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Infrared Thermography: A Tool for Defect Identification

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Abstract: ***In this work, the potential of infrared thermography (IRT) to assess moisture related phenomenon was tested. Infrared thermography, due to its non-contact character that allows for quick surface mapping, represents a powerful tool for non-destructive testing (NDT) of materials and structures. As Infrared thermography is still not completely exploited and traditional methods are still employed. Due to the ambiguity in the analysis by using traditional methods of non-destructive testing this method emerges as an easy and quick method. So, in this paper, different areas were taken for inspection on the college campus and at the same location traditional method of NDT were also performed and the results are compared. The same has also been performed by casting the concrete cube having porous pipes inserted into a cube and the source of leakages was detected. At last the cost required by the conventional method and IRT was compared and found that the cost required by IRT was much economical than convention method Thus, anomalies were found during a short-elapsed time. The infrared thermography is useful in detecting invisible defects non-destructively, extensively and safely.***

Keywords: 2D surface mapping, Non-destructive testing, thermograms, Construction projects, Global Positioning System

1. Introduction

Infrared thermography is a modern non-destructive measuring method for the examination of redeveloped and non-renovated buildings. Infrared cameras provide a means for temperature measurement in building constructions from the inside as well as from the outside. It has been shown that infrared thermography is applicable for insulation inspection, identifying air leakage and heat losses sources, finding the exact position of heating tubes or for discovering the reasons why mold, moisture is growing in an area and it is also used in conservation field to detect hidden characteristics or degradations of building structures [4].

Infrared thermography is equipment or method, which detects infrared energy emitted from the object, converts it to temperature, and displays image of temperature distribution. To be accurate, the equipment and the method should be called differently, the equipment to be called as infrared thermograph and the method to be called as infrared thermography. Recently, however, more and more public literature shows the tendency not to pay attention to such appellative. We call our equipment as infrared thermography considering such generalization of the terminology. Infrared thermography is a non-destructive technique that has been applied to buildings for some decades as a valuable diagnostic tool [2].

In Civil Engineering, the application of infrared thermography is not limited to passive investigations of the quality of thermal insulation of building envelopes. Defects like voids in concrete or masonry, delamination's at interfaces can be localized and characterized. Infrared thermography, due to its non-contact character that allows for quick 2D surface mapping, represents a powerful tool for non-destructive evaluation (NDE) of materials and structures. [2]. notwithstanding this, Infrared thermography is still not completely exploited. In contrast to the conventional use where natural temperature gradients are utilized, the NDT applications take an active approach.

2. Factors affecting Infrared Thermography

Thermograms are affected by various parameters and it is crucial to understand them to accurately interpret the temperature readings. The camera receives infrared radiation emitted by the surface and surroundings and radiation reflected by the surroundings. There are two types of parameters that can influence results: one related to the properties of the material and ambient conditions and the other to the specifications of the camera. The most important parameters are as follows:

1. Emissivity is a highly material-dependent surface property, which defines the material's capacity to emit energy. These range from 0 (in the case of a perfect reflector) to 1 (a black body). Most common building materials, except for metals, have emissivity values over 0.8.
2. Reflections on metal or glazed surfaces may distort the interpretation of the thermogram.
3. Meteorological conditions such as air temperature, precipitation, wind speed, cloud cover and direct sunlight, may affect the transfer of energy, and consequently thermograms. Each thermographic record may require specific environmental conditions. Moreover, heat sources near the measurement area may also affect the results as well as the existence of a thermal equilibrium between the object and the environment.
4. The distance between the camera and object may attenuate thermal radiation for distances over 10 m.
5. The specifications of the camera also affect results. There is at present a broad range of cameras in the market. For this reason, it is vital to choose the right specifications for the application required, namely: resolution, spectral sensitivity, precision and pixels.
6. The calibration procedures available on the camera are also important to ensure precise measurements. These include

environmental compensation (this compensates for the influence of temperature, the distance between the camera and objects and relative humidity) and reflection calibration.

3. Basic Study Outline

3.1 Area of study

The area of study was the campus of Veermata Jijabai Technological Institute, Matunga, Mumbai having coordinate $19^0$1’17.00’’N latitude and $72^0$51’20.62’’E longitude. The site was chosen as it is one of the heritage building in Mumbai. As it is not legit to perform the destructive test on heritage building. So, in such cases, the test in which the building will not get impair was used of which one of such testing is by Infrared Thermography.

3.2 Experimental Procedure

The experimental was divided into three steps. At first, the suitable site was selected where the thermography is to be conducted. The second step is to take the thermograms of the area of interest and the third step was to use the other NDT method in this case rebound hammer for cross-checking the results. An experimental setup was prepared to find the source of leakages in the concrete cube.

