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Forensic Engineering Minimally Invasive Testing For Water Intrusion Using Infrared Technology

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Abstract

Infrared technology is gaining popularity in the identification of water intrusion damage to building wall systems due to its ability to pinpoint the exact locations of anomalous conditions that may be indicative of damage without wholesale deconstruction. However, the common method of utilizing infrared technology to identify this water intrusion damage relies entirely on the ability of the thermographer to correctly identify this damage without any verification as to the accuracy of these findings. The approach proposed herein to identify the extent of water intrusion damages to wood frame structures incorporates a program of infrared imaging combined with limited destructive sampling. By mapping the entire structure using infrared imaging, or thermography, the thermographer is able to identify the areas within the exterior surface of the subject structure evidencing atypical temperature variations. Once identified, these temperature variations, or thermal patterns, are assessed using a knowledge of wood frame construction, experience in the identification of water intrusion, the science of thermography, and selective destructive sampling. Once assessed, these thermal patterns are categorized as either indicative of underlying damage or otherwise. Utilizing this approach, the thermographer is able to accurately identify the extent of water intrusion and/or related damage and thereby provide accurate findings while eliminating the need for wholesale deconstruction.

Keywords

Infrared Thermography, Deconstruction, Water Intrusion, Hidden Damage, IR Survey

Current Methodology

The current methodology in identifying water intrusion damage involves one of the following approaches: 1) the wholesale removal of a building's exterior cladding in order to definitively locate all underlying water intrusion damage, or 2) utilizing infrared images to locate areas of suspected water intrusion and/or related damage (thermal anomalies) with no further investigation. The first approach,

Photo 1
Wholesale Skinning of a Structure's Exterior

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while 100% accurate in identifying all areas of damage, is prohibitively expensive and in many cases unacceptably intrusive. The second approach relies entirely on the abilities of a thermographer to correctly interpret the thermal images and identify water intrusion damage without verification or correlation that all damage has been correctly identified. Photo 1 depicts a structure in the process of having its entire exterior skin removed for the purpose of identifying and repairing underlying water intrusion damage.

Non-Destructive Data Collection

The thermographic mapping approach proposed herein involves capturing infrared images from varying distances and varying angles, capturing corresponding digital images, recording atmospheric conditions, and recording sources of thermal variations readily identifiable in the field as being indicative of something other than water intrusion related. Specifically, the mapping is to consist of:

1) Infrared images are taken of exterior wall surfaces
   a) Initial infrared images are taken from a distance of approximately 25 to 35 feet. Sequential images are overlapped so as to provide multiple images of every surface area from varying angles
   b) If thermal patterns are observed, additional infrared images of these areas are taken at a distance of 10 to 25 feet. The angle from which this image is taken is required to differ from the angle from which the previous long range image was taken when practicable
   c) Regardless of whether thermal patterns are observed, areas of typical water intrusion such as the perimeters of window openings and roof/wall interfaces are thermographically investigated and additional infrared images are taken from a distance of 10 to 25 feet
2) Every infrared image taken is to be accompanied by a standard digital image taken from the same vantage point. The thermal image file number assigned by the Infrared camera is documented within the field notes with a brief description of the location as well as the distance between camera and subject
3) Sources of thermal variations readily identifiable in the field as being indicative of something other than water intrusion damage are recorded

Non-Destructive Data Evaluation

The initial thermographic mapping provides the thermographer with the images necessary to identify temperature variations, or thermal patterns, within the exterior surfaces of the subject structure. Utilizing a knowledge of wood frame construction, experience in the identification of water intrusion, the science of thermography, and selective destructive testing, the thermographer is able to eliminate certain thermal patterns attributable to sources other than water intrusion damage. Such typical thermal patterns include: crawl spaces or cavities between floor levels, the intersections of wall framing between adjacent rooms/units, wall areas directly adjacent to reflective surfaces such as metal roofs and thermal patterns resulting from shadows, attic ventilation, active dryer vents, recent sprinkler activity, or morning dew accumulation.

Once thermal patterns attributable to sources other than water intrusion damage are eliminated, the remaining thermal patterns are classified as thermal anomalies potentially attributable to either saturation or water intrusion damage. Photo 2 is an Infrared image demonstrating an anomalous thermal pattern at the bottom left corner of the window opening where reflection from adjacent metal roofing has affected the apparent surface temperature of the lap siding. This potential "false positive" was confirmed by the destructive testing performed at the interior face of this wall (Photo 3) where no water intrusion damage was found.

Photo 2
IR Image of Anomaly

Photo 3
View From Within Wall Cavity

The infrared camera is able to detect anomalous conditions consistent with moisture within the wood members underlying the exterior wall cladding due to the fact that the presence of moisture affects the rate of heat transfer between the individual components of the exterior wall construction. Furthermore, the infrared camera is able to detect potential degradation of wall sheathing due to the fact that this degradation disrupts the continuous path through sequential layers of building materials which subsequently affects the rate of heat transfer between individual components of the exterior wall construction. These mechanisms, referred to as thermal bridging, occur according to the thermodynamic principle that heat always flows towards areas of lower temperatures. These conditions are detected as a subtle variation in surface temperatures of the wall cladding. The fact that wall cladding materials on residential structures are typically comprised of materials such as cementitious stucco or cement composite siding boards, both of which having high capacities to emit energy by radiation (emissivity), contributes to the facilitation of water intrusion and damage detection.

