figures 7-8**). This has stabilized several areas of detachment and has minimized the life safety risk.

Methodology

To determine if infrared thermography is a viable assessment tool for plaster at the Aiken-Rhett House, several members of the Meadors team conducted a pilot assessment of the plaster as a blind study. Architectural conservators evaluated the plaster surfaces in the 2nd floor southeast and southwest bedchambers using traditional methods of sounding. Separately, additional team members independently assessed the plaster in the same rooms using infrared thermography. Two separate investigation teams were used for each evaluation method to ensure that the results were not biased. The goal of this study was to compare the traditional sounding & IRT methods to evaluate the efficacy of each approach and to determine if IRT is a viable method for assessing the plaster at the Aiken-Rhett House. Additionally, a secondary goal of this project was to establish the environmental conditions necessary for infrared analysis within the Aiken-Rhett House.

Documentation

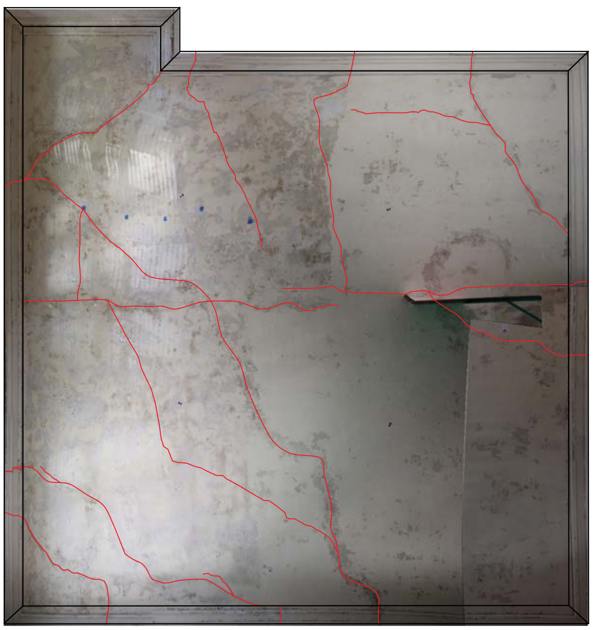
Prior to analysis, the existing plaster conditions were documented and photographed. Previous annual crack studies conducted by Historic Charleston Foundation were used as the basis for noting extant plaster deterioration and separation. In addition to this existing documentation, the plaster walls and ceilings were divided up into quadrants and documented by creating rectified photographs. These images were then photo merged and overlain with the prior crack studies to determine the accuracy of the crack locations. Discrepancies were resolved and verified on site in order to accurately locate each feature. The updated crack diagrams and images were then used as a baseline to document detachment for both assessment methods.

Tactile Assessment

Tactile assessment was conducted during the first three weeks of August 2014 by Betty Prime and Fillmore Wilson of Meadors Conservation. A 10-foot moveable scaffolding tower was erected in each room in order to physically access each plaster surface.

During the tactile assessment, the plaster surface was lightly tapped using a plastic mallet in order to determine the degree of detachment. Areas that sounded hollow were marked as detached areas and recorded on field drawings. A stethoscope was employed to hear and detect subtle changes in detachment that were not normally audible. The upper walls and ceiling were accessed via the use of moveable scaffolding. During the course of the assessment, the scaffolding was systematically moved around the room. Protective Thermo-ply floor covering was used in order to avoid damaging the historic floors.

SOUTHWEST CHAMBER



SOUTHEAST CHAMBER

Figure 9: Southwest chamber, facing northwest: Stabilization installed in 2014. The battens in this room only partially span the ceiling.

Infrared Analysis

Thermal imaging was performed using a Fluke TI400-60Hz Infrared Camera. The images were recorded in the range of wavelength 7.5- 14.0 µm. The emissivity of the plaster was set to 0.90. Infrared analysis was conducted by Kalen McNabb of the Meadors team with assistance from Meadors Intern Bridges Williams.

The ability to distinguish differences or defects within a material largely depends on the difference between the thermal characteristics (thermal diffusion, porosity, density, etc.) Passive and active thermography were both attempted in order to analyze the flat plaster walls and determine delamination of the plaster. Passive thermography was performed during several days in late July and findings were recorded.

Following analysis of passive thermography results, a series of tests using active thermography were conducted on the plaster walls. Heated forced air via the use of a conventional hair dryer on low blow was applied to the surface of the plaster in order to manipulate the surface temperature of the material. Visible light photographs and thermograms were taken simultaneously of the area of study at 15 second intervals during the cool down phase to document the change in temperature of the plaster as it cooled. Data was not recorded when the heat was applied as it created a uniform temperature increase across all areas of plaster. In other words, the response of the plaster when cooled was found to be more indicative of deterioration than during the heating phase of the experiment.

After several trials, areas of sound plaster were found to display a uniform temperature distribution and thermal diffusivity when forced heat was applied and then removed. Area of deterioration and cracking were discovered to appear as bright areas on the thermogram with uneven temperature distributions, allowing areas of concern to be easily identified. Furthermore, areas adjacent to the cracks would show a greater increase in surface temperature than other areas of the wall. When visible, this area was believed to indicate areas of detachment. In order to access the upper walls and ceiling, a 10- ft ladder was used to apply forced heat to the wall. Infrared readings were taken from ground level. This methodology was applied to both chambers on the second floor.

Following on site documentation, analysis was performed on the captured thermograms using SmartView software produced by Fluke. Temperature spans were adjusted using this software to best illustrate plaster conditions. Color palettes were selected and modified in order to identify conditions within the thermogram.

Diagrams

Using data from the IR and tactile assessment, a map of plaster conditions was created. These diagrams were created to compare both methods of analysis and can be used by Historic Charleston Foundation to establish the scope for necessary plaster repairs for each room investigated during the course of this study and isolate areas of repair.

Environmental Conditions

Annual Weather Data

The deterioration of historic building materials can be heavily influenced by changes in the environmental conditions such as ambient and surface temperatures, relative humidity, moisture levels, and ventilation. Diagnostic monitoring of such environmental conditions can help one understand the deterioration of historic materials and finishes.

During 2013, Historic Charleston Foundation recorded environmental data in the southwest chamber using a HOBO data logger (Figure 12). By analyzing the fluctuations in temperature and relative humidity throughout the year, it is possible to understand how seasonal fluctuating environmental conditions affect the finishes and materials within the Aiken-Rhett House.

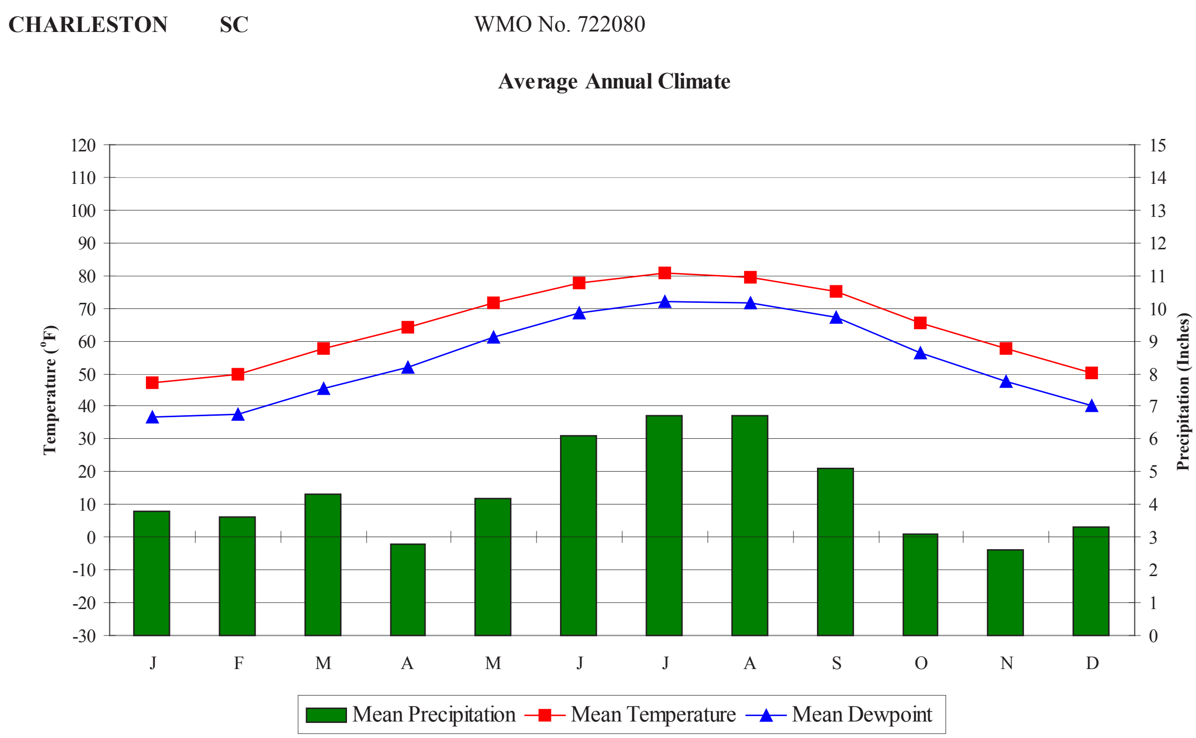


Figure 10: Average Annual Climate for Charleston, SC. (Engineering Weather Data)

Weather data recorded in 2013 is similar to the average annual climate of Charleston, SC. This is expected as the 2nd floor chambers are unconditioned and commonly have the windows open to promote ventilation. Analysis of the data indicates that the spring and summer months maintain a high average temperature and relative humidity, while the winter and fall show daily fluctuating changes in both the temperature and relative humidity. Furthermore, according to the 2013 data, from June to October, the relative humidity ranges from 60% to 80%. During other months, the relative humidity can range from 30% to 90% RH. Due to project constraints, infrared images taken during the course of this testing were recorded in the summer between August and September. However, analysis of this annual weather data indicates that more successful readings may be possible during the winter, as the fluctuating temperature and relative humidity can create greater temperature differentials necessary for analysis.

Standards & Recommended Parameters

Currently there exists no standard for the infrared analysis of detached or delaminated plaster. However, several standards exist for the inspection of modern building materials than can serve as a proxy for plaster analysis. ASTM C 1060 for the "Thermal Inspection of Insulation Installations in Envelope Cavities of Frame Buildings" offers guidelines for inspectors when determining thermal insulation deficiencies. The standard recommends a minimum temperature differential of 18 degrees Fahrenheit (10 degrees Celcius) from the interior surface to exterior surface for at least 4 hours prior to inspection. This allows sufficient heat movement through the wall so that an infrared inspector can measure heat loss. This temperature guideline is particularly difficult to achieve as the Aiken-Rhett House Museum is largely unconditioned and maintains similar temperature and relative humidity levels to the outside.

During the course of this study, this standard was used as a guide for analysis. Deviations from the standard were performed when necessary to capture the data relating to plaster detachment.

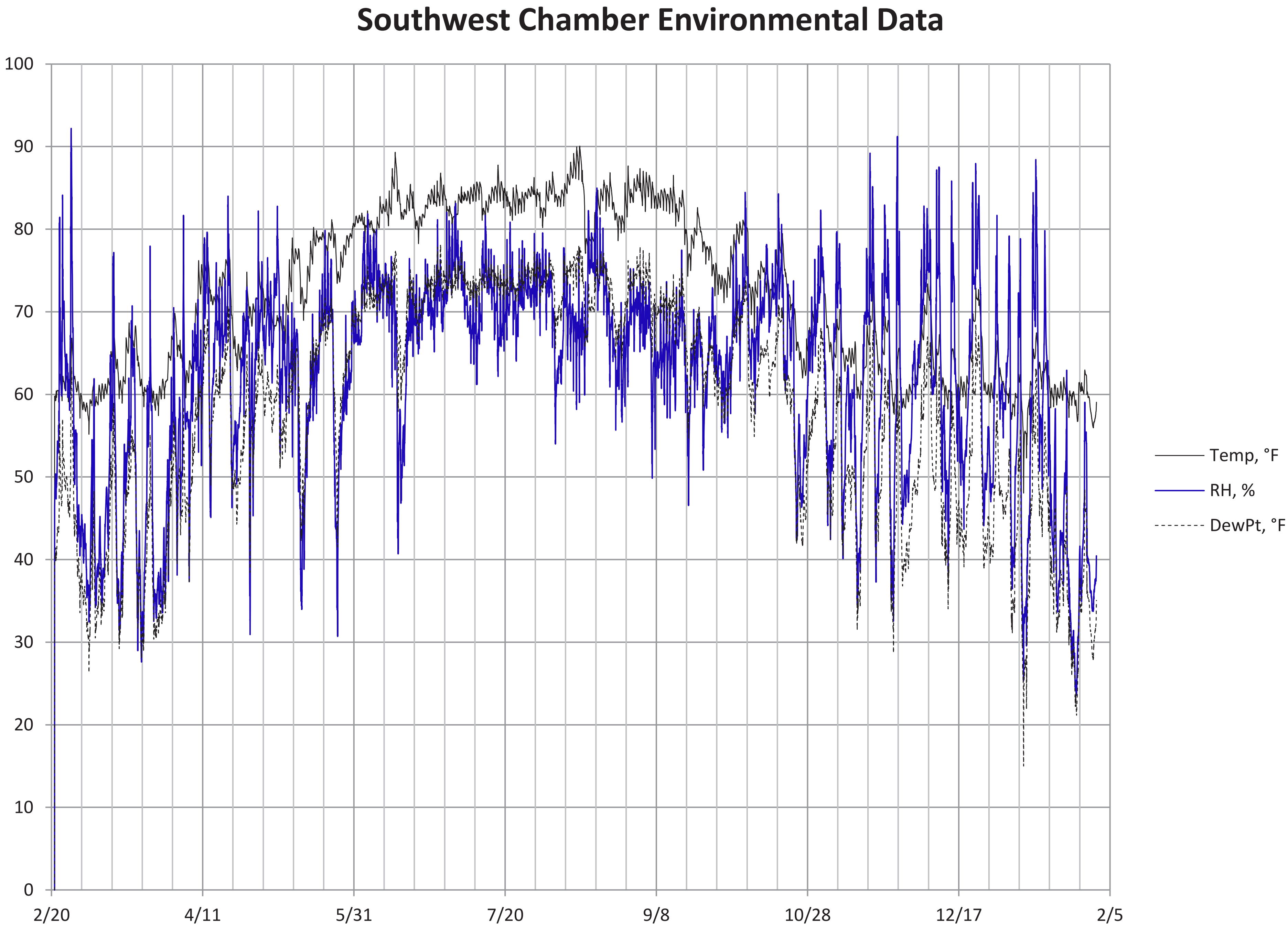


Figure 11: Environmental data from the southwest bed chamber.

Tactile Assessment

Tactile Assessment

A tactile survey was undertaken to determine the condition of the plaster using a well established field method. The assessment began by first evaluating the ceiling, and then the walls. Initially, some areas of the plaster ceilings were difficult to decifer. Areas appeared to have slight variations during sounding, but the change in sound was too small to accurately determine whether the plaster was loose or whether the material became thicker. For this reason, a stethoscope was used as a means of hearing small audible differences. The stethoscope was placed directly against the plaster ceiling and then the plastic mallet lightly tapped the area adjacent to the stethoscope. The process was repeated over the entire ceiling. The walls did not require the use of the stethoscope, except in a few select locations. Through this type of analysis the conservation team was able to physically inspect the entire surface of each wall and ceiling located in the southwest and southeast bedrooms.

Figure 12: Southeast chamber: A stethoscope and a plastic mallet was used to delicately sound the walls and listen for audible changes, indicating changes in the density of the plaster.

Figure 13: Southeast chamber, cornice: Rolling scaffolding provided access to plaster within the room, ensuring that all surfaces were physically inspected.

Figure 14: Southeast chamber, east wall: Note: Scaffolding was installed high enough to inspect all areas of the ceiling.

Passive Infrared Assessment

Passive Thermography

Passive thermograms were taken during the course of this experiment to establish the baseline images. Passive thermography utilizes the thermal energy already available in the surrounding environment such as the sun, and is heavily dependent upon environmental conditions such as temperature and relative humidity. As shown below, passive thermograms captured during this phase of testing displayed a uniform temperature on most plaster surfaces within each room. This type of assessment was not able to detect small deficiencies within the plaster, and likely not an appropriate method to assess detachment. This result was expected as each room does not experience active thermal heating from the sun and therefore there is little to no temperature gradient within the plaster itself.

