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The Application of Infrared Thermography to Condition Assessments of Guastavino Vaulting

ELWIN C. ROBISON (*), CATALINA ESTRADA (**)

SUMMARY. – *Guastavino vaulting has been known to develop delaminations between tile layers. Currently, condition assessments of Guastavino vaulting in North America typically are conducted by tapping each tile separately with a hammer and locating voids between tile layers by sound. This requires significant expense both for the time of the engineer or technician performing the sounding and also for the lift or scaffolding required to access the vault. Infrared thermography (IRT) is able to identify anomalies in the vault remotely, potentially directing engineers to key locations for more detailed investigative study.*

1. Introduction

Catalan vaulting, brought to the United States by Raphael Guastavino Sr., was an important structural technique in the late 19th and early 20th centuries (1). It provided a low cost fireproof structural solution for institutional buildings. Guastavino vaults were initially used for floors, but when the firm was taken over by Raphael Guastavino, Jr., it focused more on decorative applications employing domes and other vaults over large, public spaces.

The standard procedure of structural survey of Guastavino vaults consists of tapping individual tiles to look for delaminations and other structural distress. This technique can be expensive due to the time required, and the expense of providing lifts or scaffolding. Techniques other than direct sounding have been tried on Guastavino vaulting, but only with limited success (2). IRT imaging has great potential for Guastavino vault assessment because imaging can be conducted from the ground level, and large areas can be scanned in relatively small time periods. The successful use of passive IRT imaging to identify features on the

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extrados and internal to the vault demonstrates that IRT imaging can be a cost effective alternative for initial vault surveys, and significantly reduce the need for sounding individual tiles.

2. West Side Market, Cleveland, Ohio

The West Side Market was built in Cleveland, Ohio, in 1912. Constructed when Raphael Guastavino, Jr. controlled the firm, the vaulted ceiling over the main market hall features decorative glazed tiles installed on the underside of the vault (Fig. 1). The vaulted ceiling consists of seven bays, with steel trusses marking the division between each bay. The Guastavino vaults are self-supporting, with the steel trusses carrying all roof loads.

FIG. 1

A view of the main market hall of the West Side Market looking east.

Guastavino vaults are composed of multiple layers of clay tile. Typically the first layer would be installed using gypsum mortar, with subsequent layers of tile laid up using Portland cement mortars. The quick setting gypsum mortar reduced construction time by providing a stable substrate for subsequent tile layers. As adapted by Raphael Guastovino, Jr., later Guastavino vaults, like the West Side Market vault, often had a finish tile layer installed underneath the vault with either decorative or acoustic properties.

3. Application of IRT

The temperature differential between the attic space above the vaulted ceiling and the building interior provides an opportunity to apply passive IRT techniques to the ceiling vaults. In winter months the interior is heated and the attic space is significantly colder, while in summer months solar radiation makes the attic significantly warmer. The heat flux between the intrados and extrados of the vault provides boundary conditions conducive to passive thermography.

Imaging of the vault was conducted during both winter and summer seasons to evaluate the same vault under varying boundary conditions. Imaging of the West Side Market Guastavino vaults was done with a Flir T620 camera. Two different lenses were used in the investigation: a 41.33 mm and 24.9 mm lens, with the former providing a mild telephoto option.

4. Internal Vault Observations

The back side of Guastavino tiles have a ribbed surface, which provides greater contact area with the mortar bed. These ribs are visible in the IRT image in Fig. 2 and are represented by the temperature surface pattern of lighter lines running longitudinally along the tile. Successful identification of these features occurred during winter season imaging when solar heating produced a heat flux through the vault. Identification of such small features on the back of the tile confirm the potential sensitivity of IRT imaging.

