Localization of wood floor structure by infrared thermography

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ABSTRACT

One of our industrial partners, Assek Technologie, is interested in developing a technique that would improve the drying process of wood floor in basements after flooding. In order to optimize the procedure, the floor structure and the damaged (wet) area extent must first be determined with minimum intrusion (minimum or no dismantling). The present study presents the use of infrared thermography to reveal the structure of (flooded) wood floors. The procedure involves opening holes in the floor. Injecting some hot air through those holes reveals the framing structure even if the floor is covered by vinyl or ceramic tiles. This study indicates that thermal imaging can also be used as a tool to validate the decontamination process after drying. Thermal images were obtained on small-scale models and in a demonstration room.

Keywords: infrared, thermography, wood floor, flooding, basement, wet area detection.

1. INTRODUCTION

Restoration of a flooded basement may cost thousands of dollars. According to CMHC [1], they are up to 40 000 reported cases of basement flooding in Canada each year. Damages resulting from a flooded basement typically range from $3000 to $5000, but can also be a lot more. Furthermore, in addition to the mess and inconvenience, flooding can cause health hazards, and lead to structural damages.

In most cases to fix the damages, wood floors in flooded basements are to be removed completely. Our industrial partner offers a viable alternative to demolition: drying the wood structure with fans which circulate hot dry air under the floor. Good drying performance is obtained depending on the air volume that flows under the floor, its velocity and its temperature.

Because the direction in which the airstream flows is very important in the drying process, the floor framing structure must first be determined. Direct inspection using probes is not always the best approach because it involves puncturing the floor in many places while such an approach means also spending a lot of time mapping the floor and determining the extent of the damages.

1.1. Proposed approach

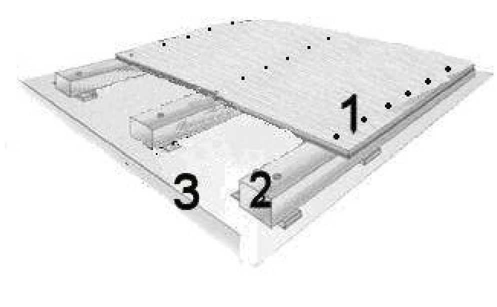

Fig.1. Standard structure of a wooden floor. 1.Plywood 5/8'; 2.Spruce Joist; 3. Concrete.

Since specific heat capacity of water is much higher than the one of wood [2][3], it means that water must receive more energy than wood (through heat transfer) to raise its temperature of a unit mass by one degree. The system formed by

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the concrete floor, the wood floor (Fig.1) and ambient air reaches a heat equilibrium point that is modified by the sudden added moisture due to the flooding. Infrared thermography enables to detect the abnormal temperature equilibrium resulting from flooding and thus the given extent of the wet damaged area thanks to the temperature difference between dry and wet area. In this study, infrared images were taken with a Micro A10 infrared camera sensitive in the 8-12 µm band. It should be noted that images taken by this camera are not temperature calibrated, they only show the temperature gradients (Fig.2).

Fig.2. Micron A10 IR Camera.

The proposed novel approach thus involves inspection by infrared thermography in combination with minimal direct inspection. The idea is that a qualitative (or quantitative) image of the pointed surface is quickly obtained with an infrared camera.

2. PRELIMINARY STUDY OF FLOOR MODELS

Several small-scale floor models were built. In Fig.3, two models measuring 2ft x 4ft with a 16-inch gap between joists are shown.

Fig.3. Models 2 (right) and 3 (left).

Before the infrared images were taken, the models stayed in water for a period of 8 hours. Only the joists came in contact with water and only one half of each model was kept wet. Ambient temperature in the chamber was approximately 24°C and floor temperature was 19°C. Moisture content measurements were taken with a conventional wood moisture meter. An absolute temperature was recorded using a Mikron MI – N14+ pyrometer.

Fig.4 shows models 2 and 3, after they were taken out of the water and put on a colder floor (of temperature 15°C). The conditions of this experiment were: floor temperature 15°C, ambient temperature 19°C, model surface moisture content 11%, dry joist moist content 11%, wet joist moisture content 25%.