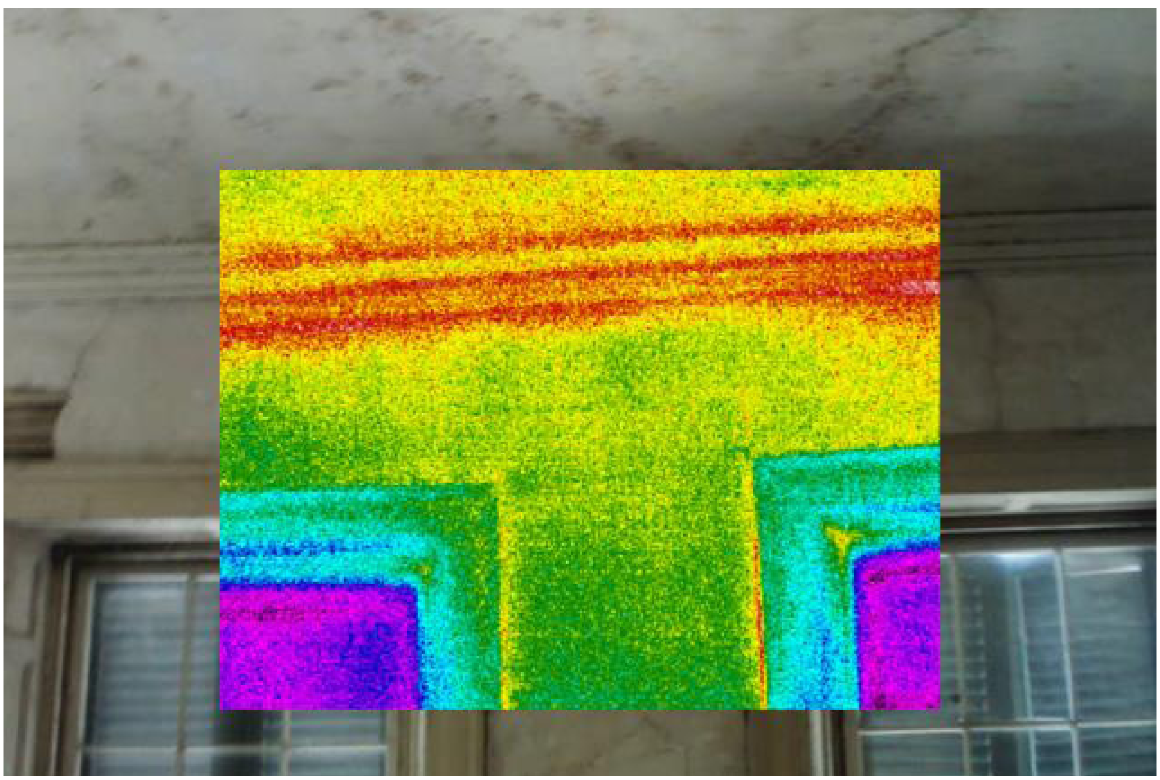


Figure 15: Southwest chamber, west wall: Thermograms taken with passive thermography showing even temperature distribution. Higher (red) temperatures common on corners were there is reduced air flow. Note: Pixelation of image due to narrow temperature range detected on wall.

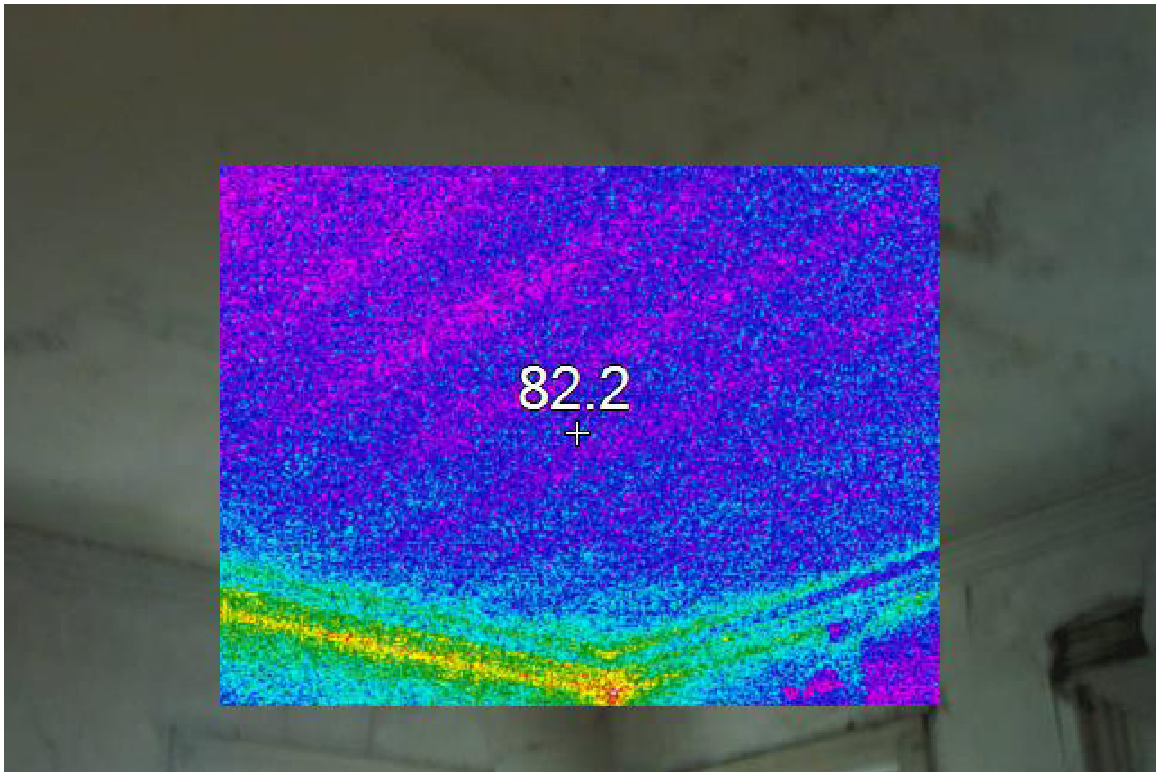


Figure 16: Southwest chamber, ceiling: Passive thermography trials enabled accurate mapping of ceiling framing members (purple).

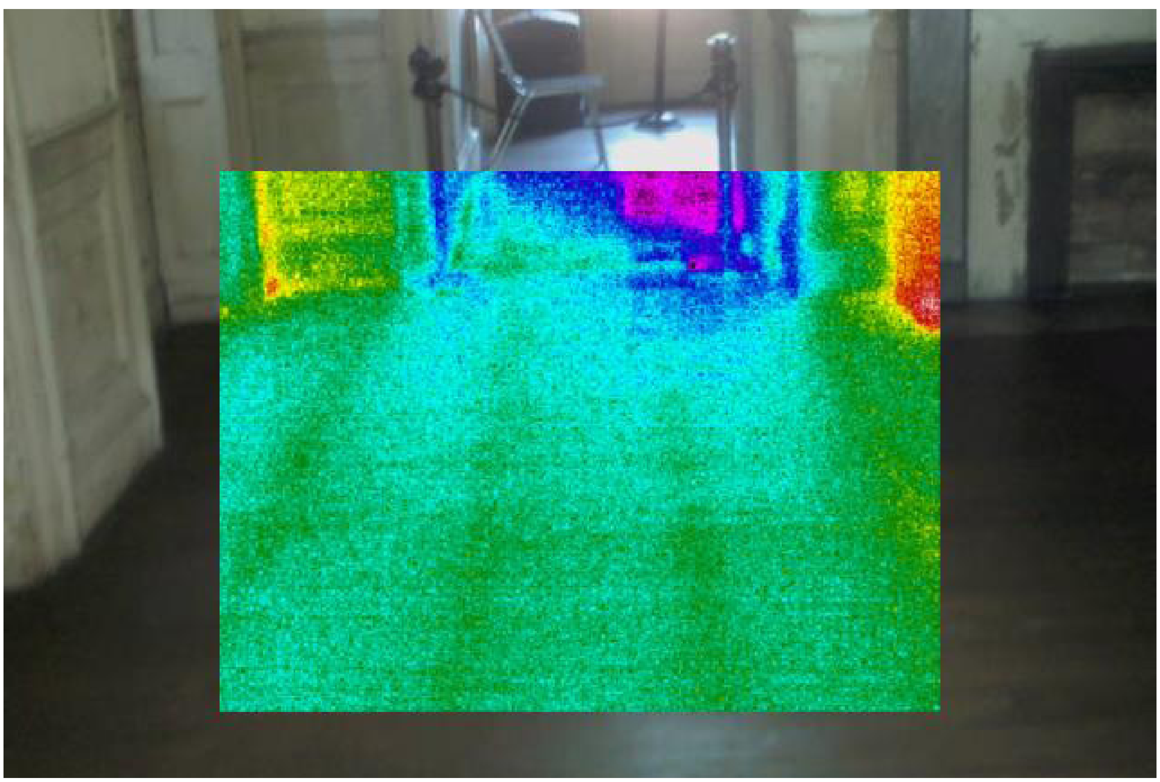


Figure 17: Southwest chamber, ceiling: Passive thermography also allowed for mapping of floor framing members (green). Location of the framing can be further verified by marking the nailing patterns within the flooring.

Active Infrared Assessment

Active Thermography

Following the inconclusive results during the passive infrared assessment, an active thermographic assessment was conducted using forced air via a conventional hair dryer. By using this method, temperature differences were able to be created within the wall system allowing for areas of separation or detachment to become apparent. Specifically, as forced air was directed over the surface of the detached or cracked plaster, heat was distributed differently than areas of sound plaster. This method allowed for investigation of the plaster beneath the wallpaper in the southeast bedroom. Surface cracks normally hidden beneath the paper became obvious on the infrared camera when heat was actively applied.

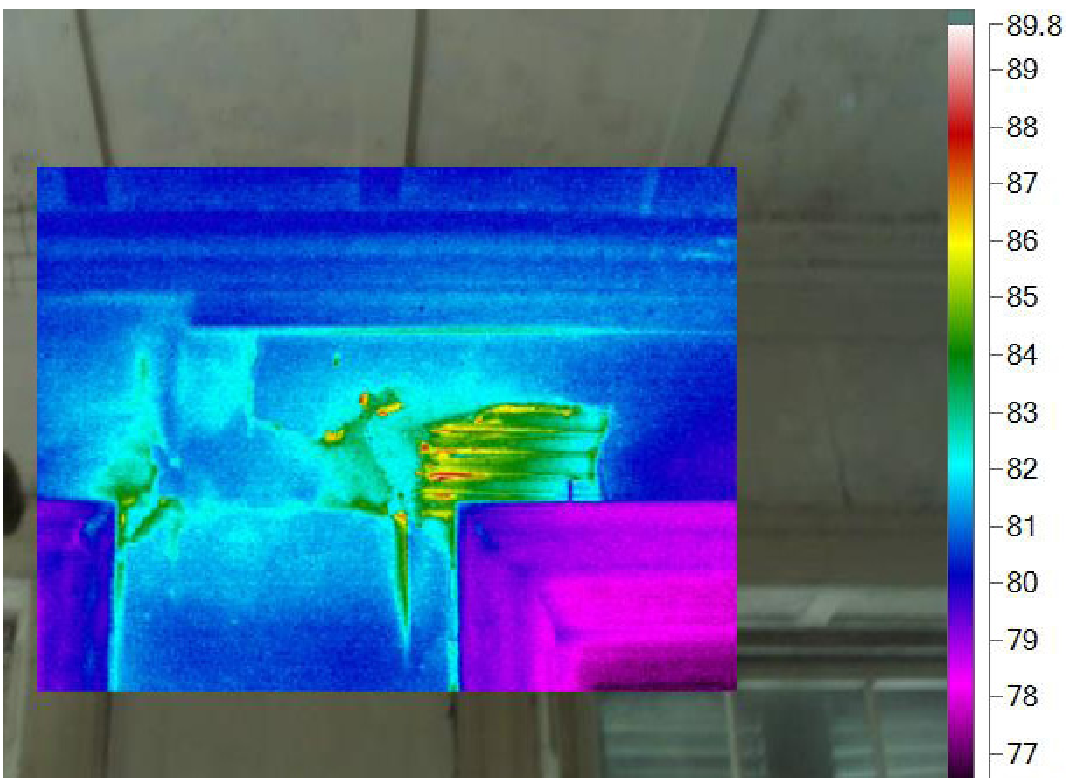


Figure 18: Southwest chamber, west wall: Thermograms taken via active thermography show areas of higher temperature (bright blue) where plaster has been compromised. Areas of complete loss and loose wall paper show higher temperatures (green).

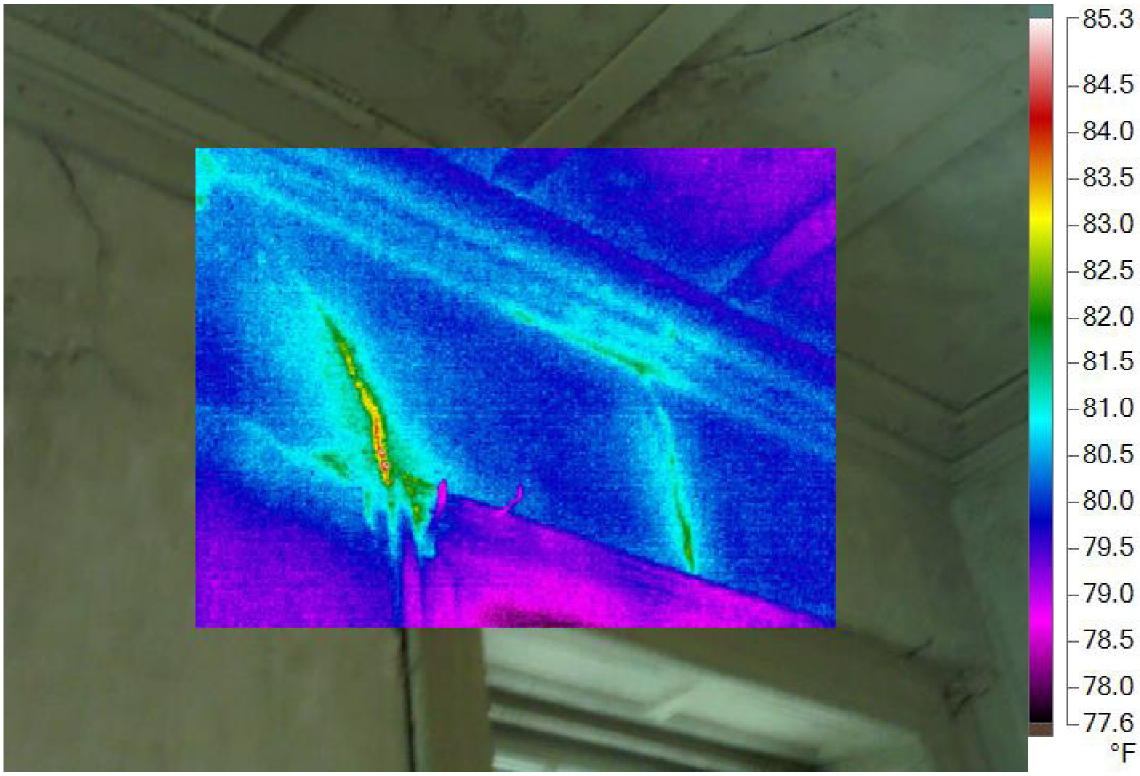


Figure 19: Southwest chamber, west wall: Note: Areas of higher temperatures and presumably detachment along open cracks. Void spaces within cracks correspond with highest temperatures.

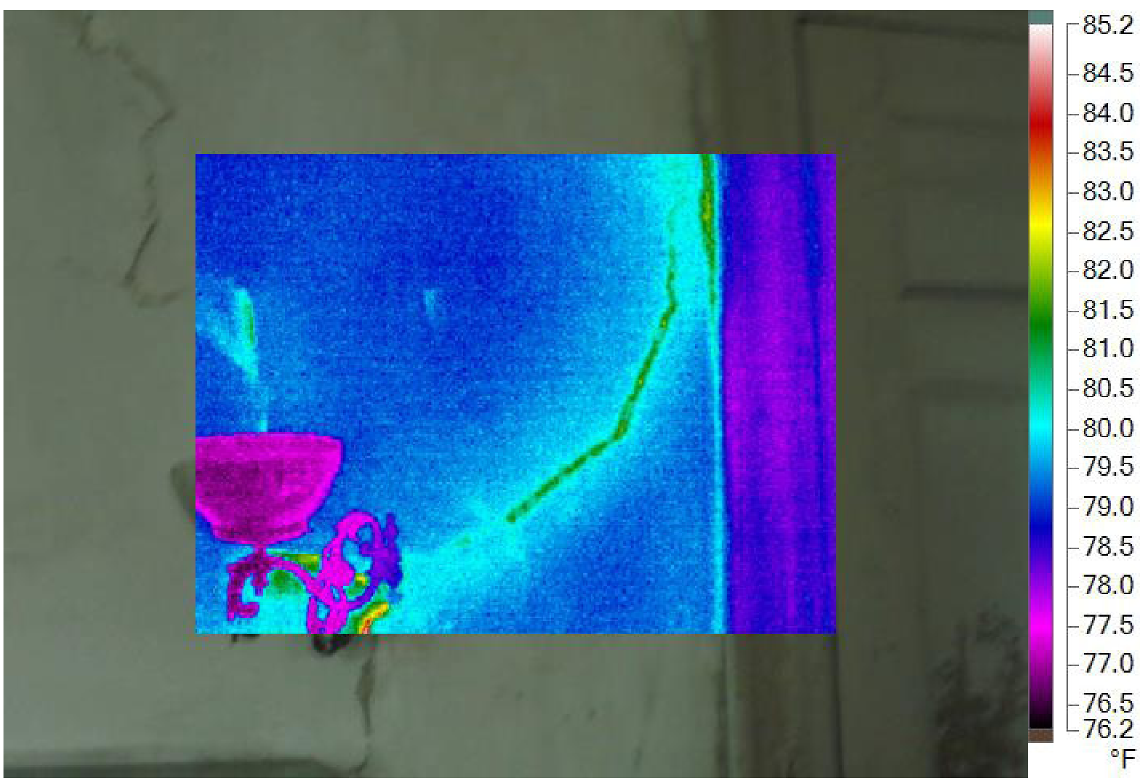


Figure 20: Southwest chamber, north wall: Areas of higher temperatures present along cracking near sconce above the mantel.