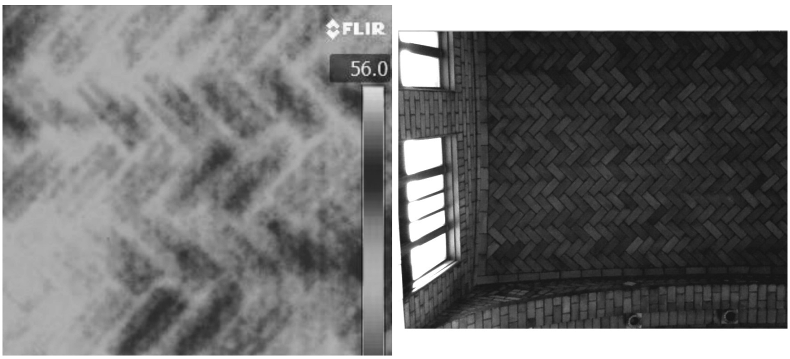

FIG. 2

An IRT image (above) and optical image (below) with the ridges on the back side of the Guastavino tiles registered as stripes on the IRT image.

5. Extrados Vault Observations

Features on the extrados of the vault were also successfully observed. Electrical conduit is supported by 2×4 wood sleepers set on to the vault surface (Fig. 3). A disruption of the heat flux through the vault was observed during summer season imaging with a strong heat flux through the vault. The anomaly visible in Fig. 4 corresponds with the wood sleeper in Fig. 3.

FIG. 3

A view of the extrodos of the West Side Market Guastavino vault showing a wood sleeper supporting electrical conduit (arrow).

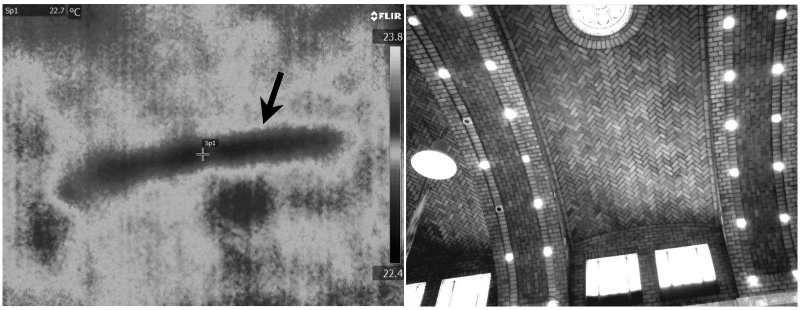

FIG. 4

An IRT image (left) and optical image (right) of the second bay from the west showing a cool anomaly in the IRT image corresponding to the wood sleeper in Fig. 3.

6. Condition Assessment

Two primary types of anomalies important for a conditions assessment were observed. The first type is a cool anomaly which was associated with observed efflorescence in mortar joints between the glazed tiles (Fig. 5). Moisture infiltration from the roof system was not confirmed by water leakage testing, but observed condtions strongly suggest roof leaks as a cause of these anomalies. Give the typical use of gypsum mortars for the first layer of tile during construction, long term leaks on to Guastavino vaults may cause unwanted expansion of gypsum and subsequent vault deterioration. IRT imaging easily locates areas of moisture infiltration on Guastavino vaults.

A second type of anomaly was consistently observed near the corners of about 50% of the vaults. These anomalies were observed during both winter season (Fig. 6) and during the summer season. The Guastivino vaults have an additional layer of tile installed at the perimeter of the vault (Fig. 7). The anomaly occurs at the limit of the additional layer of tile at the perimeter.

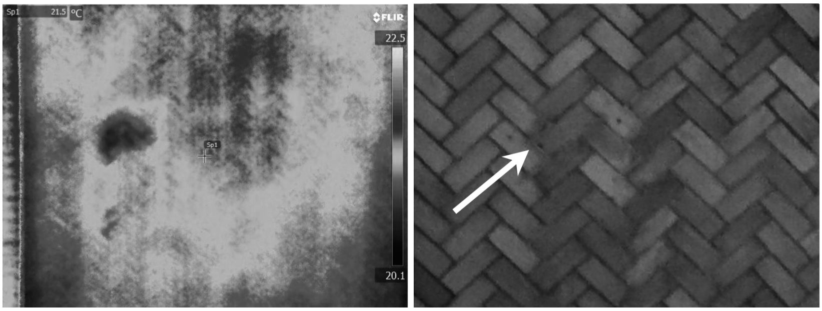

FIG. 5

An IRT image (left) and optical image (right) of the first bay from the west showing a cool anomaly in the IRT image corresponding to an area of efflorescence on the mortar surface.