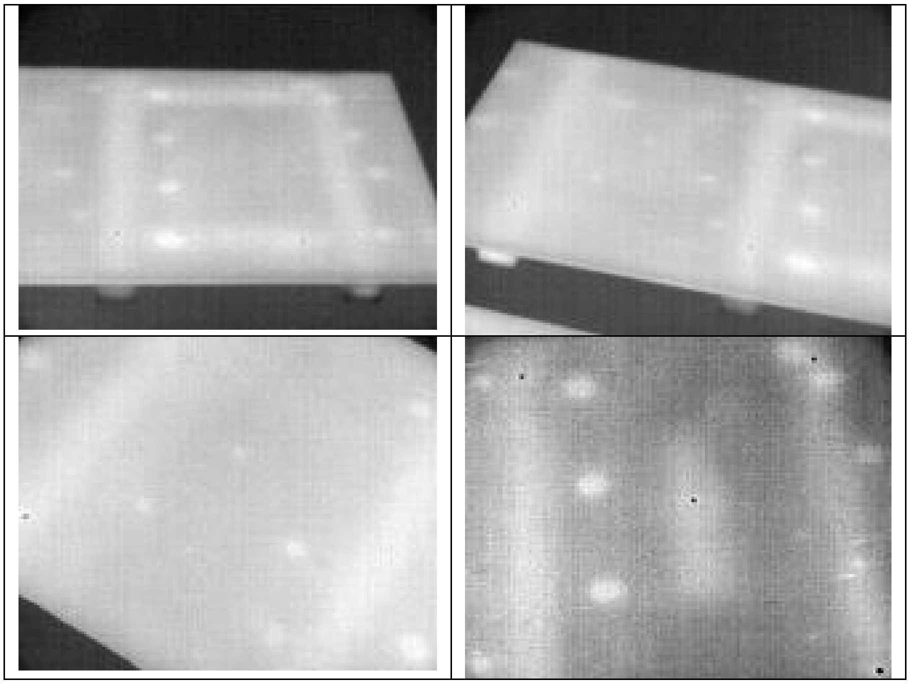


Fig.4. Models 2 (bottom) and 3 (top) on the cold floor.

As seen in Fig.4, the wood floor framing structure is clearly visible in infrared. By moving the structures from a warm floor to a colder floor the heat balance was broken and temperature gradients became visible to the infrared camera thus revealing the frame structure.

Fifteen minutes later, new images were taken (Fig.5). A careful study of this figure indicates that the two joists on the right (the wet ones) are colder (they appear darker in the infrared images).

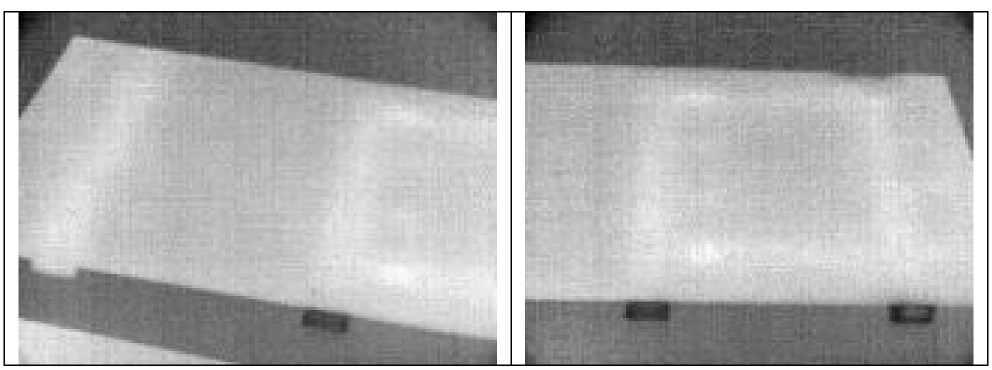


Fig.5. Model 3 after 15 minutes.