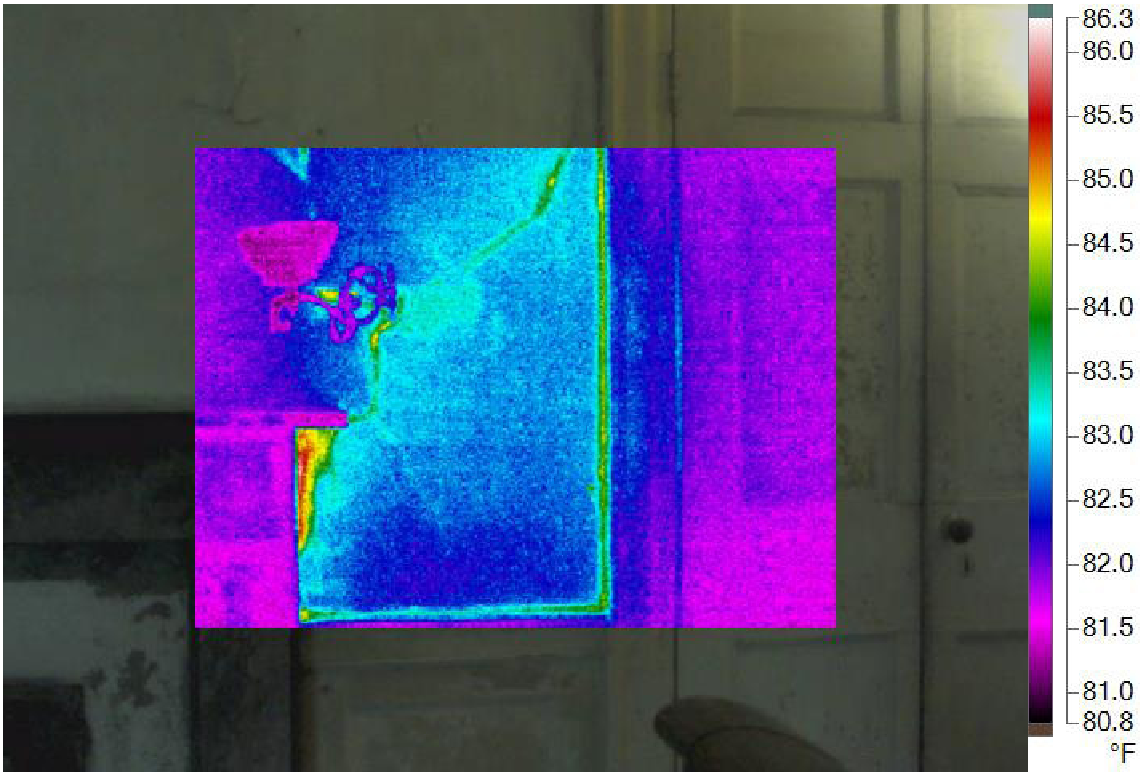


Figure 21: Southwest chamber, north wall: Large view of area adjacent to fireplace sconce, indicating possible detachment (green to bright blue).

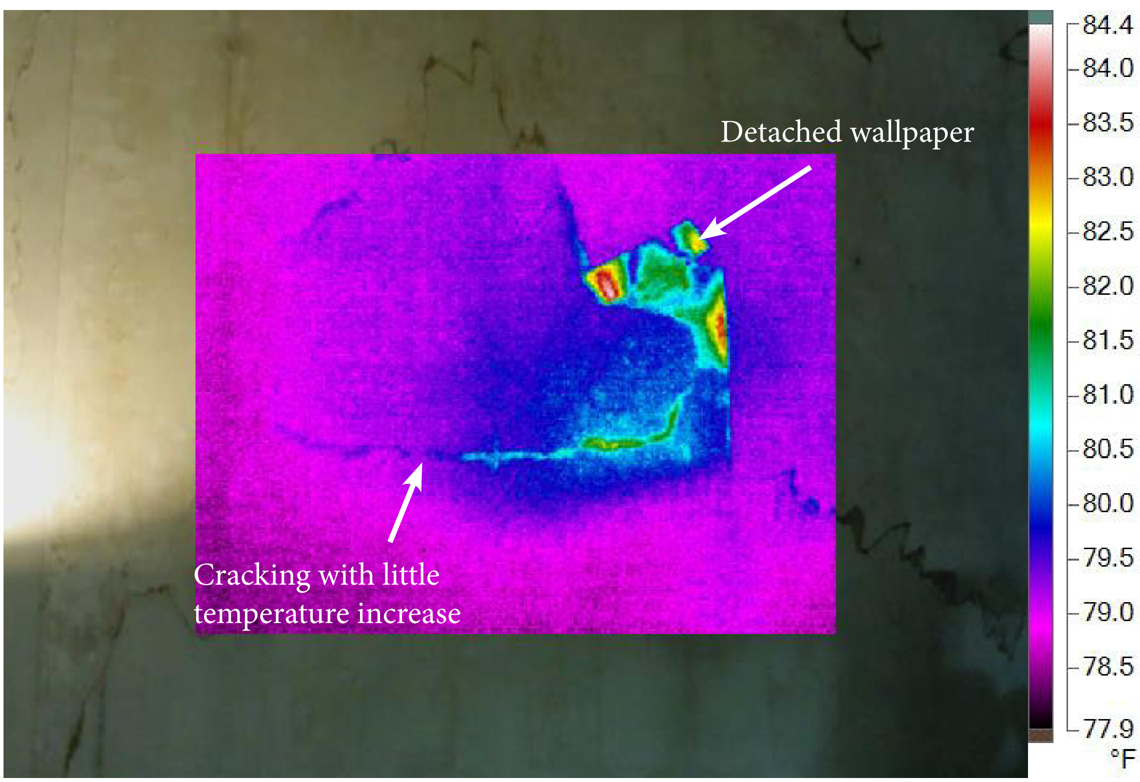


Figure 22: Southwest chamber, east wall: Note: slight temperature increases seen adjacent to the door.

Figure 23: Southeast chamber, west wall: The cracking within the plaster obscured by wallpaper was visible through infrared analysis.

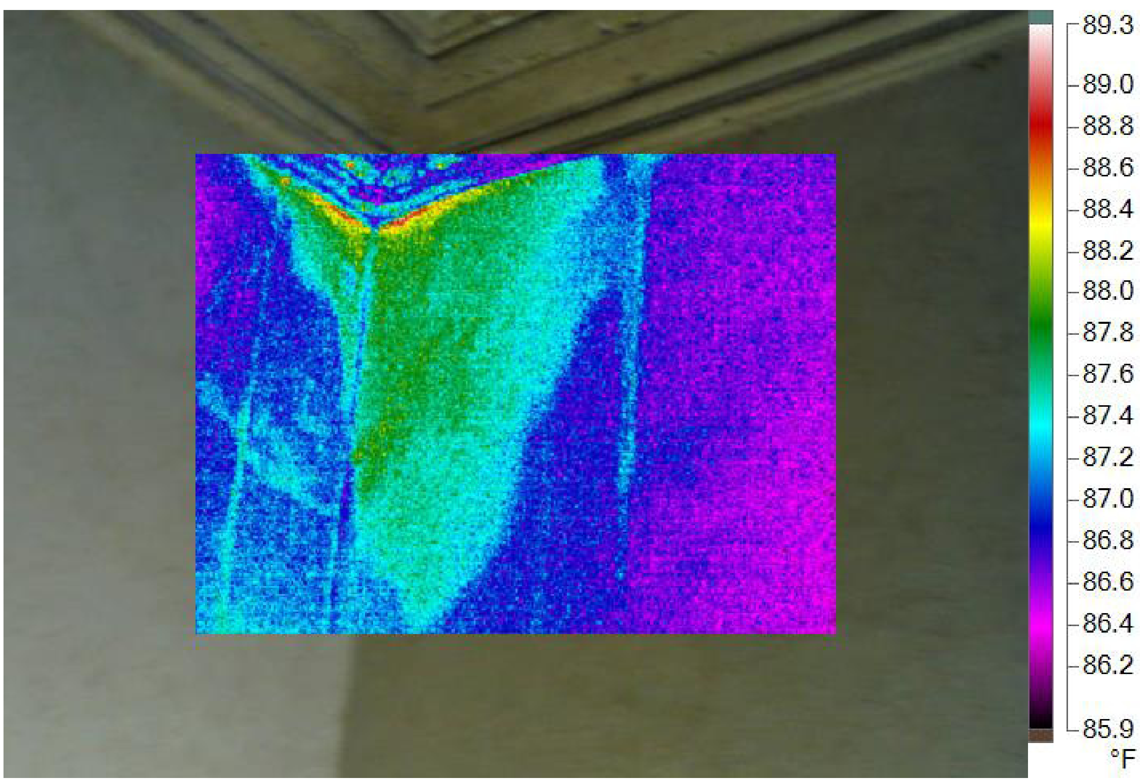


Figure 24: Southeast chamber, northwest corner: Note: Areas illustrating detachment of wallpaper without noticeable plaster damage.

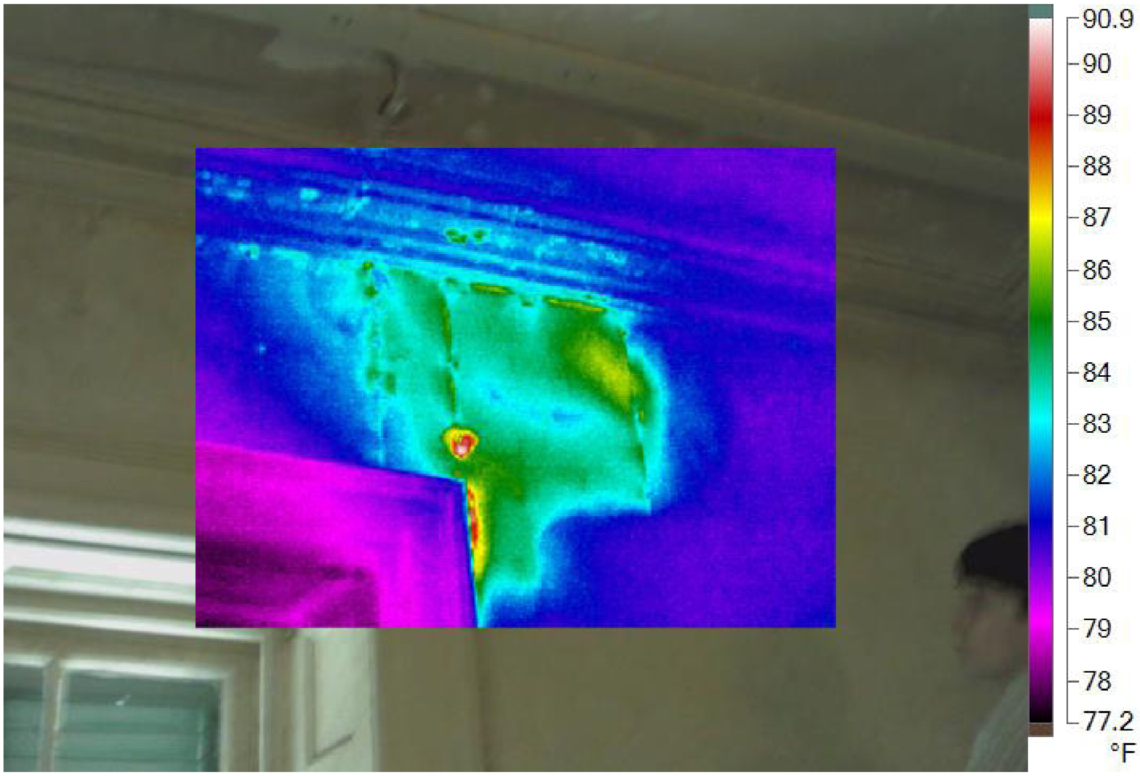


Figure 25: Southeast chamber, south wall: Analysis above window showing visible temperature differences between wallpaper detachment (green) and cracking (blue).

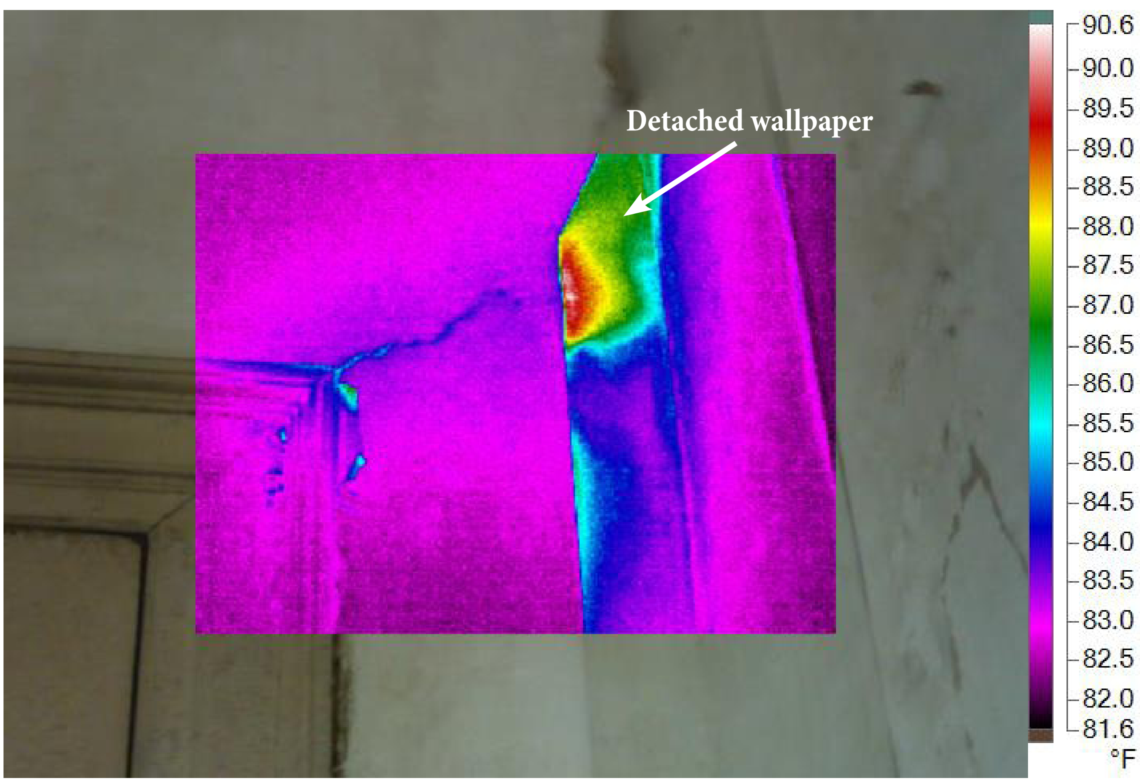


Figure 26: Southeast chamber, west wall: Note: Temperature increases seen adjacent to the door. Areas of detached wall paper display visible temperature differences.

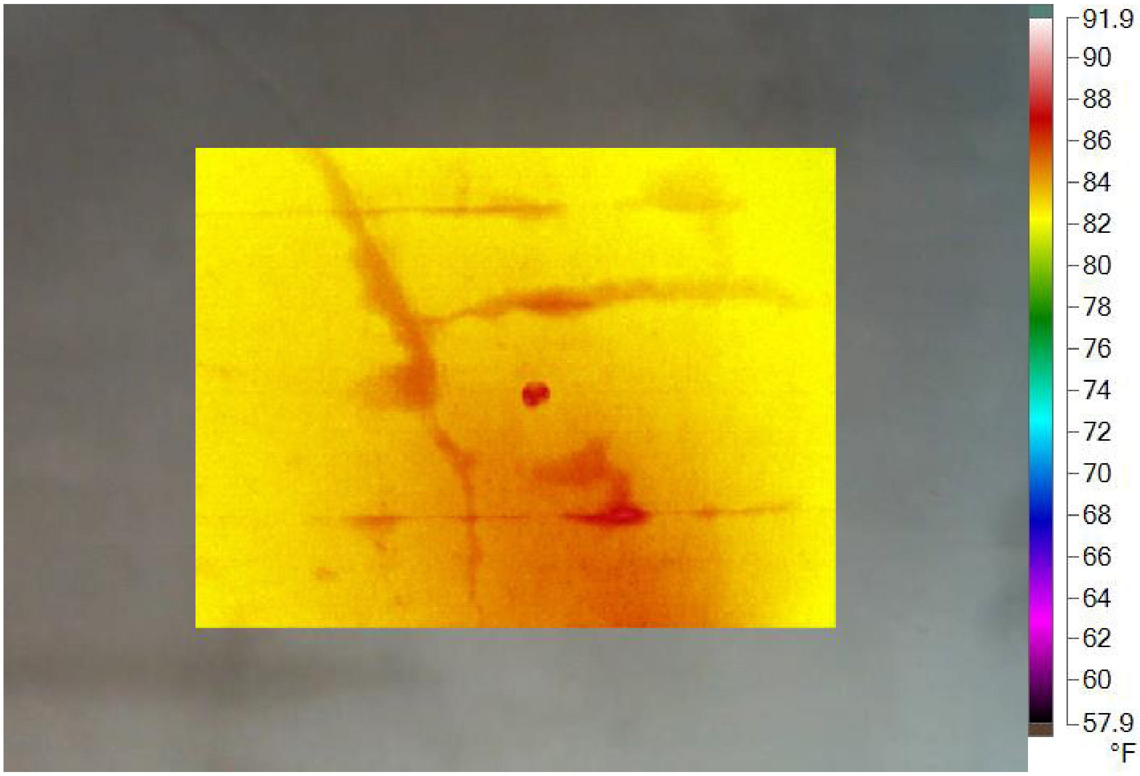


Figure 27: Southeast chamber, ceiling: Analysis of ceiling indicated cracking obscured by wallpaper. Note: Horizontal lines denote edges of individual sheets of wallpaper.