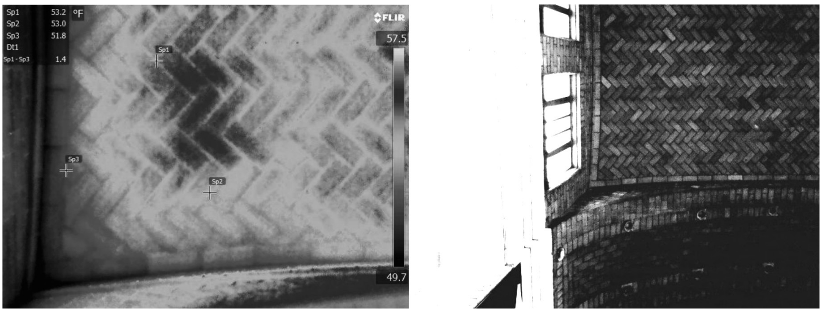

FIG. 6

A view of the West Side Market ceiling vault with the IRT image to the left and the optical image to the right. The image was taken during the winter season, with the anomaly showing as a warm area.

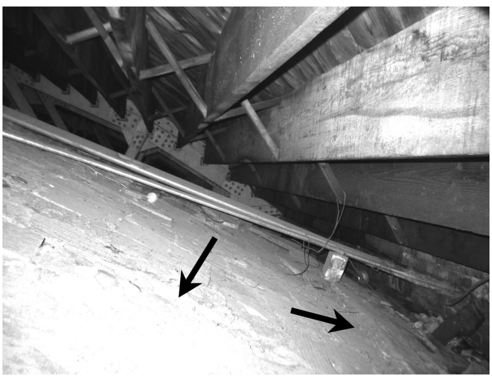

FIG. 7

A view of the West Side Market ceiling vault extrados. The black arrows indicate the limit of the additional layer of tile installed at the perimeter.

No sounding of the vaults was conducted during this preliminary investigation, but it is speculated that the anomalies in the corners of the vault are associated with dimensional changes in the clay masonry. Clay masonry is assumed to undergo moisture expansion following construction of 0.0005 in/in or 0.0000072 mm/mm (3). While the expansion across the 16 feet bay width (4.9 m) is very small, expansion along the 50 feet span (15.4 m) is anticipated to be 1/3 of an inch (3/4 cm). Such expansion following construction likely caused the vault crown to rise slightly, relieving the stress, but at the vault corners such expansion forces would create shear stresses. It is speculated that the observed anomalies are local delaminations associated with the expansion of clay masonry.

7. Conclusion

IRT imaging using ambient temperature conditions can locate internal vault structures as well as elements on the extrados of Guastavino vaults, especially in vaults underneath unheated attics with strong temperature variations relative to the building interior. IRT is particularly well adapted to locating evidence of moisture infiltration, but it also appears to have the ability to identify vault delaminations and other distress. Identifying the location and frequency of anomalies prior to hand-on sounding of vault tiles can significantly reduce the cost of later hands on condition assessments by engineers.

REFERENCES

(1) For an overview of Guastavino vaulting, see John Ochsendorf, Michael Freeman, *Guastavino Vaulting: The Art of Structural Tile*, (Princeton Architectural Press, Princeton NJ, 2010).

(2) See for example, Kelly Streeter, Kent Diebolt, *Ultrasonic Investigation for the Characterization and Evaluation of Guastavino Vaults: A Pilot Study*, paper presented at the Construction History Society of America 3rd Biennial Meeting, available at http://architecture.mit.edu/class/guastavino/Diebolt-Streeter--Ultrasonic-Investigation.pdf (accessed 19 July 2014).

(3) *Volume Changes. Analysis and Effects of Movement*, Technical Bulletin 18, Techn. Notes on Brick Construction, Brick Industry Association, 1850 Centennial Park Drive, Reston, Virginia, pp. 1-9, 2006.

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