When looking at the surface however, it is impossible to differentiate the wet joists from the dry ones. Half an hour later, the plywood surface reached its new heat balance point and the floor structure was invisible to the infrared camera (Fig.6). Plywood, which is a composite material, acts as a good insulating material because it was kept dry. It can be seen that wet joists still appear darker in the image.

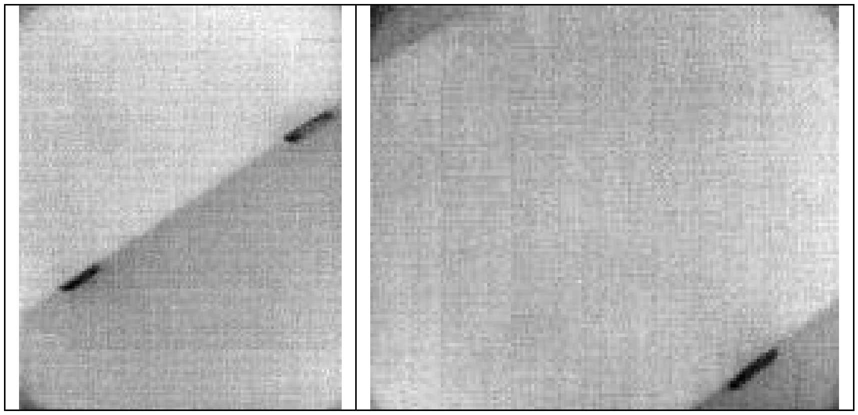


Fig.6. Models 2 and 3 after 30 minutes.

Three days later, the structures were reinstalled in the same chamber. Moisture content and temperature measurements were taken again: floor temperature 20°C, ambient temperature 24°C, model surface moisture content 12%, dry joist moisture content <10%, wet joist moisture content 15%.

Like the first time, heat balance was broken when the structures were laid into contact with a warmer floor (Fig.7): the wood floor structure becomes again clearly visible. However, as soon as the heat balance point is reached, the underlying structure becomes invisible to the infrared camera (Fig.8).