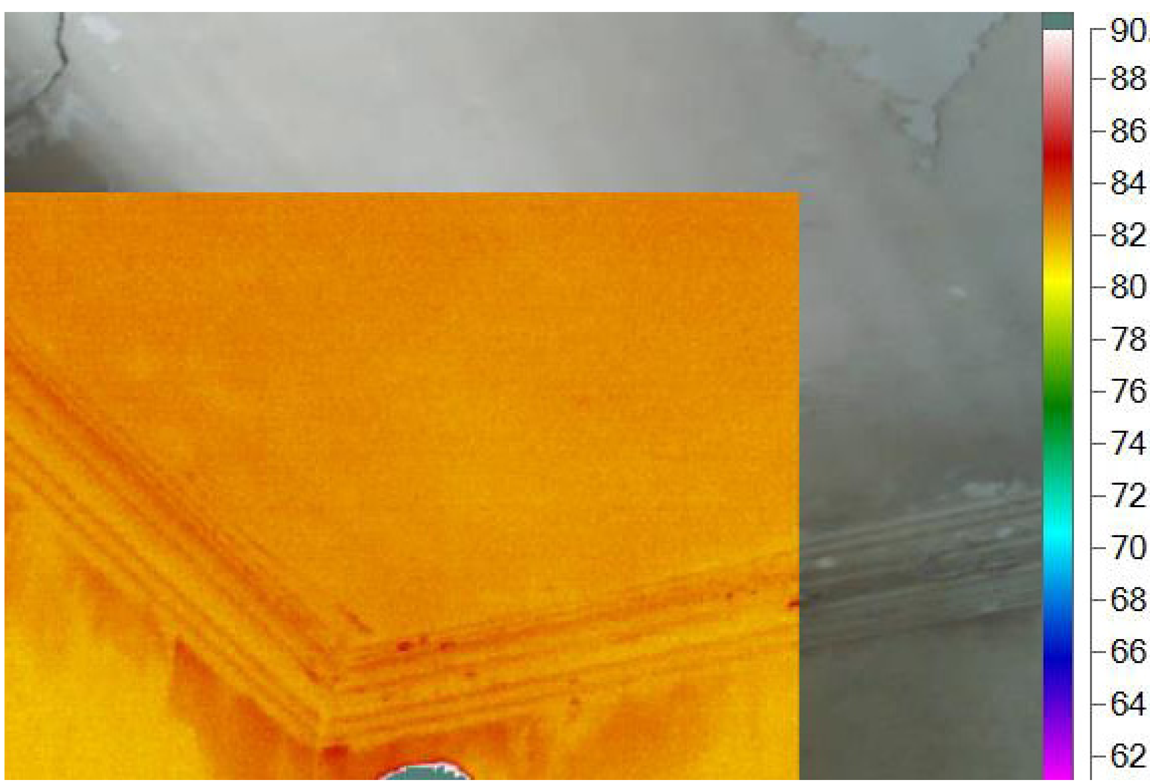


Figure 28: Southeast chamber, ceiling: Area of study where little temperature change was observed, likely indicating sound plaster.

Exterior Stucco Tests

Exterior Stucco

Current scholarly research has illustrated the success of determining plaster detachment on stucco applied on masonry. In order to validate these claims, tests were performed on the exterior stucco of the Aiken-Rhett house to determine if delamination on masonry surfaces was easier to detect than those on lath. Thermograms were taken on the west elevation in the late afternoon without the use of any active heating. Results from this test indicate that stucco detachment is much more visible after a period of solar radiation. Additionally, microcracks adjacent to visible cracking in the stucco was detected easily by infrared thermography.

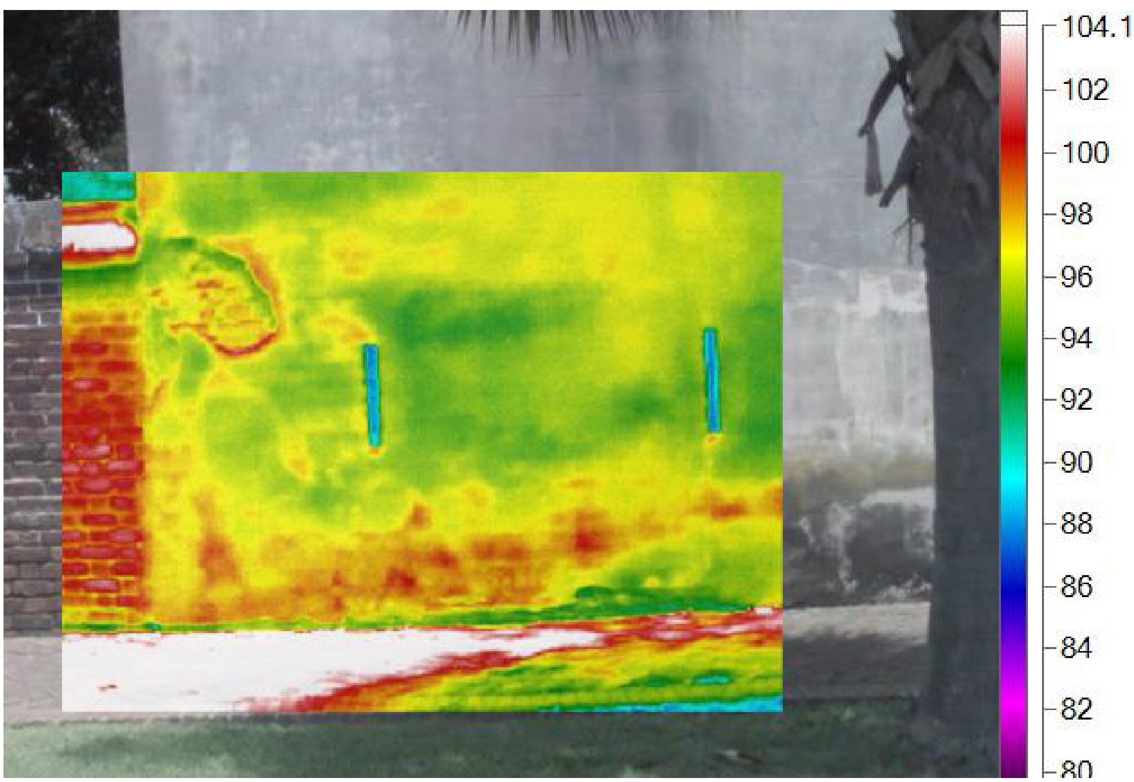


Figure 29: Exterior stucco, west elevation: Red areas on stucco indicate detachment from masonry. Detachment verified in field. Note difference between areas of repair.

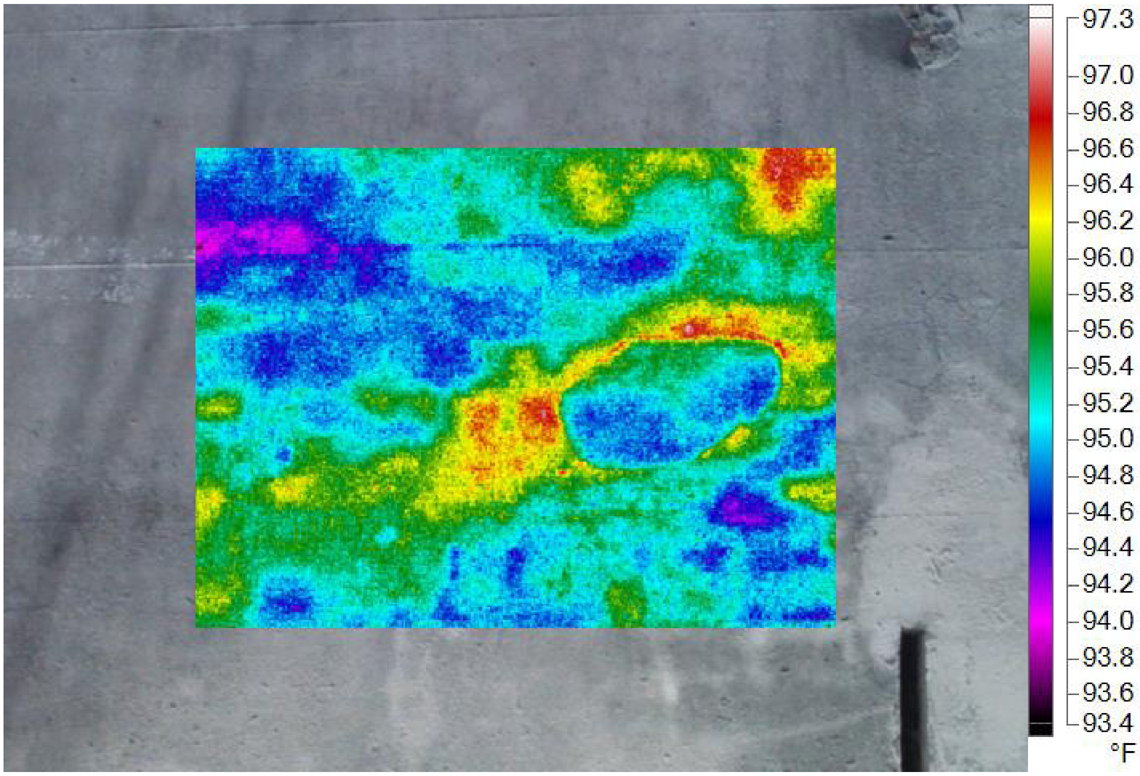


Figure 30: Exterior stucco, west elevation: Detached stucco displayed as red-yellow. The locations of the detachment was verified within the field.

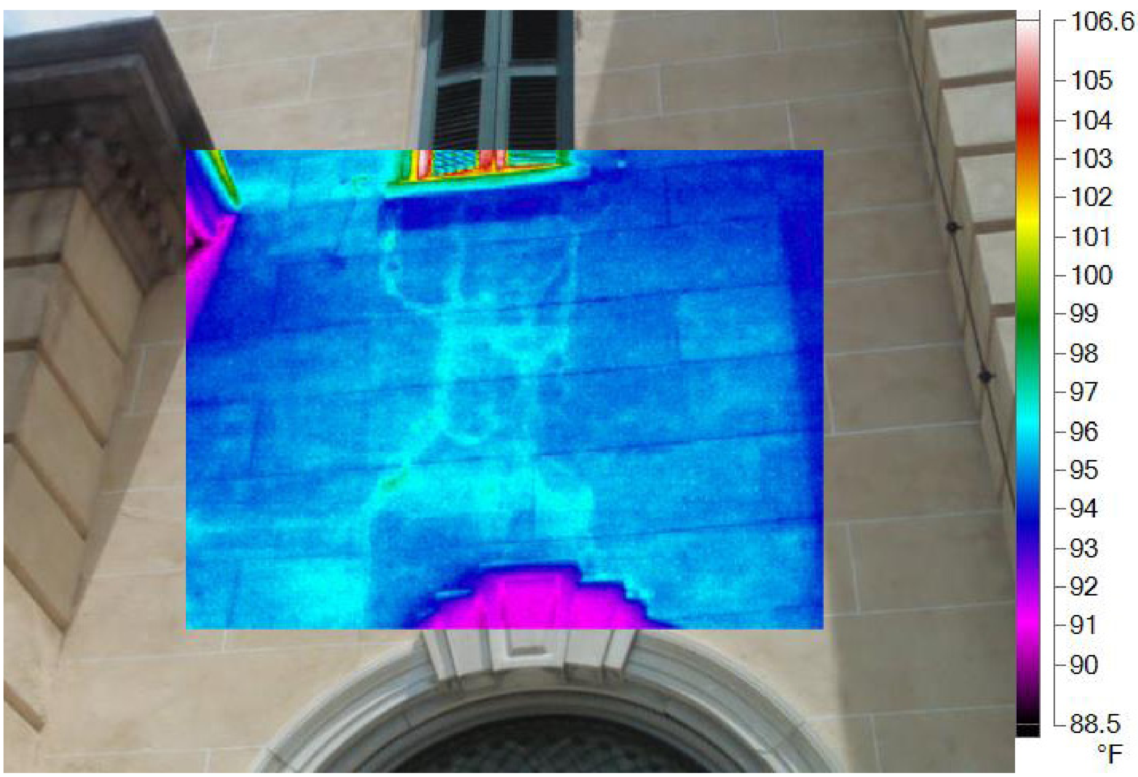
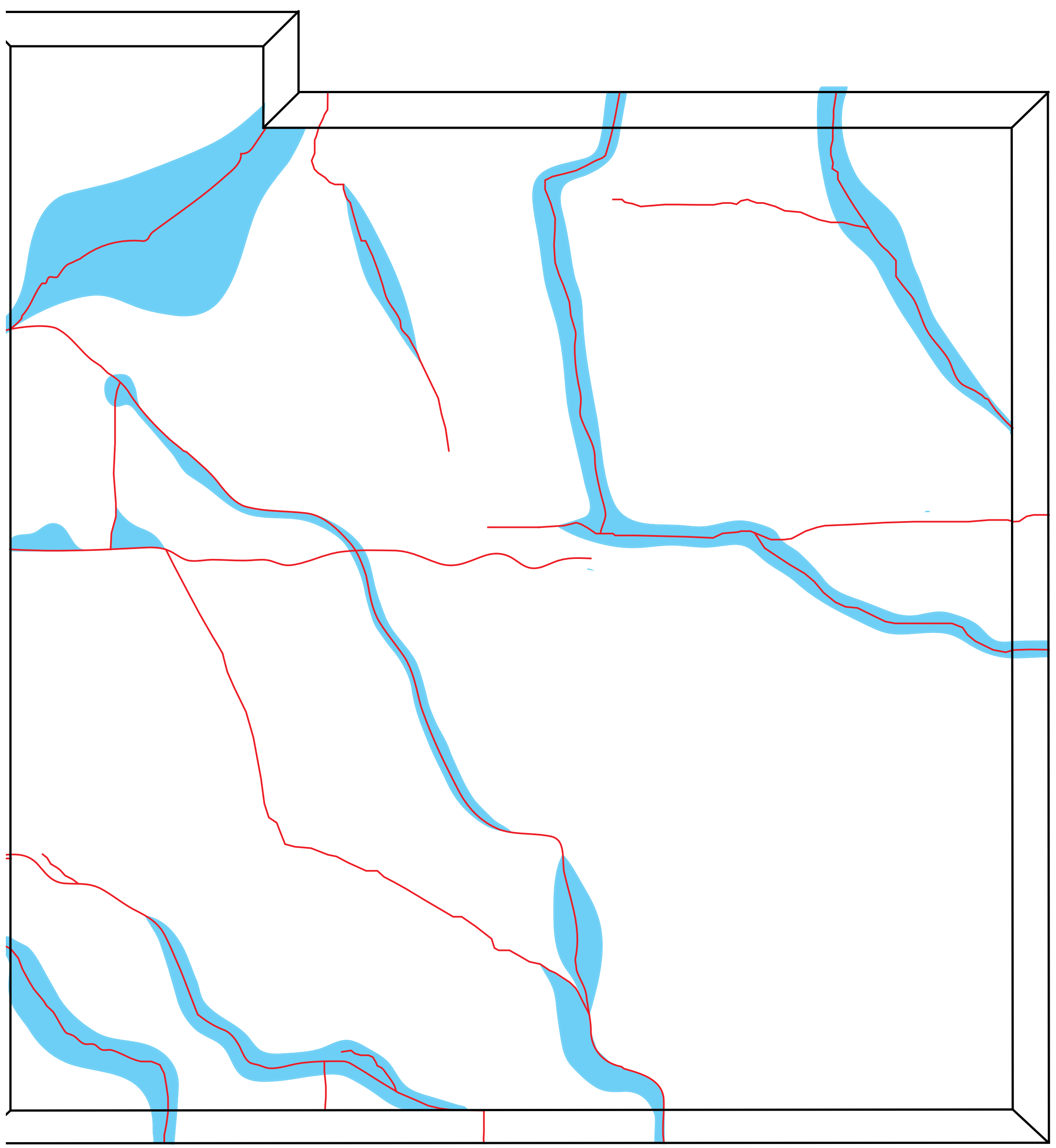


Figure 31: Exterior stucco, west elevation: Additional cracking not seen in visible light viewed in Infrared.