The procedure for step 1 is to select the area where there may be the chances of dampness, mould, moisture, leakages and air leakages on campus. Generally, the moisture or mould found behind the bathroom wall or the leakages prone areas. The air leakages are also one of the major causes of high consumption of electricity. The air leakage is due to improper insulation or silt in the doors and windows. So, all those areas are taken into consideration for the inspection purpose.

Step 2 was to take the thermograms of all the areas of the inspected in step no 1. The method used for thermography is passive thermography in which no artificial source of light was used. So, the natural source of light i.e., Sun was used in rooftop inspection. The following are some of the thermograms taken on the campus. After that, the thermograms are analyzed in the computer software called FLIR Tools. The dark violet color shows the presence of moisture in the area which cannot be seen in naked eyes and show to what extent it has spread to the wall.

Step 3 was to compare the same with the other NDT method. in this study, the Schmidt rebound hammer was used to compare the result of thermograms. Basically, the Schmidt hammer was used to compare the results obtained for moisture or dampness detection and not for the air leakages.

3.3 Equipment

During the test, two different NDT testing instrument Infrared thermal camera and Schmidt Rebound Hammer were used. Before the measurements were carried out, calibrations procedures were performed according to the operation manual of each instrument. Regarding IR cameras, emissivity coefficient was set according to the subject of interest before each measurement. The main specifications of IR cameras are listed in Table [11].

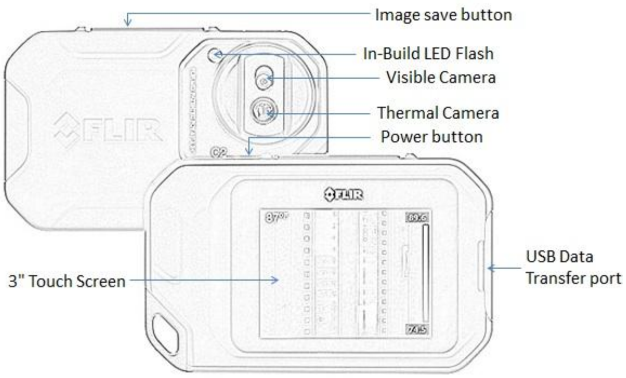

Figure 1: Thermal Camera

Table 1: Specification of Infrared Thermal Camera

Parameters	Specifications
IR resolution	80x60 (4800 measurement pixel)
Thermal sensitivity	<0.10ºC
Image Frequency	9Hz
Spectral Range	7.5-14 µm
Object temperature range	-10ºC to +150 ºC
Accuracy	+2ºC
Color pallets	Iron, Rainbow, Gray

The rebound hammer is non-destructive equipment that based on the principle that the rebound of an elastic mass depends on the hardness of the concrete surface against which the mass strikes. Thus, the hardness of concrete and rebound hammer reading can be correlated with the compressive strength of concrete. The reading displayed by the equipment is a rebound number which indicates the greater or lesser strength (lower values indicate lesser strength that corresponds to lower moisture content).

4. Data Acquisition

A series of in situ tests was carried out to validate this method of detecting anomalies in the real buildings. Measurements were taken on afternoon time when the sun intensity is high so that the thermograms can be seen distinct and clear. The thermograms were taken on the campus of VJTI show below.