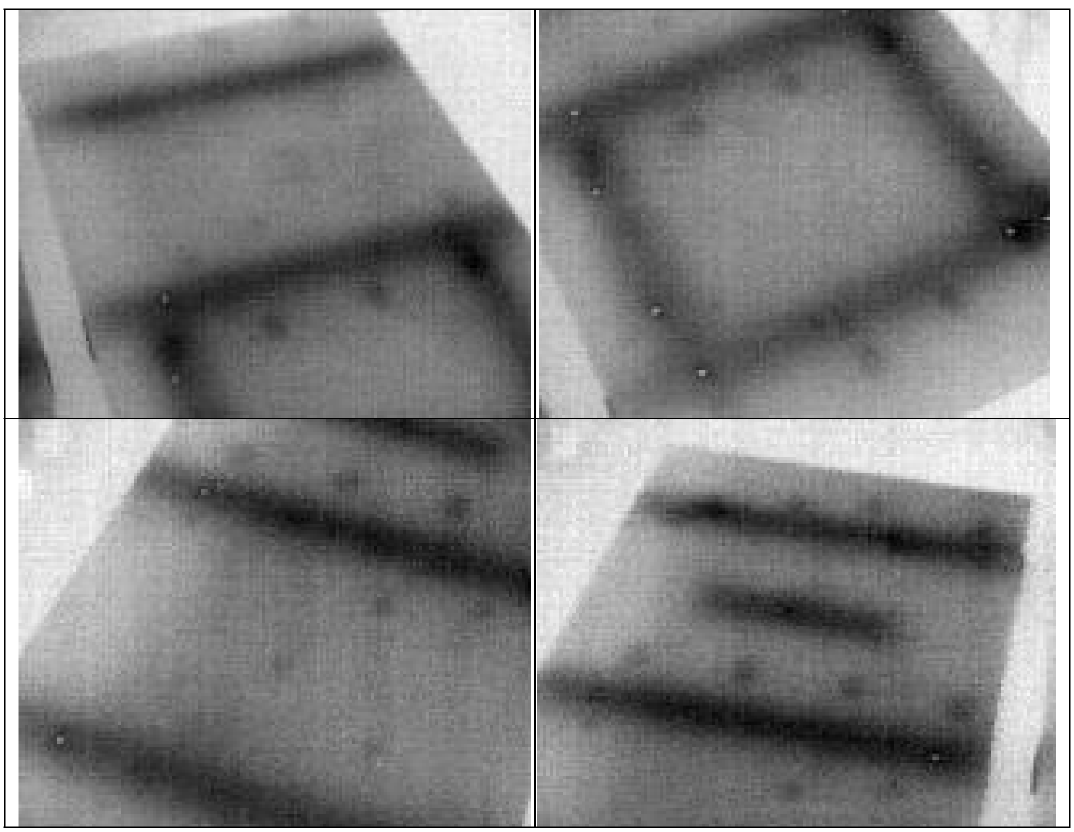


Fig.7. Models 2 (bottom) and 3 (top) on warm floor.

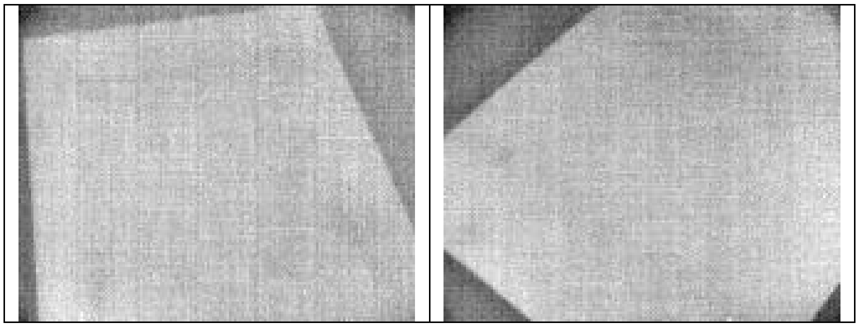


Fig.8. Models 2 (right) and 3 (left) after an hour.

3. DEMONSTRATION CHAMBER

To help conduct further investigations, our industrial partner, Assek Technologie, provided a test basement: this chamber is about 17 ft long and 12 ft wide.

The wood floor framing structure is shown in Fig.9. As shown, the wood floor joists do not rest directly on the concrete floor (there is a 2” clearance over the concrete surface as indicated on the picture).

Fig.9. Test chamber

The chamber was flooded for 5 hours prior to taking the infrared pictures. The joists had none or little contact with water. Ambient temperature was approximately 21°C; the concrete floor temperature was approximately 19°C. Fig.10 shows the test chamber floor in infrared.

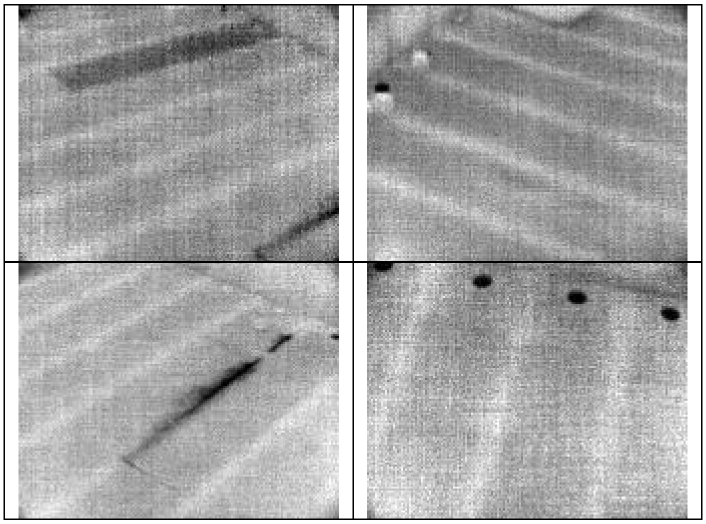


Fig.10. Test chamber floor in infrared.