Southwest Chamber- Ceiling

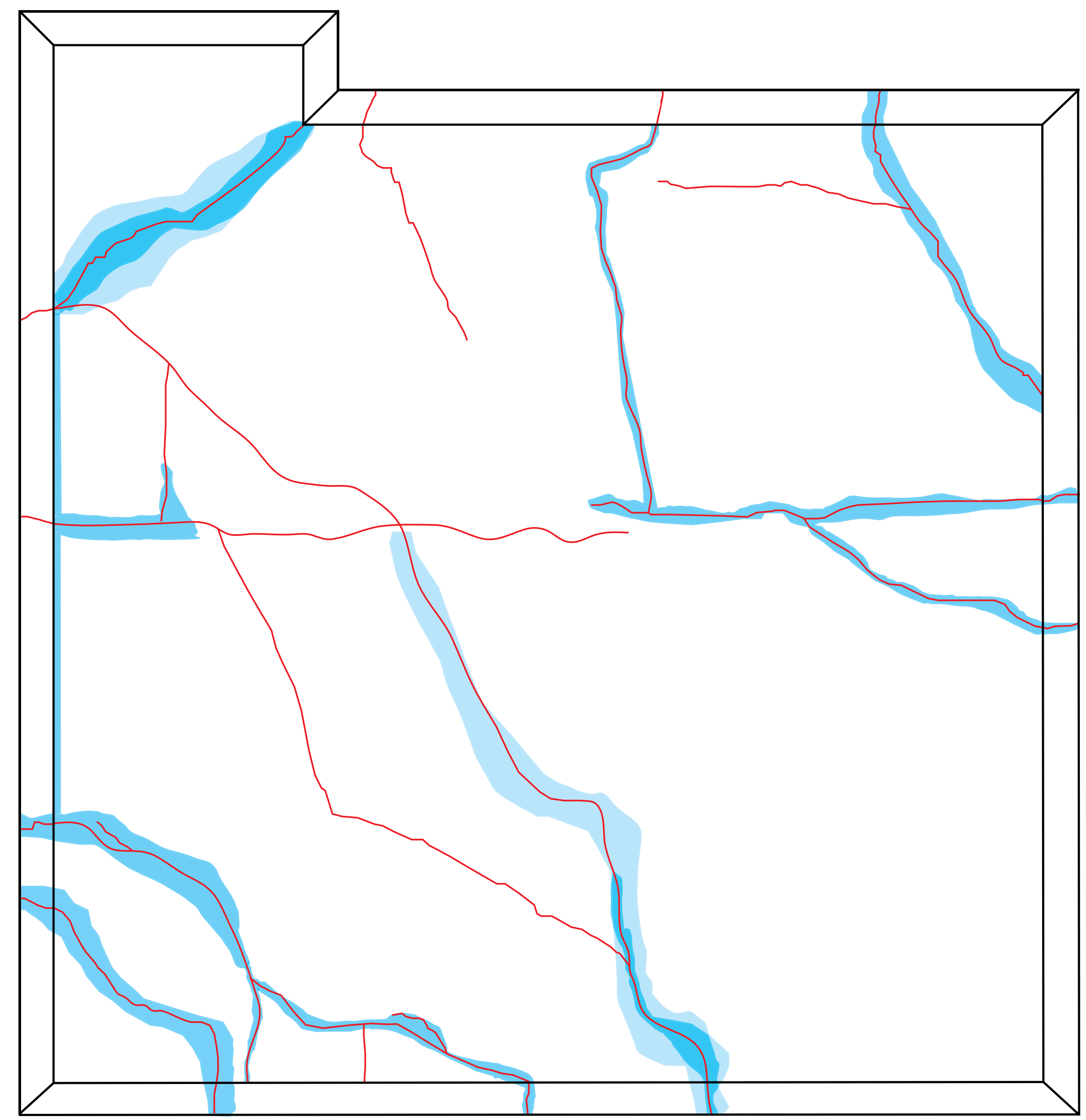
Tactile Assessment



Key:

- detached plaster
- slightly detached plaster
- visible cracks
- cracks discovered during assessment

Infrared Assessment

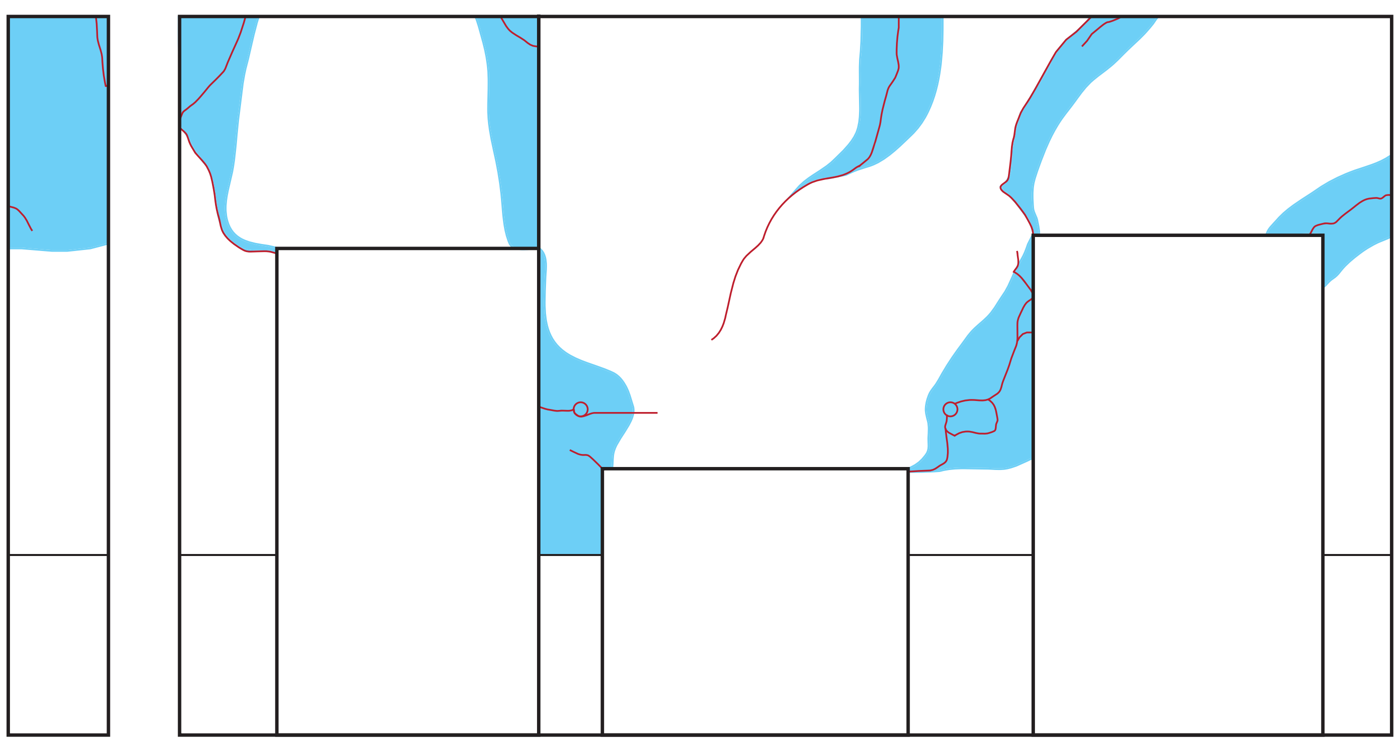


Key:

- detached plaster
- slight temperature differential in plaster- potential indicator of slight detachment
- visible cracks
- cracks discovered during assessment

SOUTHWEST CHAMBER- NORTH WALL

TACTILE ASSESSMENT



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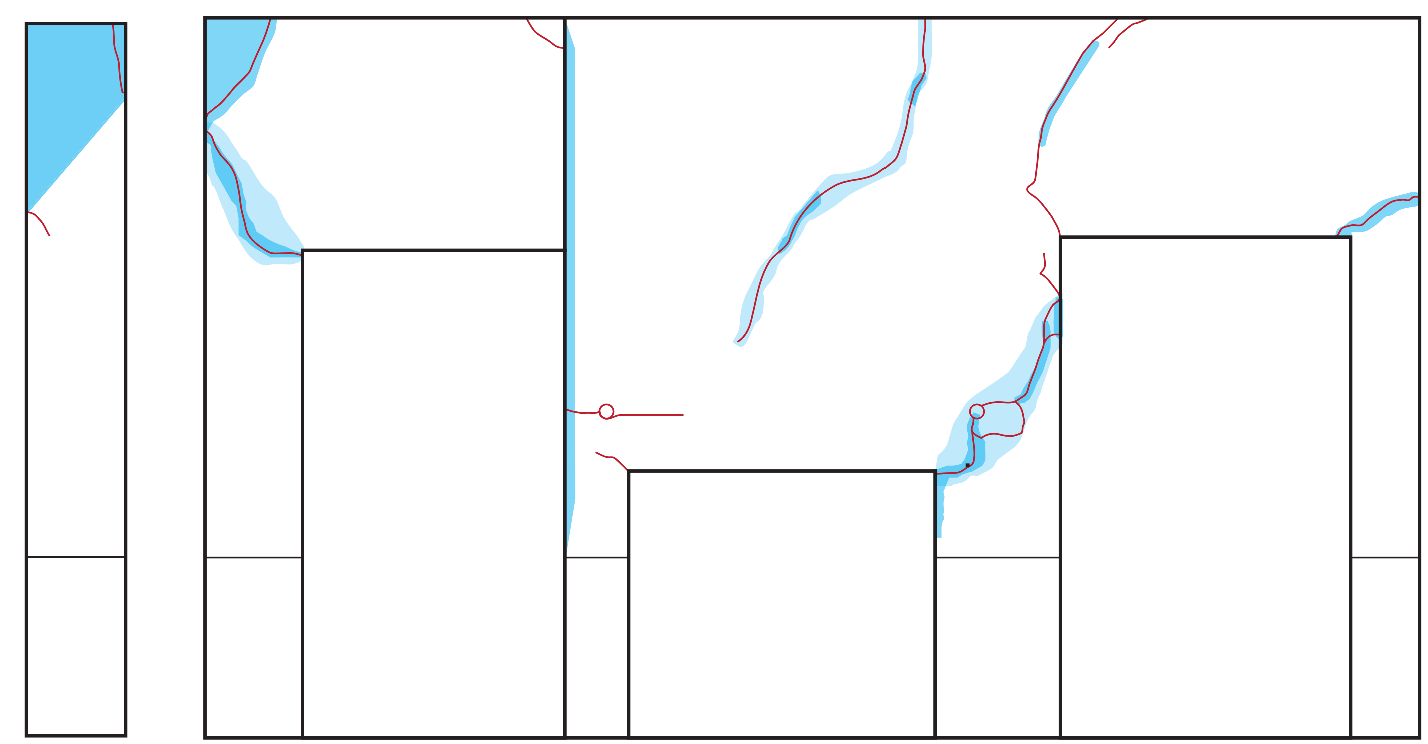
INFRARED ASSESSMENT



KEY:

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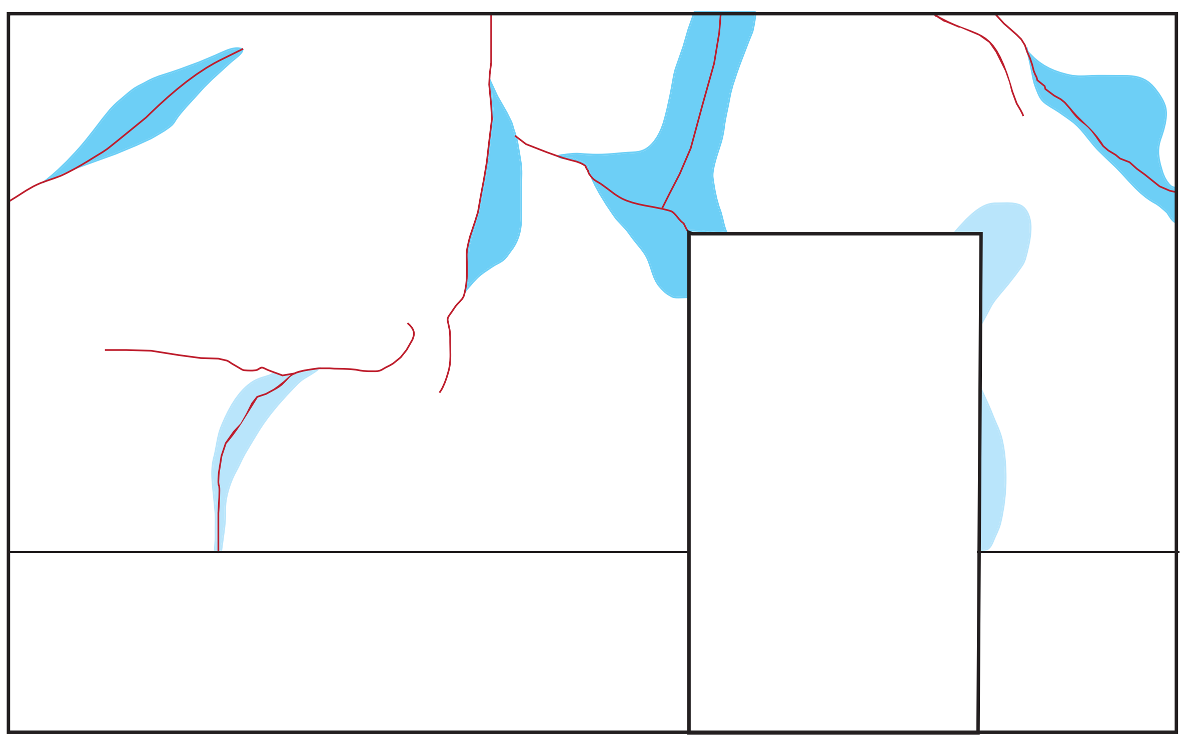
- visible cracks
- cracks discovered during assessment

Southwest Chamber- East Wall

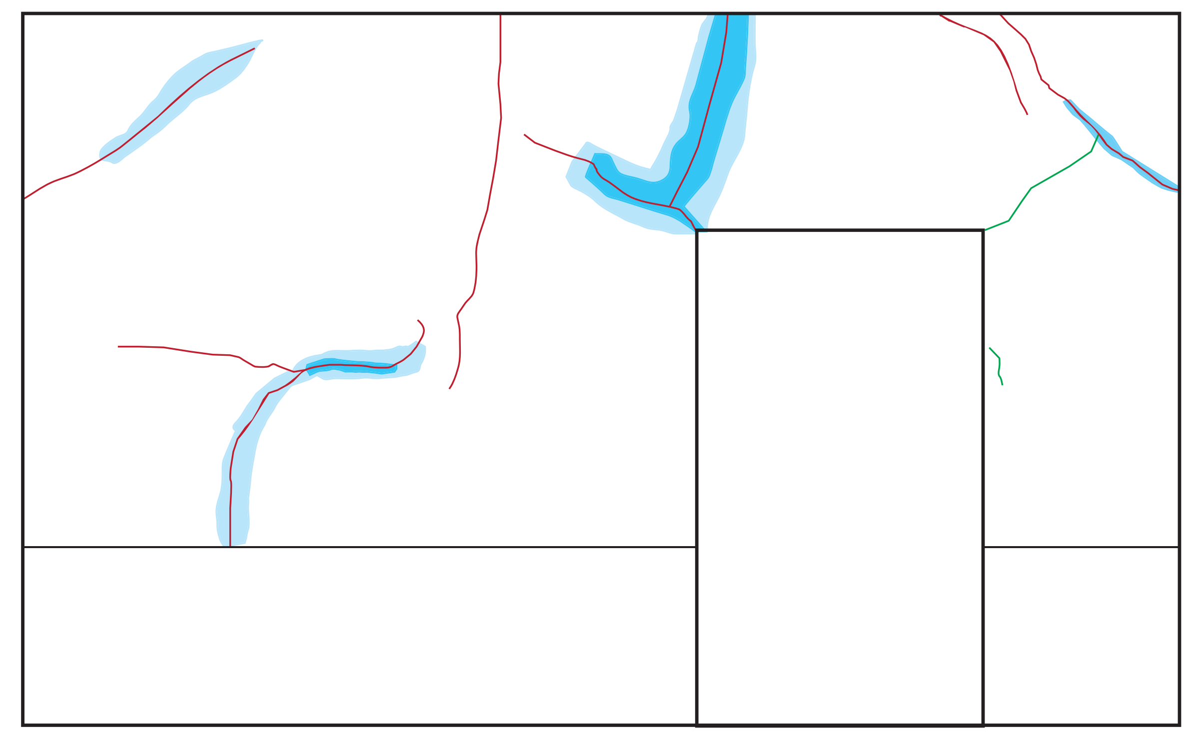
Tactile Assessment



Key:

- detached plaster
- slightly detached plaster
- visible cracks
- cracks discovered during assessment