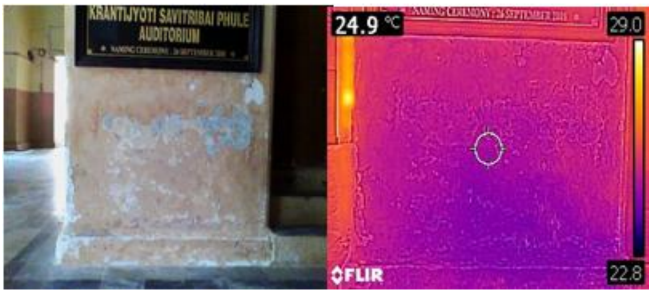

Figure 2: Auditorium Main Door

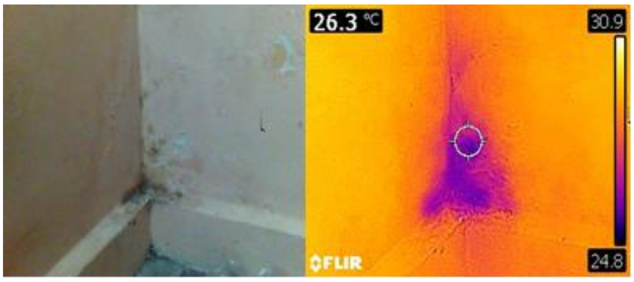

Figure 3: Computer Department Class room

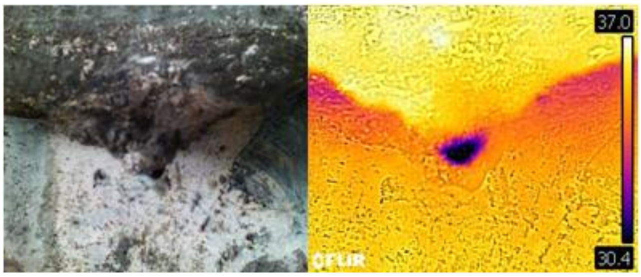

Figure 4: Water Tank no. 24 at terrace

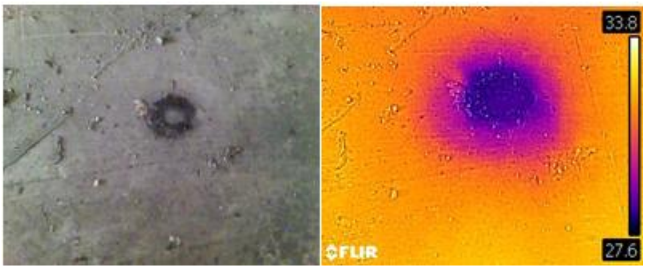

Figure 5: Spread of water on terrace

Figure 6: Behind Computer Department Toilet

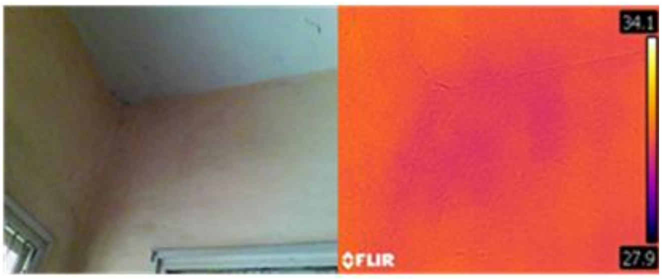

Figure 7: Electrical Department at Second floor

Figure 8: Air leakage through Meeting room

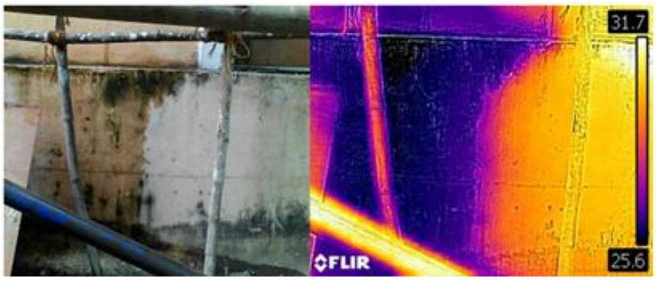

Figure 9: Outside the Mechanical Workshop

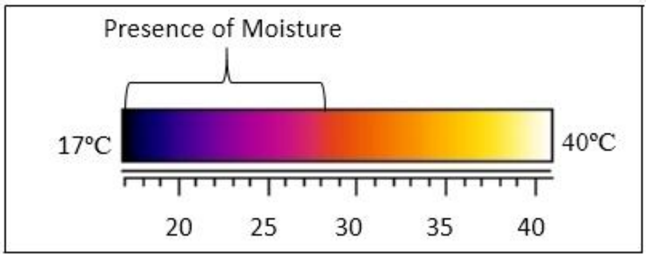

Figure 10: Temperature Scale

In Figure 2 the moisture gets accumulated due to the ground water source and creates the dampness on the wall.

In Figure 3 the accumulation of moisture at the corner of the wall and the blue portion shows the extent to which the moisture has spread on the wall.

Figure 4 is the thermogram of the water tank at the terrace of the building showing the leakage at the bottom in the dark violet color which has not seen in naked eyes.

In Figure 5 the spread of water cannot be seen clearly with naked eyes but in thermogram, the spread of water can be seen clearly in pink color.

Figure 6 is the newly constructed lavatory in the department. In this, the portion in the pink shows some of the leakages of which mostly accumulated near the pipelines.

Figure 7 shows the improper insulation at the top corner of the building which can be seen with the pink color in the vertical pattern.

In Figure 8 the air leakage of the door has shown even though the door is closed the cold air is leaking between the door and the casing.

In Figure 9 the water is continuously falling on the wall which ultimately reduces the strength and the appearance of the wall, so the extent of which the wall gets deteriorate can be seen in the thermogram.

After the collection of all the thermograms, the thermograms were analyzed on the FLIR Tool software on the computer. During analysis, the temperature can be detected which is correspond to the degree of moisture on the wall. As the moisture content increases the portion on the thermogram gets darker and darker and vice versa.