Because the joists were not in contact with water, they appear warmer. Colder plywood temperature indicates the presence of moisture in the chamber with its thermal condition influenced by the very damp air under the wood structure. When comparing the test chamber floor with the two small scale models tested in the previous section, it can be seen that the thermal instability state of the chamber floor is maintained longer since its thermal mass is much greater than in the case of the models. The thermal instability allows the detection of the floor framing structure with the infrared camera.

3.1. Decontamination of the wood structure

Bacterial decontamination of the wood structure finalizes the drying process. To accomplish this, a liquid solution is sprayed at high pressure under the whole structure.

At first, the solution was sprayed from right to left, between two joists. Ambient air was made to flow under the structure with a fan for 15 minutes. Fig.11 shows the result of this action. The liquid changed the plywood heat capacity in the sprayed zone. Ambient air injected under the structure increased the thermal contrast between the dry zone and the sprayed zone. Once again, infrared thermography proved to be a viable tool in validating the decontamination process since the spraying extent becomes visible.

A second spraying action was made at a higher pressure, Fig.12 shows the result of this action. The images were taken after some air was injected under the structure for 15 minutes. Fig.12 was analyzed by image processing to get more details (a 2D Gaussian filter was applied and the contrast was increased). This analysis reveals zones that were not well covered by the solution (Fig.13). Zone 1 marks the beginning of the sprayed zone: around the corner a zone which was not covered by the solution appears. Zone 2 marks the end of the sprayed zone; we notice that the surface between the two joists was not entirely covered by the solution. Visual inspection was conducted after both sprayings to confirm the results obtained by the infrared camera after image processing.

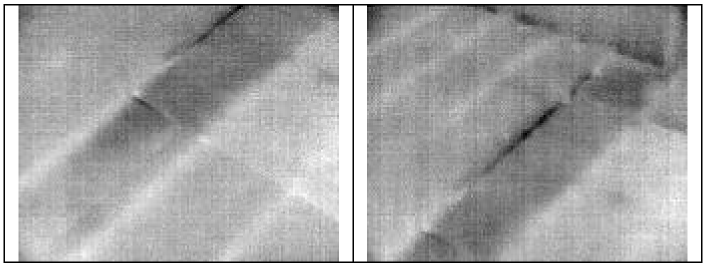


Fig.11. Liquid solution sprayed under the floor (first spraying).

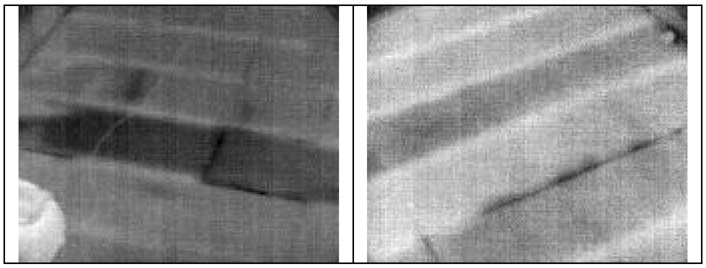


Fig.12. . Liquid solution sprayed under the floor (second spraying). Beginning of spray zone (left). End of spray zone (right).

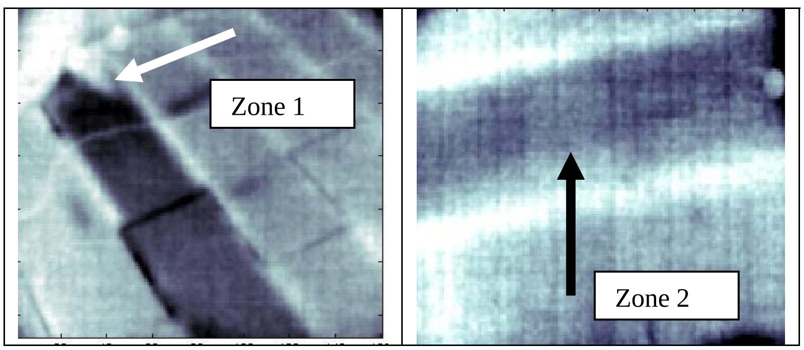


Fig.13. Second spraying. Image processing. Zone1: beginning of sprayed zone; Zone 2: end of the spraying zone. In both cases missing liquid spray is revealed.

