RESEARCH REPORT

Re: Infrared Analysis of Interior Walls at The Alamo Shrine.

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For: William Dupont
    Pamela Rosser, PA AIC, Alamo Conservator

Date: 20 June 2011

This report will address the results of the infrared analysis performed on the interior walls of the shrine at The Alamo in San Antonio, TX. The walls were photographed using an infrared camera to detect moisture in the masonry walls. Locating concentrations of water within the walls, could inform conservation efforts to address deterioration and delaminating of the limestone and plaster finish.

The temperature differentials seen by infrared camera also indicate anomalies in wall composition including voids, joints or breaks in construction. Discovery of these hidden features can lead to greater understanding of past uses as well as chronology of construction.
USE OF INFRARED TECHNOLOGY

Infrared thermography is a non-destructive tool used in building conservation to determine the presence of moisture in masonry walls. The readings of an infrared thermography camera produce an image in color, mapping the differential in temperatures of the surface of the walls. Infrared thermography is used to “gather information about wall construction by detecting very small differences in masonry surface temperature. It is often used to locate subsurface conditions, voids, infilled doors and windows, and variations in moisture in walls.”

Infrared images measure surface temperature, not water content. Moisture can be detected due to the absorption of energy during evaporation. “Each gram of evaporating water absorbs 2,500 Joules (J) of energy, cooling the surface very effectively. Therefore, moist areas are colder than dry ones, assuming the same atmospheric boundary conditions exist across the surface”.

This natural phenomenon depends on several atmospheric conditions, including air temperature, relative humidity levels, air movement and direct sun exposure. “At equilibrium the moist material supplies the water flux, which is related mainly to the porosity of the material and its soluble-salts content.”

Thermal bridges behave as heat sources. They can be visible in an infrared thermal image if enough temperature difference exists between the materials being compared. Areas of higher moisture have lower temperature due to the principle of evaporation. The temperature differentials seen by infrared camera also indicate anomalies in wall composition including voids, joints or breaks in construction.

There are two approaches to produce an infrared thermography analysis, passive and active. In an active approach, the building is heated or cooled artificially in order to create optimal conditions such as temperature and humidity levels. In a passive approach, the building is measured as is, without the use of any artificial cooling or heating methods.

METHODOLOGY

The walls inside the shrine at Mission Valero known as The Alamo were photographed using a FLIR model infrared camera. A passive infrared thermography analysis approach was chosen. The images were taken by Adriana Munoz, Graduate Research Assistant at the UTSA College of Architecture. Since the presence of moisture inside a wall will cause the surface around it to be colder, cold spots could be identified using the infrared images.

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Walls that showed most deterioration and evidence of plaster and stone delamination were selected by Pamela Rosser, PA AIC, Alamo Conservator, to be the objects of this study. The walls analyzed include:

- Wall D Nave
- Wall A Nave
- Wall R Nave
- Wall Q Nave
- Wall N Nave
- Wall M Nave
- South Wall Baptistry
- West Wall Confessional
- West Wall Monk’s Burial Grounds
- East Wall Monk’s Burial Grounds
- North Wall Sacristy
- East Wall Sacristy
A strip of each wall was selected and analyzed from bottom to top. The changes in temperature were then recorded. If a significant change in temperature or a cold spot was identified, the strip was photographed. The individual images taken were then stitched together using Adobe Photoshop, in order to be read as complete images.

As mentioned before, there are several atmospheric conditions that could affect the readings of an infrared analysis. The study was completed using two sets of images taken on different days. The first group of infrared images was taken on May 12th, 2011 from 7:30 am to 10:00 am. Several atmospheric conditions were present that influenced the results obtained, including a high humidity level and a severe thunderstorm. May 12th weather conditions were as follows:

<table>
<thead>
<tr>
<th>Time</th>
<th>Temp.</th>
<th>Dew Point</th>
<th>Humidity</th>
<th>Wind Speed</th>
<th>Gust Speed</th>
<th>Precip.</th>
<th>Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>6:53 AM</td>
<td>77.0 °F</td>
<td>73.0 °F</td>
<td>88%</td>
<td>9.2 mph</td>
<td>-</td>
<td>N/A</td>
<td>Overcast</td>
</tr>
<tr>
<td>7:53 AM</td>
<td>77.0 °F</td>
<td>73.9 °F</td>
<td>90%</td>
<td>5.8 mph</td>
<td>-</td>
<td>N/A</td>
<td>Overcast</td>
</tr>
<tr>
<td>8:53 AM</td>
<td>77.0 °F</td>
<td>73.9 °F</td>
<td>90%</td>
<td>6.9 mph</td>
<td>-</td>
<td>N/A</td>
<td>Overcast</td>
</tr>
<tr>
<td>9:38 AM</td>
<td>66.2 °F</td>
<td>60.8 °F</td>
<td>83%</td>
<td>13.8 mph</td>
<td>35.7 mph</td>
<td>0.00 in</td>
<td>Thunderstorms and Rain</td>
</tr>
<tr>
<td>9:53 AM</td>
<td>66.0 °F</td>
<td>62.1 °F</td>
<td>87%</td>
<td>25.3 mph</td>
<td>35.7 mph</td>
<td>0.03 in</td>
<td>Thunderstorms and Rain</td>
</tr>
<tr>
<td>10:01 AM</td>
<td>64.4 °F</td>
<td>62.6 °F</td>
<td>94%</td>
<td>26.5 mph</td>
<td>43.7 mph</td>
<td>0.12 in</td>
<td>Thunderstorms and Rain</td>
</tr>
</tbody>
</table>