Infrared Assessment

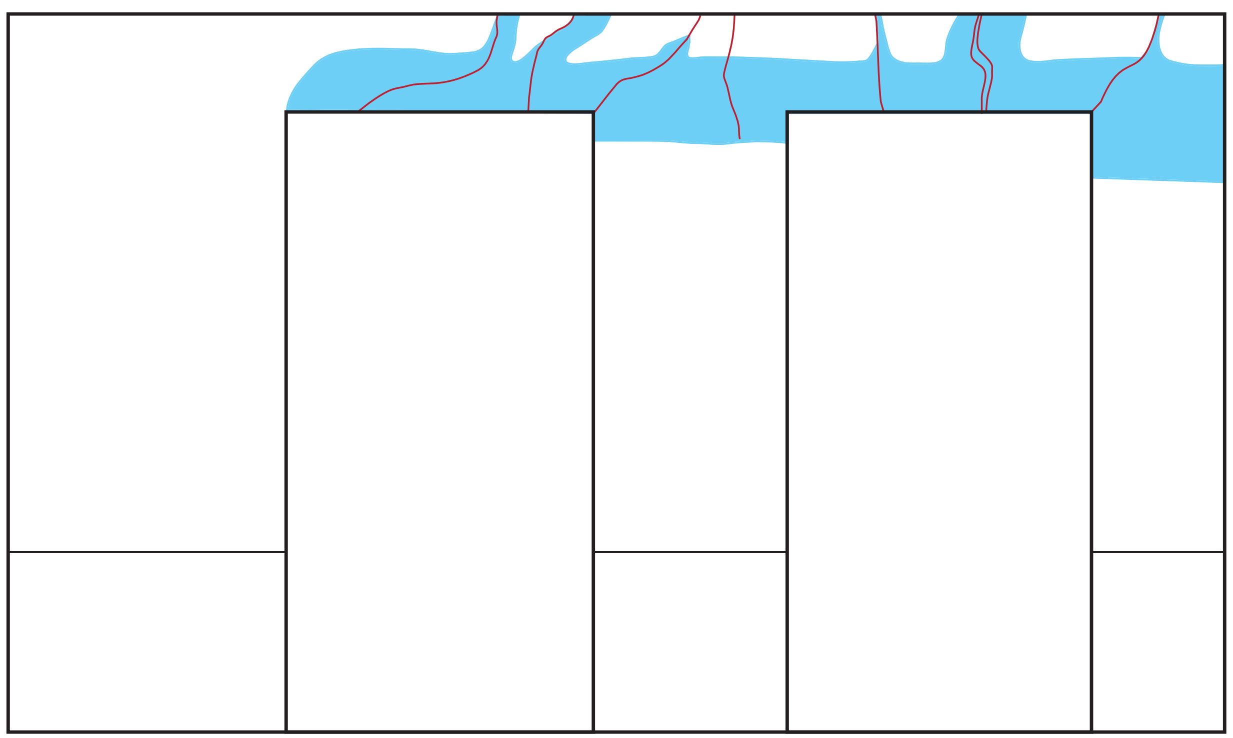


Key:

- detached plaster
- slight temperature differential in plaster- potential indicator of slight detachment
- visible cracks
- cracks discovered during assessment

Southwest Chamber- South Wall

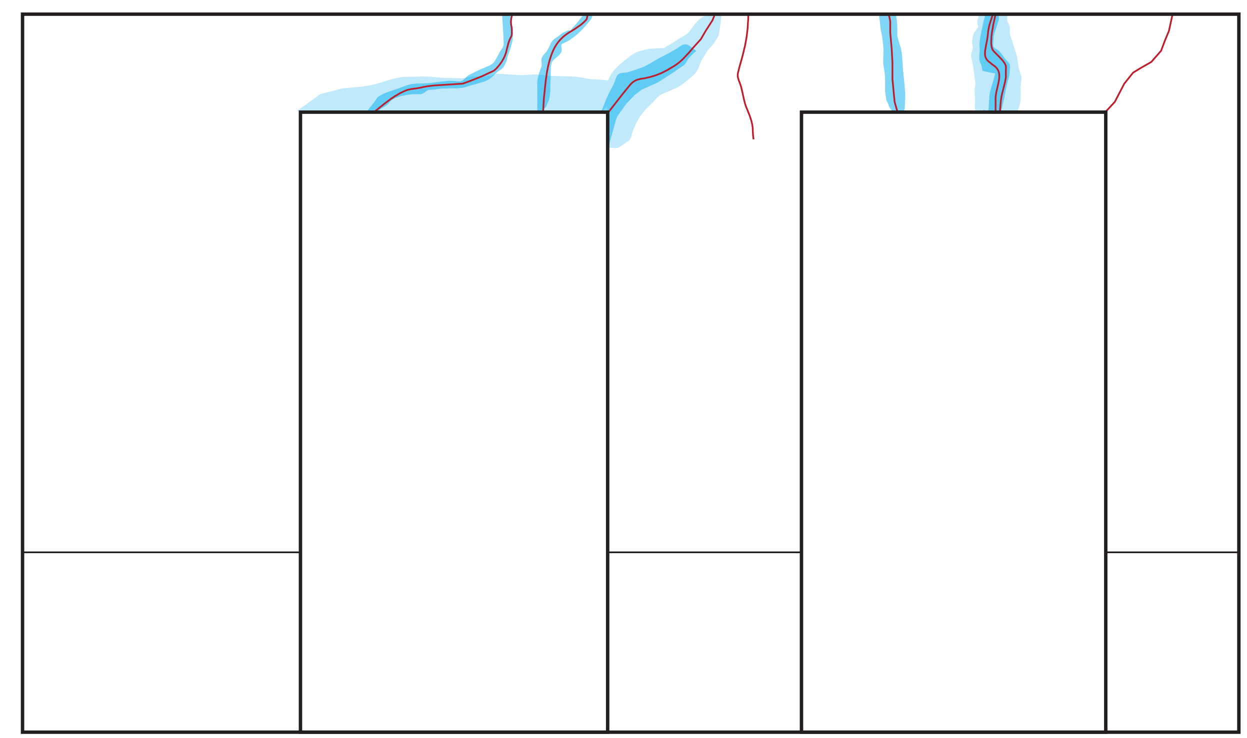
Tactile Assessment



Key:

- detached plaster
- slightly detached plaster
- visible cracks
- cracks discovered during assessment

Infrared Assessment

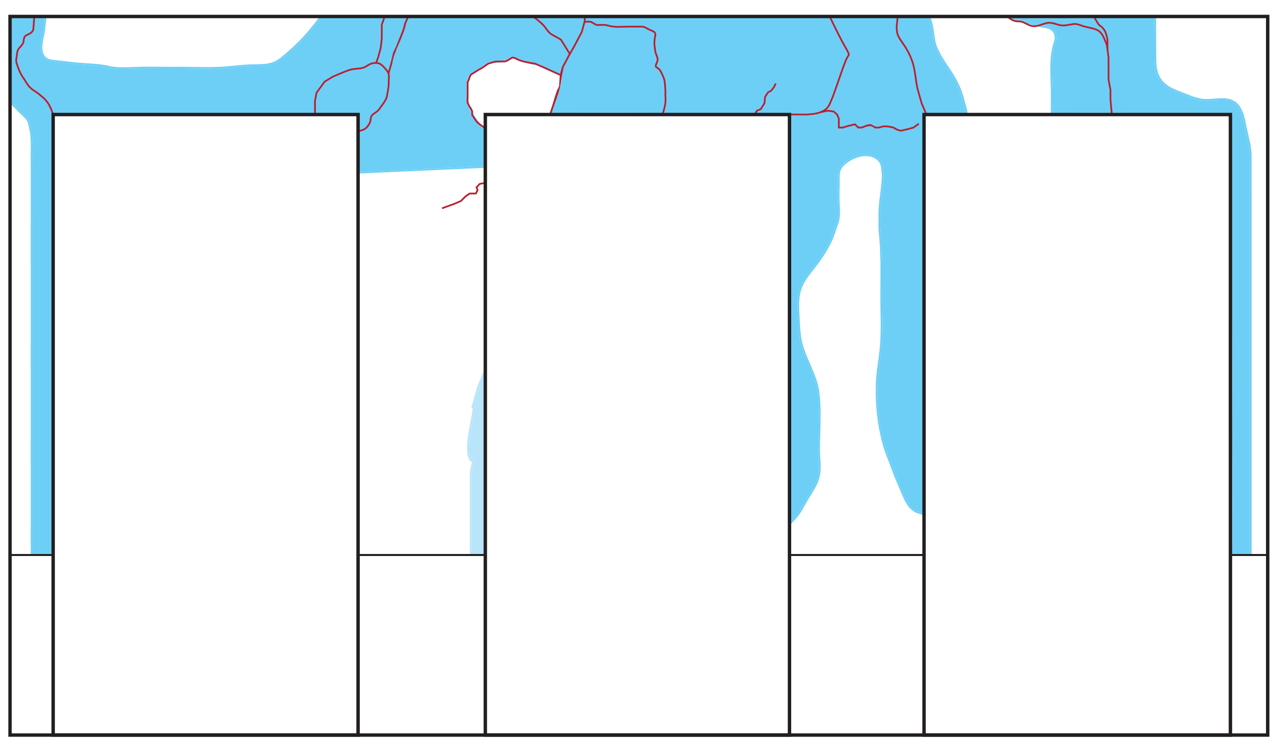


Key:

- detached plaster
- slight temperature differential in plaster- potential indicator of slight detachment
- visible cracks
- cracks discovered during assessment

Southwest Chamber- West Wall

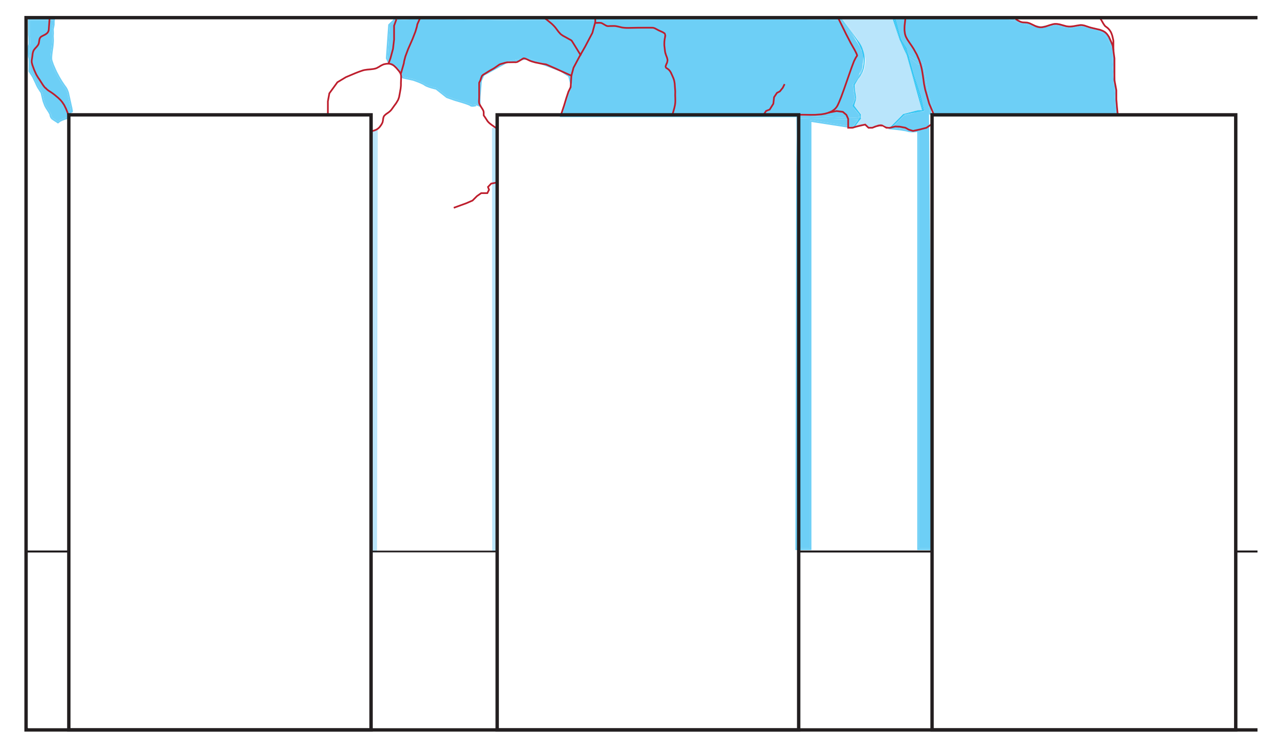
Tactile Assessment



Key:

- detached plaster
- slightly detached plaster
- visible cracks
- cracks discovered during assessment

Infrared Assessment

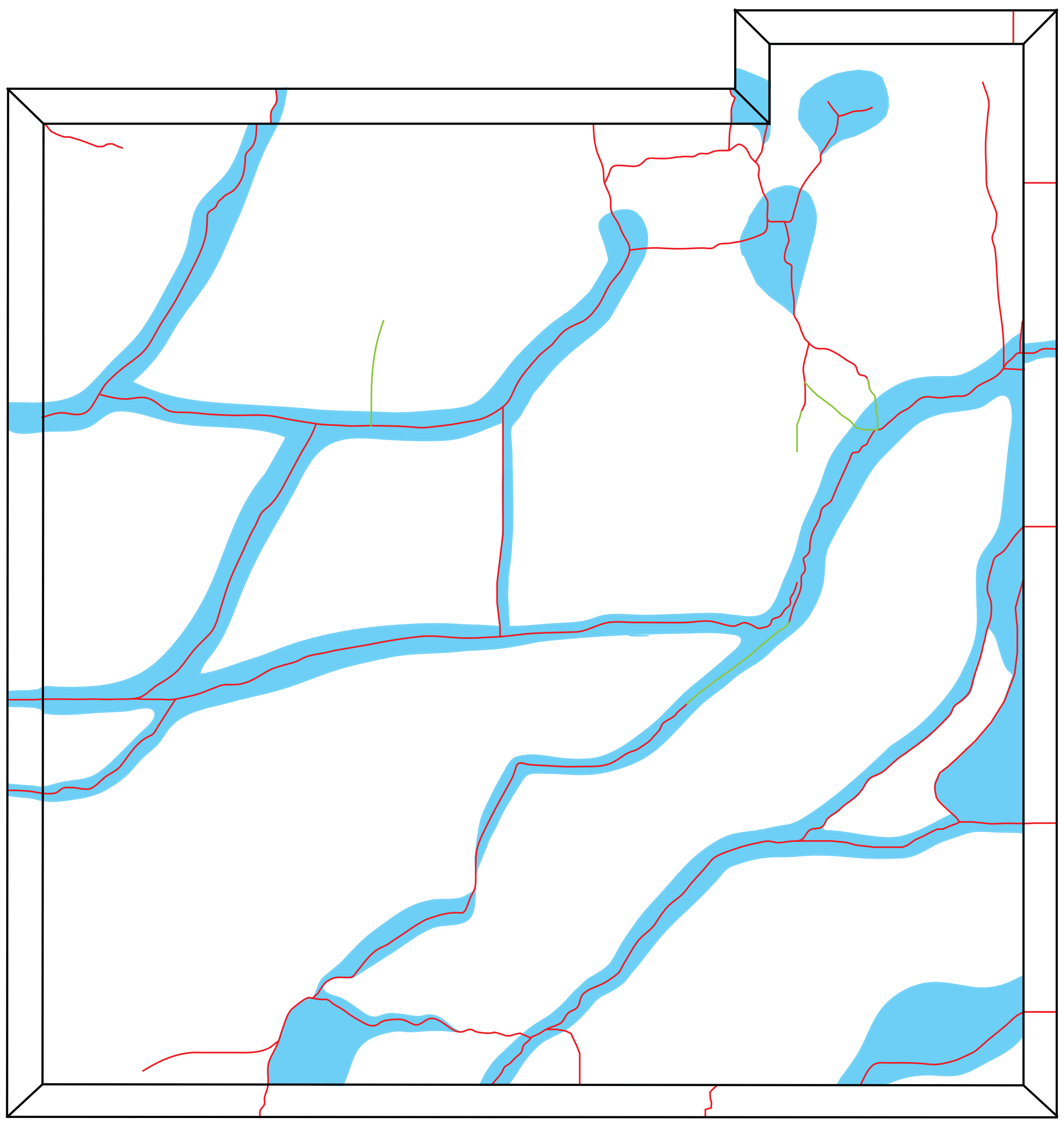


Key:

- detached plaster
- slight temperature differential in plaster- potential indicator of slight detachment
- visible cracks
- cracks discovered during assessment