4. SCALE MODELS WITH HOT AIR

For a better simulation of a basement floor, models 2 and 3 were encased in a Styrofoam box so that they no longer had direct contact with the chamber floor. Hot air produced by an air dryer at about 35 °C was injected in the box with a fan (Fig.14), wet joist moisture content was approximately 14%.

Fig.14. Model 2, insulated in the box

Hot air flowing under the floor broke the heat balance state and the - cooler - structure appeared clearly in infrared images (Fig.15).

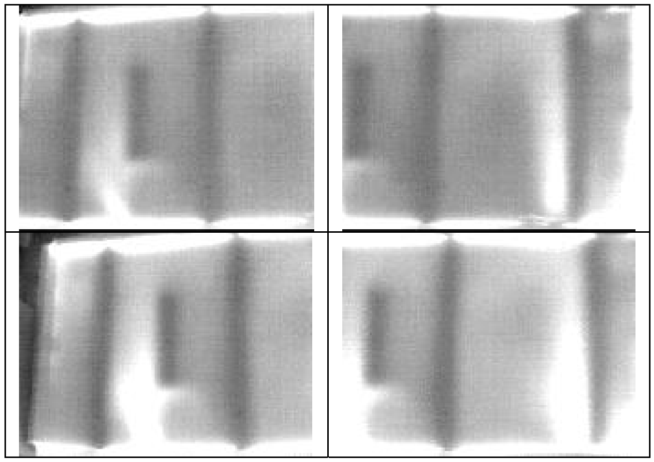


Fig.15. IR images of the left half (left) and of the right half (right) for model 2. Model 2 heated for 10 minutes (top); Model 2 heated 15 minutes (bottom).

At first, it is impossible to differentiate wet joists from the dry ones. However, when Fig.15 is studied closely, it is possible to notice « black dots » that are in fact the screws holding the joists in place: the screws that fasten the wet joists stay cold longer. Fig.16 shows the same model heated for 15 minutes and left to cool down for 15 minutes: it is now easier to differentiate the colder screws from the warmer ones.

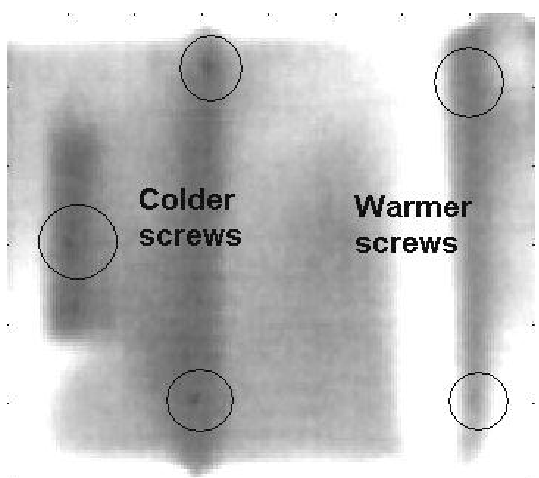


Fig.16. Difference between colder and warmer screws on model 2, after the model was heated.

4.1. Covering flooring material

A problem that can arise while taking infrared images is the flooring material which acts like a thermal insulator, hiding the floor framing structure. To simulate flooring materials most commonly found in basements, several ceramic tiles and one vinyl tile were laid over model 2 (Fig.17).