Photo 4 shows a view of the Infrared image of a thermal anomaly detected at the bottom left corner of the window opening where water intrusion damage (deteriorated sheathing) was confirmed during limited destructive testing as viewed in photo 5.

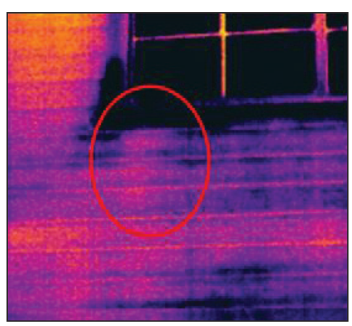

Photo 4
IR Image of Anomaly

Photo 5
View of Damaged Sheathing

However, while the infrared camera is able to detect conditions consistent with elevated moisture levels within wood frame walls or deterioration of the wood members within wood frame walls, it is not able to detect staining on the wood members within the walls which no longer contain elevated moisture levels and which have not experienced significant section loss. This is not considered to be problematic as given the lack of structural damage, simple remedial measures to prevent further water intrusion are all that is warranted.

Photo 6 shows a view of an Infrared image demonstrating no significant thermal anomaly at the bottom left corner of the window opening whereas minor staining and surficial damage of the underlying wall sheathing was discovered during limited destructive testing as viewed in photo 7.

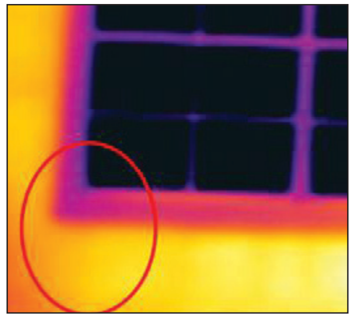

Photo 6
IR Image showing no Anomaly

Photo 7
View of Sheathing

Minimally Invasive Sampling

Subsequent to the thermographic mapping, destructive testing is performed on a limited number of areas within the exterior walls of the subject structure. In so doing, the thermographer is able to establish a correlation between the thermal anomalies observed during the thermographic mapping and actual damages discovered during destructive sampling. By correlating the thermal images with limited destructive sampling, the thermographer is able to eliminate regions with anomalous thermal patterns which prove to be indicative of either non-structural damage or no damage. However, this is only possible when the thermographer is able to coordinate the destructive sampling effort with the thermal mapping and subsequently target these regions with anomalous thermal patterns.

The selection of the locations for the limited destructive sampling must be determined in such a way so as to allow the thermographer the ability to eliminate thermal patterns that are attributable to sources other than water intrusion damage as well as identify thermal anomalies indicative of underlying damage. The number of sampling locations can be minimally obtrusive but must represent each unique condition represented by the subject structure(s).

Photo 8 provides an example of water intrusion damage repair where wholesale removal of the exterior cladding was avoided by utilizing a system of Infrared imaging combined with limited destructive testing.

Photo 8
Selective Skinning of a Structures Exterior

Conclusion

In summary, infrared mapping in conjunction with limited destructive sampling is not only reliable in the identification of underlying water intrusion and damage to wood frame structures but also cost effective and minimally intrusive. Proper coordination of limited destructive sampling with the thermal imaging only serves to better eliminate temperature variations that are not indicative of underlying water intrusion or damage (i.e. false positives). Given that these thermal variations would otherwise be incorrectly identified as thermal anomalies and potentially identified as areas of underlying water intrusion or damage, the destructive testing provides for a more accurate assessment resulting in a more cost effective and less intrusive damage repair regimen.

Case Examples

We have developed standardized approaches and methodologies based on the science of infrared thermography that when followed have helped to bring cases to resolution. In particular these standardized approaches and methodologies have enabled us to assist in settlements being reached with regards to claims.

With regard to cases that that address the use of IR technology we offer the following:

KYLLO *v.* UNITED STATES in the United States court of appeals for the ninth circuit, No. 99-8508. Argued February 20, 2001--Decided June 11, 2001

This was a case that was based in part on the legality of the use of IR technology when conducting search and/or surveillance. Given that the criminal and civil courts have found IR technology to be reliable, the courts are merely faced with determining its legality and applicability.

In their brief, FindLaw, a Thomson Reuters company wrote: Suspicious that marijuana was being grown in petitioner Kyllo's home in a triplex, agents used a thermal imaging device to scan the triplex to determine if the amount of heat emanating from it was consistent with the high-intensity lamps typically used for indoor marijuana growth. The scan showed that Kyllo's garage roof and a side wall were relatively hot compared to the rest of his home and substantially warmer than the neighboring units. Based in part on the thermal imaging, a Federal Magistrate Judge issued a warrant to search Kyllo's home, where the agents found marijuana growing. After Kyllo was indicted on a federal drug charge, he unsuccessfully moved to suppress the evidence seized from his home and then entered a conditional guilty plea. The Ninth Circuit ultimately affirmed, upholding the thermal imaging on the ground that Kyllo had shown no subjective expectation of privacy because he had made no attempt to conceal the heat escaping from his home. Even if he had, ruled the court, there was no objectively reasonable expectation of privacy because the thermal imager did not expose any intimate details of Kyllo's life, only amorphous hot spots on his home's exterior.

Therefore, because the courts have found IR technology to be reliable its the legality and not the legitimacy of using IR technology that one must address.

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