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Methodology for monitoring cracking in historical wattle-and-daub ceiling slabs using Infrared Thermography

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1 Abstract

Wattle-and-daub ceiling slabs, common in Europe until the early 20th century, are highly prone to cracking and plaster detachment. This study assesses the use of active, quantitative infrared thermography to detect and characterize such cracks, distinguishing between superficial and through-thickness damage by analyzing thermal responses to low-intensity heating, while maintaining a workflow consistent with realistic diagnostic practices in heritage environments. The approach combines step heating and lock-in thermography to obtain qualitative anomaly maps and depth estimates. It introduces a new acquisition protocol that utilizes temporary room depressurization to enhance thermal contrast, along with an improved dynamic signal-analysis algorithm. The outcome is a reliable, contact-free procedure for monitoring degradation in wattle-and-daub slabs, suitable for large or hard-to-access areas, supporting conservation planning.

Keywords: Active IRT, Wattle-and-Daub Ceilings, Crack Detection, Heritage Conservation

2 Introduction

Wattle-and-daub ceilings [1] are challenging to inspect due to limited access and large surface areas, making conventional inspections slow and impractical. Common degradations - such as timber deformation, plaster cracking, and detachment - are difficult to detect without scaffolding or contact tools. Infrared thermography (IRT) offers a contact-free, repeatable solution, with active and quantitative IRT improving sensitivity and reliability [2,3,4,5,6]. This study develops and validates active IRT methods for historic wattle-and-daub ceilings, enabling distinction between superficial and through-thickness cracks for preventive conservation. The stratigraphy of wattle-and-daub ceilings consists of a primary and secondary timber framework, a woven cane mat attached to the structure, lime- and gypsum-based plaster coatings, and decorative finishes.

3 Methodology and Experimental Setup

The common approach to crack detection by active IRT applies a controlled thermal stimulus to create transient temperature responses that reveal subsurface defects via variations in thermal inertia or heat flow. Step heating from an electric heater near the ceiling generates transient temperature distributions; heating and cooling sequences are recorded at high temporal resolution for later signal processing. This methodology has been tested and the results established as a baseline for comparison with the novel contribution of this study: the introduction of low-level depressurization as active stimulus. By slightly reducing indoor air pressure, airflow across micro-cracks increases, producing localized thermal perturbations that increase the thermal contrast associated with through-thickness cracks. Both methods were tested in a climatized laboratory room with controlled air and wall temperatures. A wattle-and-daub ceiling mock-up was built using plaster and cardboard slabs forming an interstitial cavity. Artificial cracks were introduced

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as 7 cm–long cuts with three different depths: (1) a superficial scratch, (2) a non-penetrating crack through the plaster, and (3) a full-thickness cut reaching the woven support. The active IRT setup included an infrared camera (FLIR SC660) and a controlled thermal stimulus (2 kW heater) applied to the inner surface. To ensure compatibility with heritage materials, surface temperature increases were kept below about 5°C above equilibrium.

4 Results

Processed thermal sequences show that the surface-heating method (Fig. 1b) detects the two deeper crack types, confirming that superficial cracks do not produce false positives. Depressurization (Fig. 1c) clearly enhanced crack visibility, enabling effective depth discrimination, as only full-thickness cracks were detected. This method minimizes false positives and artefacts from uneven heating.

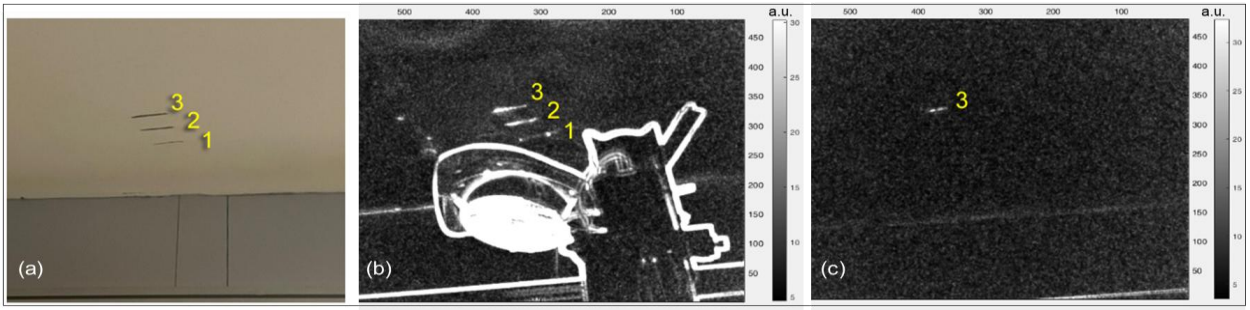

Fig. 1. Visible image (a); processed result from the surface-heating sequence (b); processed result from the depressurization sequence (c).

5 Conclusions

The study presents an applicable and repeatable methodology for diagnosing cracking and delamination in historical wattle-and-daub ceilings. The integration of active IRT, room depressurization, and the MSA algorithm represents a significant advancement, enabling accurate crack-type discrimination while preserving material safety. The approach and methodology are proved in laboratory and will be validated in selected rooms of Casa dell'Angelo, a historic building containing representative wattle-and-daub ceiling systems.

References

1. Quagliarini, E., D'Orazio, M.: Recupero e conservazione di volte in "camorcanna". Dalla "regola d'arte" alle tecniche di intervento, Editrice Alinea, Firenze (2006).
2. Maldague X. P. V.: Theory and practice of infrared technology for nondestructive testing. John Wiley & Son Inc, New York (2001).
3. Grinzato, E., Cadelano, G., Bison, P., Petracca, A.: Seismic Risk Evaluation Aided by IR Thermography. In: Burleigh D.D., Dinwiddie R.B. (eds.) Thermosense XXXI, vol. 7299, pp. 103-114. SPIE, Orlando USA (2009).
4. Bortolin, A., Cadelano, G., Ferrarini, G., Bison, P., Peron, F., e Trevisani, S.: IR Thermography and Geophysical Survey Applied to the Retrofit of an Ancient Church. In: 9th International Symposium on the Conservation of Monuments in the Mediterranean Basin, pp. 1-8. Ankara Turkey (2014).
5. Maierhofer, C., Röllig, M., Krankenhagen, R., Myrach, P.: Comparison of Quantitative Defect Characterization Using Pulse-phase and Lock-in Thermography. Applied Optics 55(34), pp. 76-86 (2016).
6. Theodorakeas, P., Koui, M.: Depth Retrieval Procedures in Pulsed Thermography: Remarks in Time and Frequency Domain Analyses". Applied Sciences 8(3), (2018).