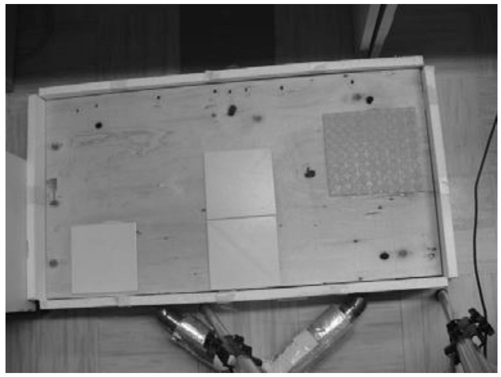
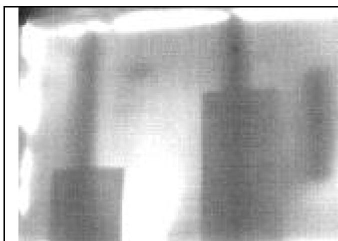
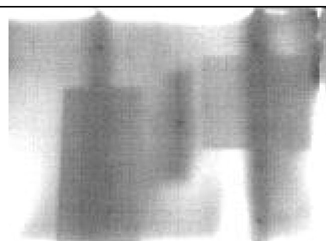
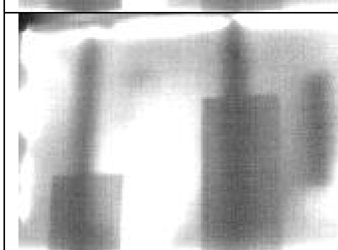
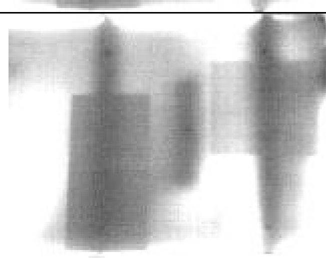
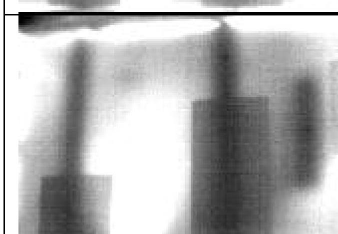
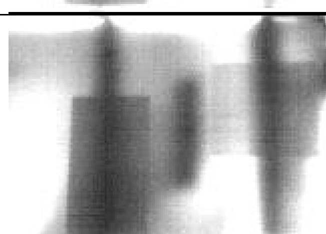
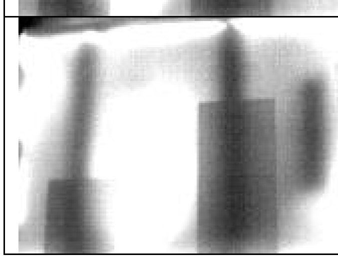
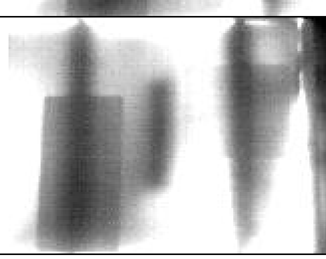


Fig.17. Model 2 covered with flooring material.

With hot air flowing under the structure, it was still possible to determine the floor framing structure (Table 1) even if the flooring made it harder to differentiate the wet joists from the dry ones.

Table 1. IR images of model 2 coved by flooring materials. In the images from left column the model is covered with ceramic tiles. In the right column, on the left there are ceramic tiles, on the right there is a vinyl tile.

		Model 2 after being heated for 5 minutes. The joist under the vinyl tile is visible in infrared, but the joists under the ceramic tiles are hardly distinguished.
		Model 2 after being heated for 10 minutes. The joist under the vinyl tile is visible in infrared, but the joists under the ceramic tiles are hardly distinguished.
		Model 2 after being heated for 20 minutes. All of the joists are visible in infrared.
		Model 2 after being heated for 25 minutes. All of the joists are visible in infrared.

5. CONCLUSION

All the procedures described in the present article indicated that infrared thermography is a viable tool in the inspection of wood floors in basements. By manipulating variables like forced air under the floor, ambient temperature or temperature of the injected air under the floor and its velocity, it is possible to reveal quickly and clearly the floor structures.

This article reports on preliminary results in a qualitative fashion. Quantitative analysis is also possible - through image processing - to extract more information. This second analysis step is still undergoing.

ACKNOWLEDGEMENTS

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