In order to set a frame of comparison, a second group of images was taken on June 7, 2011 from 8:00 am-9:00 am. The same walls that had been previously recorded on May 12th were analyzed and photographed using the same methodology in order to identify the effect of atmospheric conditions on wall temperature. June 12th weather conditions included:

| Max Temperature | 98 °F |
| Min Temperature | 75 °F |
| Dew Point       | 62 °F |
| Average Humidity| 48%   |
| Maximum Humidity| 69%   |
| Minimum Humidity| 27%   |
| Precipitation   | 0.00 in|
| Wind Speed      | 9 mph (ESE) |
The images taken during this study were analyzed and compared to physical observations recorded by Pamela Rosser during conservation efforts to stabilize Mission period plaster on the interior walls of the shrine at The Alamo.

ANALYSIS

The most obvious difference that could be observed was the change in temperature of the walls. On May 12th, the walls were much colder than on June 7th mainly due to atmospheric conditions. On both visits, there were similarities found within some of the walls that were studied. Interior walls had similar temperature ranges and distribution; the same applies for exterior walls.

On the first visit, there wasn’t much change in temperature depending on the orientation of the wall as compared to the second visit when changes were evident. During the first visit, wall temperature ranged between 72ºF and 81ºF. During the second visit, temperature ranged from 81ºF to 94º.

Most walls show a temperature rising evenly and horizontally from bottom to top. In average, walls had a temperature differential of 5ºF to 8ºF from bottom to top. One aspect that was apparent during the second visit was the effect on wall R the A/C units located at the top of walls Q and A has. During the first visit, taking infrared images of wall R was not possible due to the low temperature of the wall and the cold air being blown by the units. During the second visit, photographing the wall was possible due to the higher temperature outside providing a larger differential in temperature of wall R. Creating colder areas within a wall could prevent the moisture inside to evaporate and accumulate. Further analysis of this area is recommended in order to monitor deterioration of stone and plaster on wall R.
Two main areas of interest were identified during the first visit, one in the Sacristy and one in the Monk’s Burial Room:

- On the North wall of the Sacristy, near the northeast corner, a cold spot was identified. Environmental conditions can affect infrared readings and make them inaccurate, but since the north side of the building is most protected from sun rays and wind, a more even temperature of materials might be present at this location. Therefore, the identified area could potentially be storing moisture that by evaporating cools off the surface around it. The recorded temperature around the spot was 76°F. The center of the spot was at 75°F.
During the second visit, the area was re-analyzed. No evidence of the spot or change in temperature around this area could be found. However, limestone delamination and deterioration was found on this area.

- On the West wall of the Monk’s Burial Ground, a particular pattern of temperatures was found on the first visit. Other walls’ temperature changes gradually and horizontally as it goes up. In this wall, a curved line descending from south to north can be observed. The wall below this line is colder than the wall above it. No evident cause was identified and further research might be needed.

  During the second visit, there was scaffolding set in place in the Monk’s Burial Ground room. Although the pieces of steel were interfering with the infrared images, the curved change in temperature was still evident although its position had lowered and the material around the area was warmer.
CONCLUSION

Infrared thermography can be a useful non-destructive tool to identify moisture in masonry walls. The temperature differentials seen by infrared camera also indicate anomalies in wall composition including voids, joints or breaks in construction. Discovery of these hidden features can lead to greater understanding of past uses as well as chronology of construction.

Locating concentrations of water within the walls, could inform conservation efforts to address deterioration and delaminating of the limestone and plaster finish inside the shrine at The Alamo.

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Most of the images captured using the infrared camera, confirm the observations made by Pamela Rosser during her conservation efforts of plaster and murals at The Alamo. According to her observations, most walls show signs of efflorescence on their bottom parts. This is the area the infrared images showed the coldest temperatures on all walls. Therefore, moisture infiltration is higher at the bottom of the walls causing efflorescence.

Serious attention should be given to the effect the A/C units located next to the main entrance have on wall R. Further analysis and monitoring of deterioration of wall R is recommended in order to verify the impact that direct exposure to A/C has on the wall.

As mentioned before, climatic conditions affect thermal images. Some conditions might be present in the walls studied that were not captured by the infrared camera due to the high temperature at the time readings were recorded. A winter time reading is recommended.

REFERENCES


INFRARED PHOTOGRAPHY AND LOCATION DIAGRAMS
West Wall. Monk’s Burial Ground.

May 12th.

June 7th.

West Wall
Monk’s Burial Ground
INFRARED PHOTOGRAPHY AND LOCATION DIAGRAMS
Wall D. Nave.

May 12th.

June 7th.

Wall D
Nave
INFRARED PHOTOGRAPHY AND LOCATION DIAGRAMS
Wall N, Nave.

INFRARED PHOTOGRAPHY AND LOCATION DIAGRAMS
West Wall, Confessional.
INFRARED PHOTOGRAPHY AND LOCATION DIAGRAMS
North Wall. Sacristy.

May 12th.

INFRARED PHOTOGRAPHY AND LOCATION DIAGRAMS
South Wall. Baptistery.

May 12th.
INFRARED PHOTOGRAPHY AND LOCATION DIAGRAMS
Wall M and R. Nave.

Nave
Wall R South Section
June 7th.

Nave
Wall R North Section
June 7th.

Nave
Wall M
June 7th.