Southeast Chamber- Ceiling

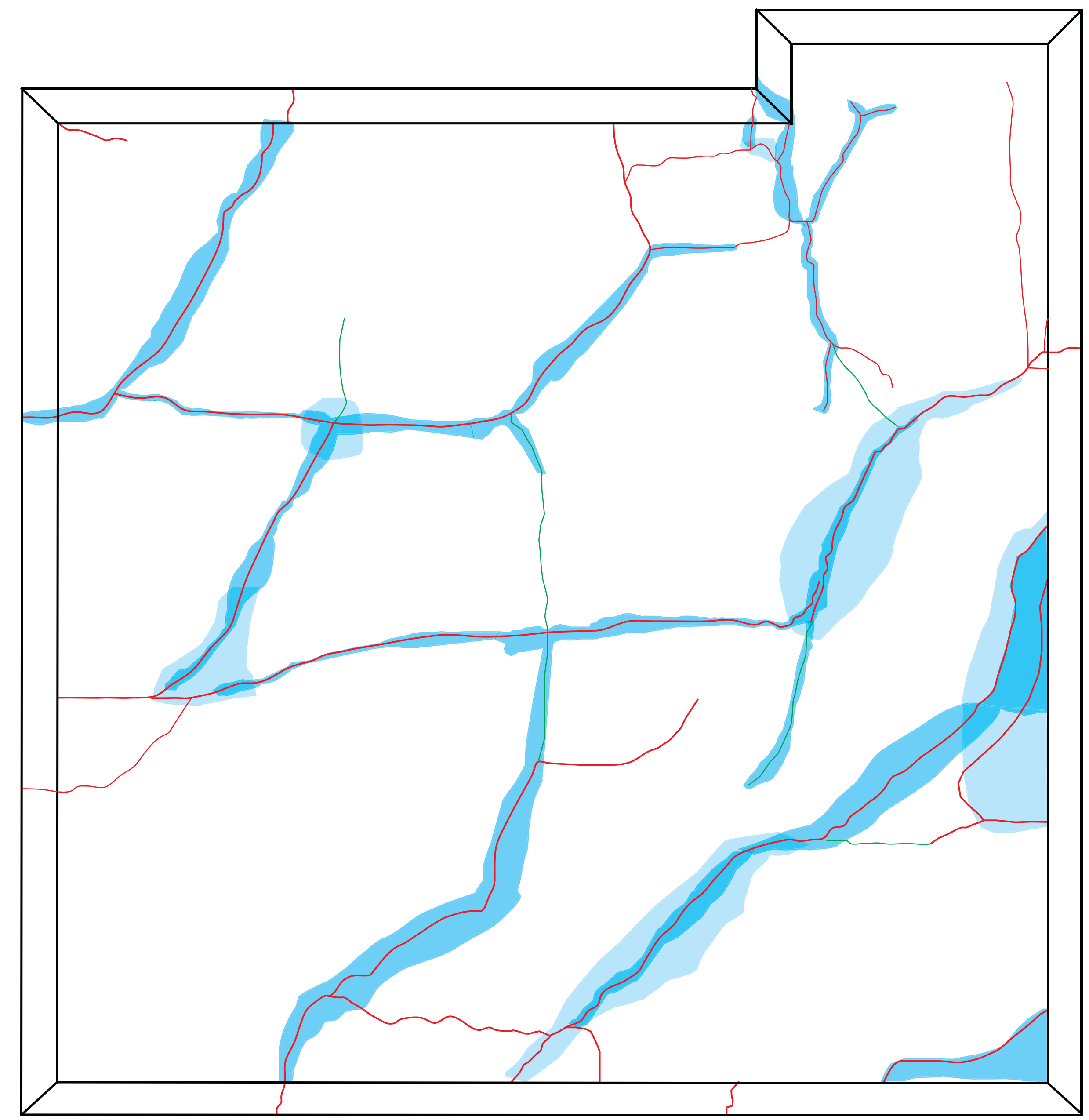
Tactile Assessment



Key:

- detached plaster
- slightly detached plaster
- visible cracks
- cracks discovered during assessment

Infrared Assessment

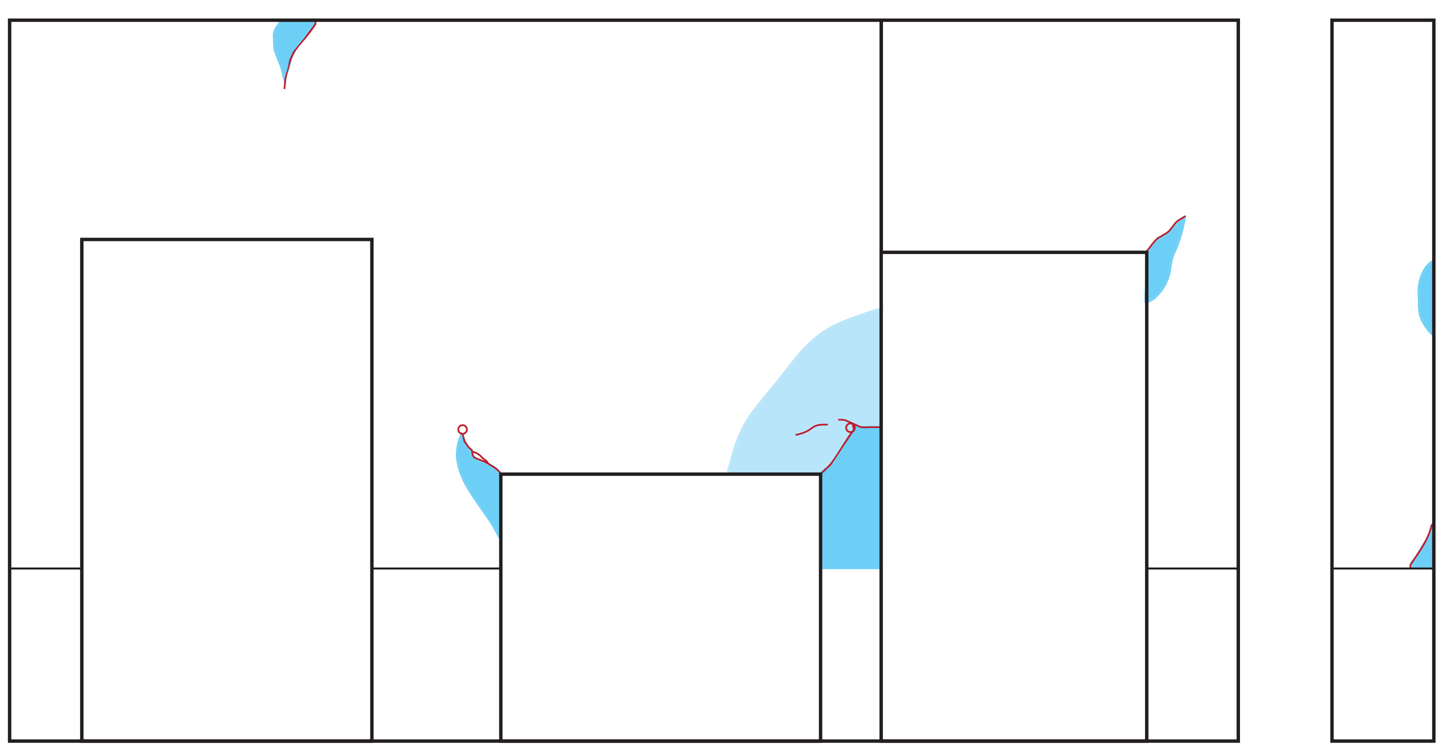


Key:

- detached plaster
- slight temperature differential in plaster- potential indicator of slight detachment
- visible cracks
- cracks discovered during assessment

Southeast Chamber- North Wall

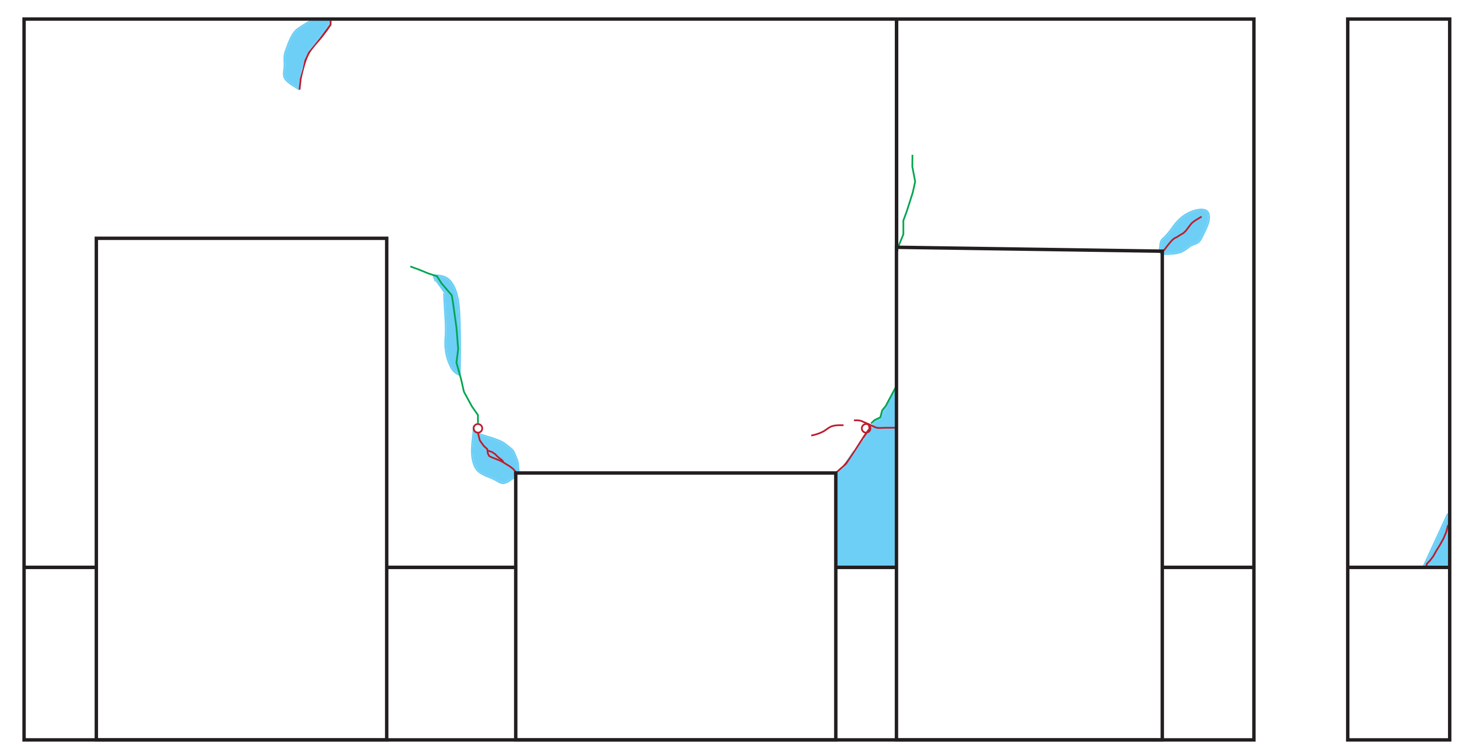
Tactile Assessment



KEY:

- detached plaster
- slightly detached plaster
- visible cracks
- cracks discovered during assessment

Infrared Assessment

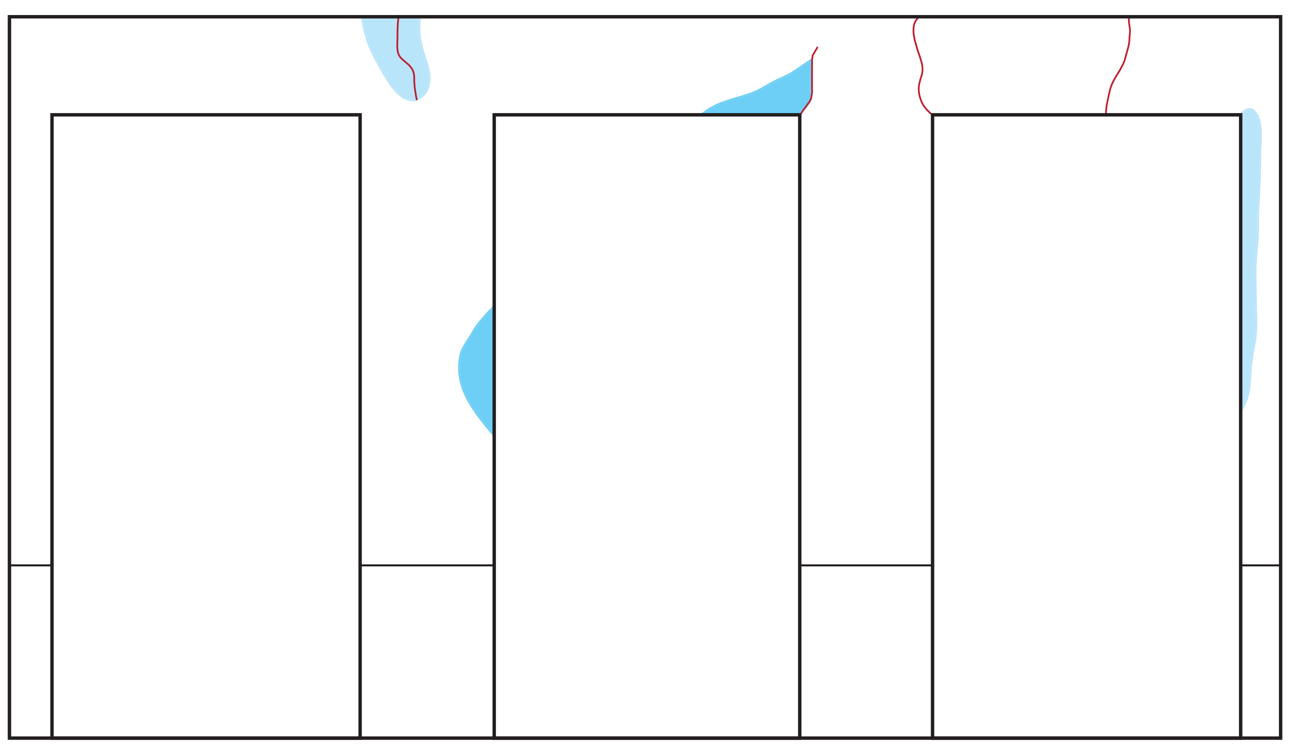


KEY:

- detached plaster
- slight temperature differential in plaster- potential indicator of slight detachment
- visible cracks
- cracks discovered during assessment

Southeast Chamber- East Wall

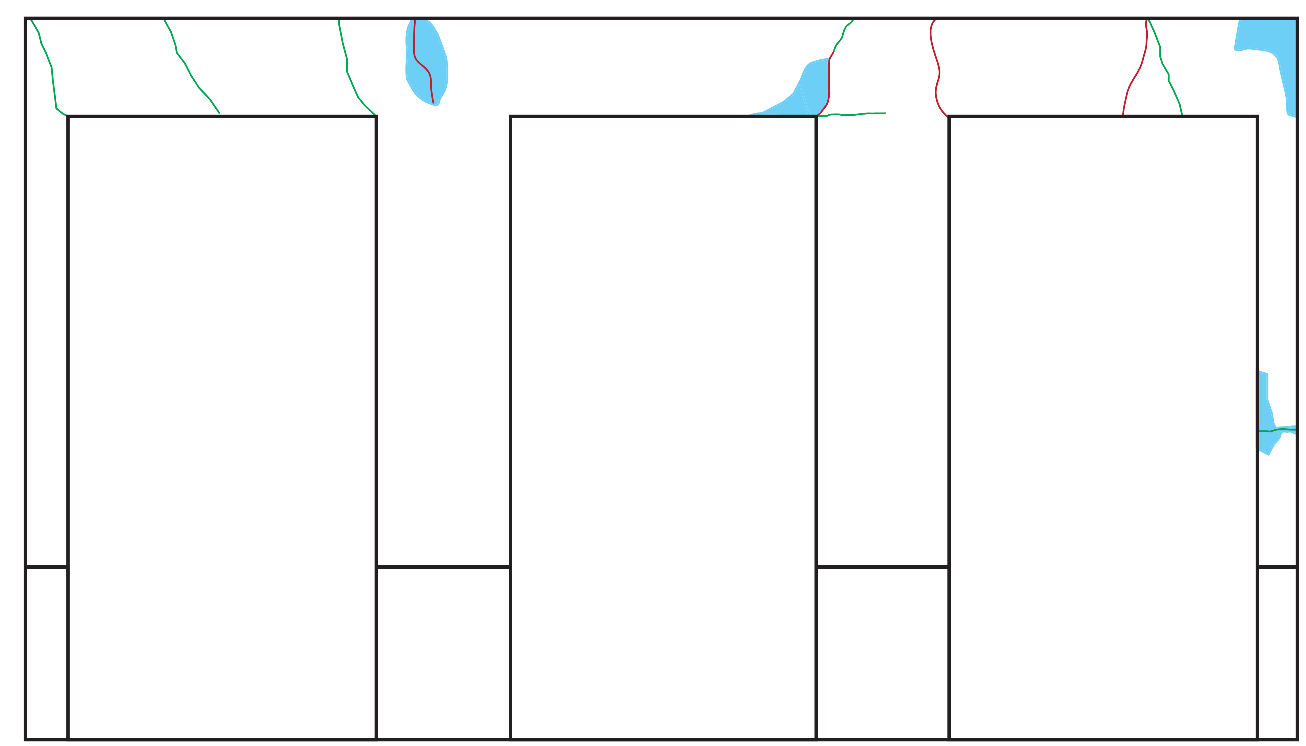
Tactile Assessment



Key:

- detached plaster
- slightly detached plaster
- visible cracks
- cracks discovered during assessment

Infrared Assessment

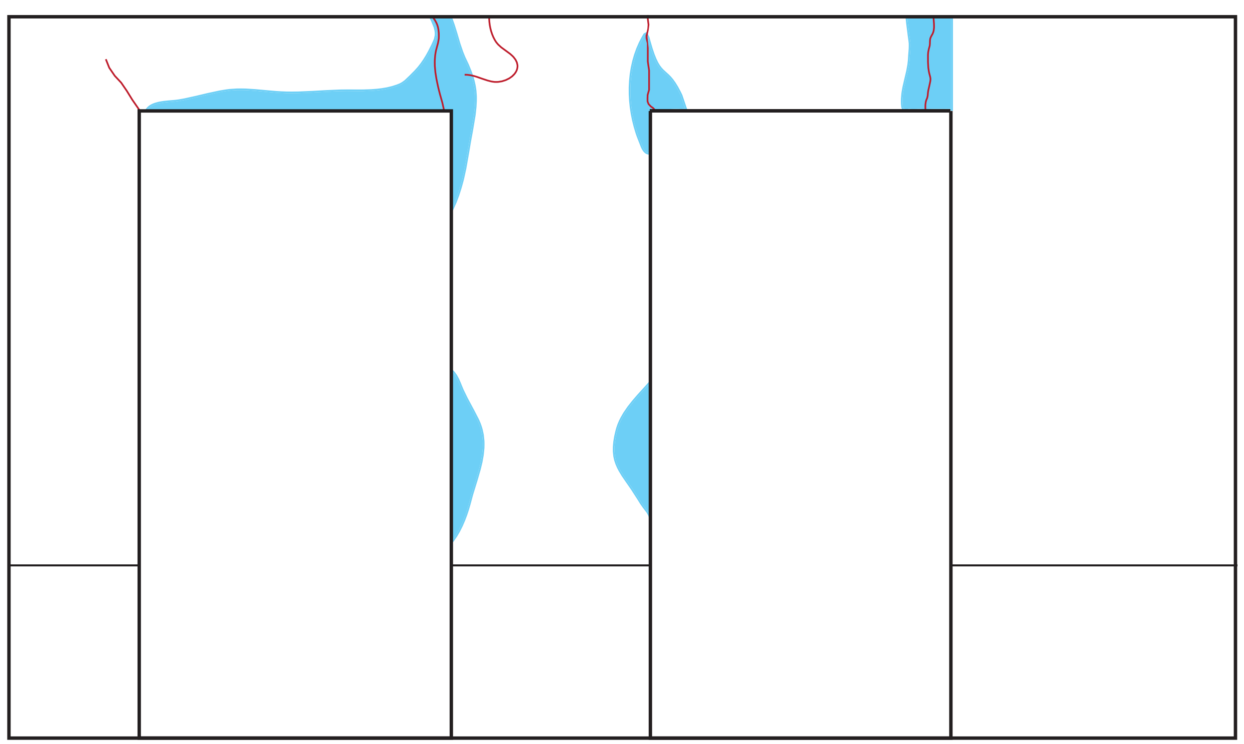


Key:

- detached plaster
- slight temperature differential in plaster- potential indicator of slight detachment
- visible cracks
- cracks discovered during assessment

Southeast Chamber- South Wall

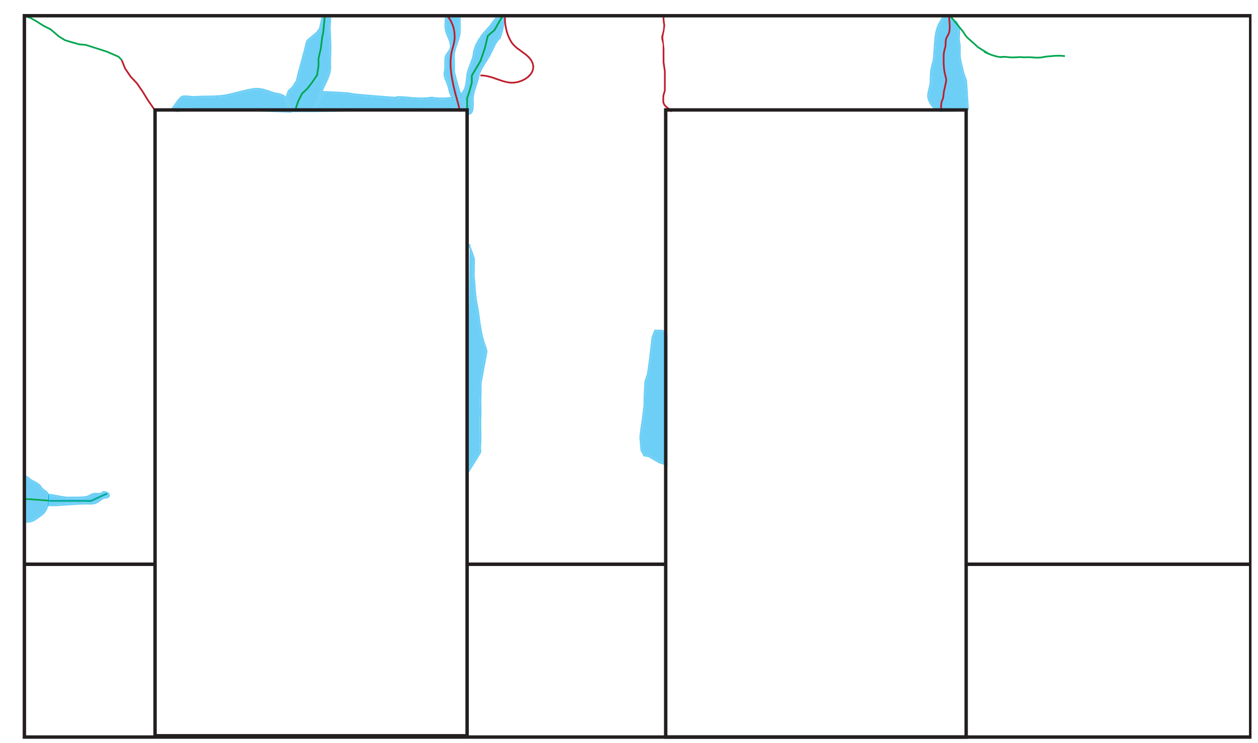
Tactile Assessment



Key:

- detached plaster
- slightly detached plaster
- visible cracks
- cracks discovered during assessment

Infrared Assessment

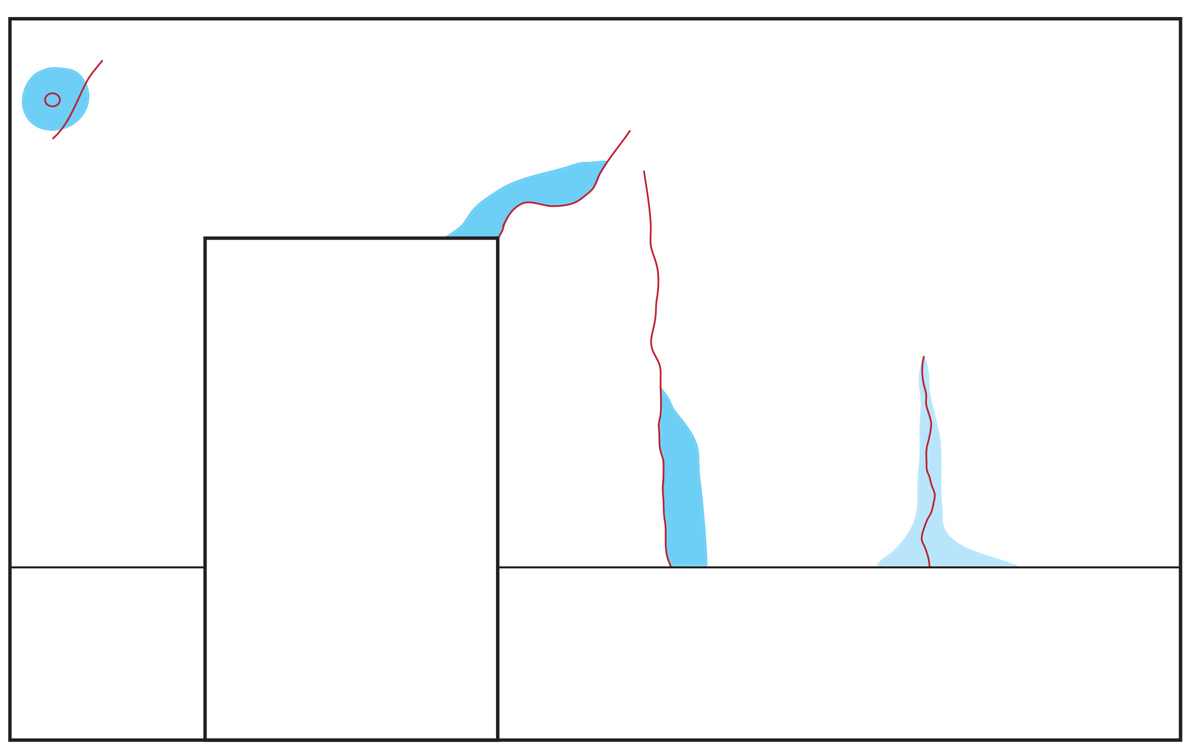


Key:

- detached plaster
- slight temperature differential in plaster- potential indicator of slight detachment
- visible cracks
- cracks discovered during assessment

SOUTHEAST CHAMBER- WEST WALL

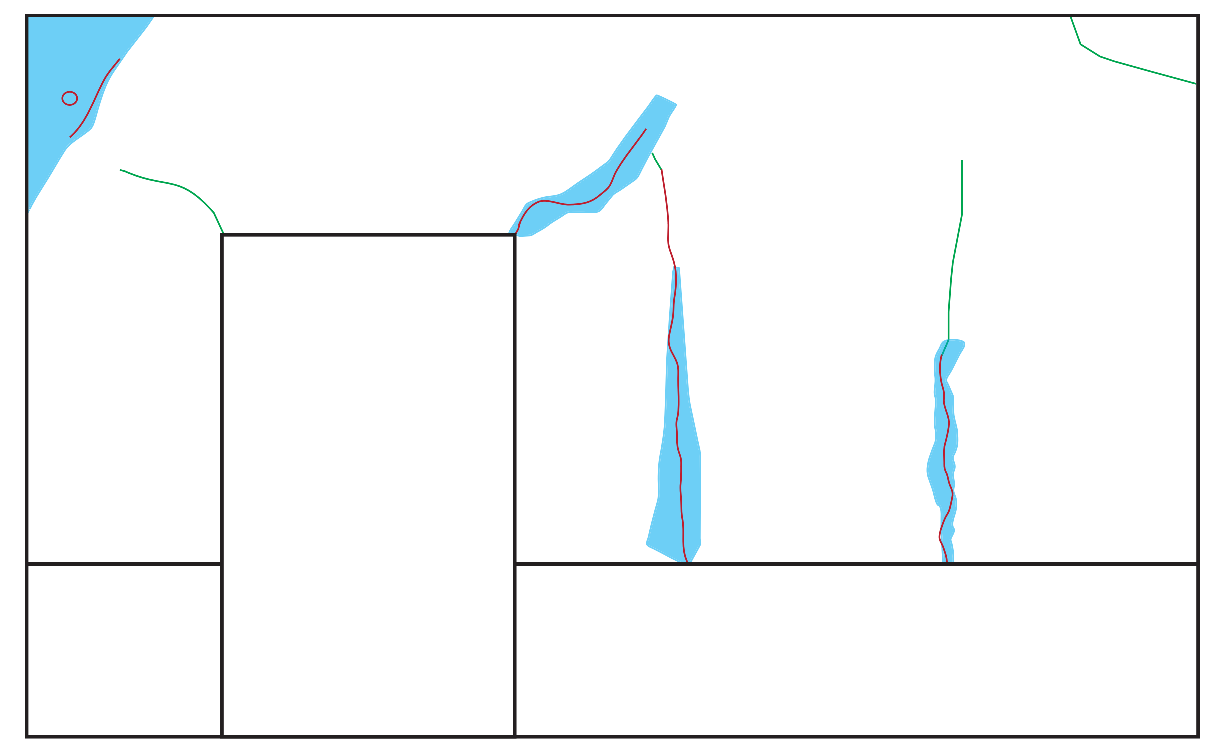
TACTILE ASSESSMENT



KEY:

- detached plaster
- slightly detached plaster
- visible cracks
- cracks discovered during assessment

INFRARED ASSESSMENT



KEY:

- detached plaster
- slight temperature differential in plaster- potential indicator of slight detachment
- visible cracks
- cracks discovered during assessment

Discussion

Tactile Assessment

Tactile analysis was found to be largely successful in differentiating between areas of sound and detached plaster. One difficulty encountered during this analysis was the inability to determine the degree of detachment. Audible differences could only confirm or deny the presence of detachment.

Additionally, due to the physical nature of this technique, this method can cause damage to original finishes and may initiate further plaster detachment. No damage was observed during the course of this study, but this should always be considered before employing this method.

Infrared Assessment

The infrared assessment of both rooms was able to produce a large amount of data within a relatively short time frame.

Passive thermography was quickly able to determine the locations of floor and wall framing members, but could not adequately diagnose thermal differences within the plaster itself. The ability to accurately locate structural and framing members is invaluable when recommending plaster repairs in a historically sensitive environment.

Active infrared thermography was able to successfully diagnose areas of deterioration and cracking, not usually seen in visible light. In the southeast chamber, the immediate benefit of this method was the ability to find cracks that were normally obscured by the finishes. This has great potential to further assess other rooms within the structure with delicate finishes, such as the ballroom.

Assessment via this method did require extensive interpretation of the thermograms to accurately identify and diagnose deterioration. It is possible that a change in the heat source from a conventional hair dryer to a more uniform source could produce simpler data over a larger area. The forced air hair dryer was chosen as it was portable and did not expose the wall and finishes to high temperatures. Infrared heat lamps were tested during the course of this experiment but were not able to adequately heat the surface of the plaster to create a temperature differential. Assessment using a forced air only allowed for localized areas of investigation and was not able to create stable temperature differentials across the full width of the walls or ceilings. Nevertheless, readings via this method were repeatable under varying environmental conditions.

As indicated from tests on the exterior of the structure, infrared thermography may serve as a viable method to assess exterior stucco damage and detachment. Solar radiation plays a larger role than on the interior of the structure, and further study would be needed to determine the optimal time of day to conduct an exterior assessment.

Comparison of Methods

Comparison between the two methods revealed slight differences in the data produced. As illustrated in the respective plaster detachment diagrams, assessment via tactile methods noted a greater degree of deterioration than the infrared assessment. However, it is important to note that with a few exceptions, both types of analysis identified the same areas of deterioration.

Assessment by tactile methods was able to diagnose and document general detachment within the flat surfaces of the room. However, this method has a difficult time differentiating between fully detached and slightly detached areas, where infrared analysis commonly documented slight temperature variations within the plaster, currently believed to indicate phases of detachment. On each thermogram, large temperature increases were seen adjacent to most cracks, indicating detachment in these areas. Additionally, on each image a zone of cooler areas can be seen, possibly indicating a lesser degree of deterioration. However, without further destructive testing, this can not be verified at this time.

The time required to perform each assessment was also drastically different. Assessment of each room using infrared analysis took on average approximately 1.5 hours to inspect all surfaces. Alternatively, tactile assessment took approximately 8-10 hours for each room, not including the time to set up and remove the scaffolding system. This comparison helps illustrate the rapid and cost effective nature of thermography.

Limitations & Sources of error

Limitations

During the course of the IR thermography assessment, the main factors found to affect the thermal behavior of the plaster included:

- *Climatic conditions:* wind, ambient temperature, relative humidity.
- *Pattern characteristics:* emissivity/reflectivity of the plaster and finishes, stains on wall surface, previous areas of repair, thickness of plaster surfaces
- *Environmental deficiencies:* angle of vision and survey distance.

In certain cases, a combination of these factors created false readings in the infrared camera and visual analysis was required to verify the findings. Analysis on wallpapered plaster was found to obscure and over exaggerate the degree of deterioration and cracking on the plaster where the wallpaper had detached form the substrate. Additionally, if thermograms are recorded during the heating phase, thermal gradients can be created that produce erroneous data.

The use of a conventional forced air hair dryer is an easy and low cost method of performing active thermography. However, interpretation of the thermograms created by this type of active heating requires detailed analysis. Images can easily be influenced to create false readings.

Ultimately, non-destructive infrared testing only measures the radiated surface temperature which is influenced by emissivity and reflected radiation. Successful use of this tool and correct interpretation of the temperature maps relies on careful evaluation of the thermal parameters and the historic building materials being assessed.

However, despite these limitations, it is apparent that using infrared thermography to assess historic plaster and stucco does have success under the correct conditions.

Conclusion

Conclusion

Plaster detachment and deterioration is a common concern in historic buildings such as the Aiken-Rhett House Museum. Often obscured by finishes and wallpaper, complete plaster detachment often occurs without warning. The sudden loss of large sections of plaster pose a life safety risk for visitors and creates irreparable loss of historic fabric. The identification of delamination and detachment is a main priority for the preservation of these spaces.

The results from this study indicate that infrared thermography is certainly a viable method for rapidly assessing historic plaster for damage and detachment. As shown within this report, areas of deterioration can visually be located via active thermography when a heat source is applied . This method of heating allows the generation of a thermal gradient for detecting delamination. Preliminary results have also indicated that infrared assessment of exterior stucco is also a potentially viable method of assessing stucco on masonry for detachment and deterioration.

With the proper environmental conditions, large areas of wall surfaces can be surveyed from the ground through the use of IRT to map surface level temperatures. Discrepancies between the infrared and tactile assessment highlight limitations and exaggerations between both methods of analysis. Despite these differences, it is recommended that a combination of both methods can be performed to accurately assess the historic finishes. Based upon our results, preliminary assessments should be conducted using infrared thermography to assess deterioration and locate areas requiring further inspection, which can then be physically surveyed.

IR thermography allows restorers to perform a preliminary map of defects, and identify structural supports for interventions without physically touching the surface. This analysis can also be repeated at specified intervals, allowing for the deterioration to be monitored over time. Areas of repair can be further observed to monitor the results of such interventions.

The use of non-destructive testing and in particular, infrared thermography to assess cultural heritage is a burgeoning area of research within the field of preservation. This study illustrates the importance of evaluating and using this new technology in the field of historic preservation and on historically sensitive sites such as the Aiken-Rhett House Museum.

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