The last step is to cross check with the rebound hammer. The following bar chart shows the reading collected on site testing using rebound hammer testing. Y-axis shows the Rebound Hammer Number. The strength of concrete on dry area is 32 N/mm^2 while on wet area, its strength comes to 26 N/mm^2 in case of Mechanical Building, which shows that the strength comes more on dry area rather than wet area. So, in thermogram on yellow shows the dry portion while violet shows the wet one. The rebound value was come to be lesser when the test performed on the wet area because the strength gets considerably reduces when the wall become wet. On several other areas, the test was conducted to make sure that the result obtained from the thermal camera was absolute.

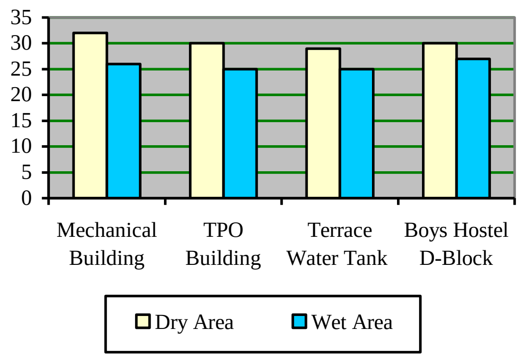

Figure 11: Result of Rebound Hammer Test

5. Laboratory Experiment

The test involved the evaluation of the surface temperature variation using a thermal infrared camera and source of heat as the sun to simulate the source of leakages on the concrete cube. The sample was cast in 15x15x15 cm^3 by inserting two cast iron pipes diagonal to each other. Casted cube is designed in accordance with IS code as shown below.

The test was performed under approximately constant environmental conditions (ambient temperature = 30°C). The concrete cube has placed in the open environment for nearly two hours so that the cube got heated uniformly. The thermograms are taken at nearly 30cm from the cube so that the source of leakages can be detected preciously in the cube sample.

As seen from the Figure 13. The source of leakage can be easily detected. The dark blue portion shows the accumulation of water in the concrete block. For experiment purpose, the water was poured in the pipe which is in the concrete block and kept for some time.

Figure 12: Before pouring water

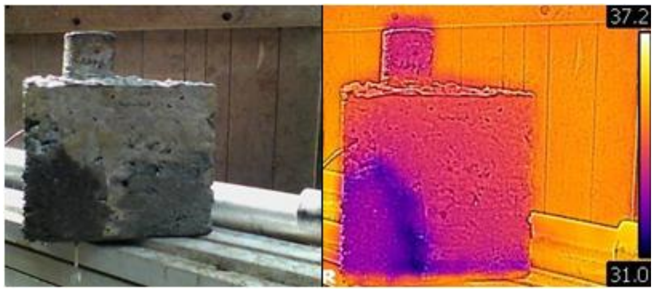

Figure 13: After pouring water

Figure 12 is the thermogram prior to pouring the water. After that, the water started leaking out of the concrete block. In Figure 13 as we can see in the normal photo it was hard to predict the exact location of leakage but in thermogram, the dark violet shows the most accumulation of water which is ultimately the source of leakage.

Consider a building to be investigated, with the help infrared thermography, the exact location of the defect can be detected and there will be no need to demolish the whole plaster of the wall. So, the ultimately the cost required for demolishing the plaster get mitigated. The effective are is repaired instead of the whole wall. Even if the personal experience or visual inspection is used, it might be the case in which the whole wall needs to be repaired because one cannot determine the exact moisture location.

6. Conclusion

This work presents the results of an experimental carried out in situ. An analysis of the parameters affecting the IRT accuracy was performed by comparing the results obtained by two different devices to measure the extent of anomalies. Surface characteristics and incident solar radiation significantly influenced the results, especially, when using the infrared camera. Metallic surfaces (high reflectance) are not easy to access using IRT as the exact contribution of reflections is difficult to quantify.

The comparison between the Conventional method and IRT has been computed and it was found that the cost required using conventional method is much more than that of IRT by 43.45%. So, the cost saved is comparatively high by using IRT and the time saving is 17.07% when compared to conventional method.

Application of Infrared Thermography helps to reduce the time required for the analysis of defects in structure. When the testing is carried out and the anomalies is found; to that location is recorded by using IRT. And as per the locations the defects are marked for repair. As far as time saving is concern, during the Conventional method of repair take much time because the area required to repair is comparatively more than that of by using IRT. In every case of Conventional method, the area required to chipping out the plaster and reconstruct the whole surface takes more time and resources (viz. material and labour). Hence IRT emerges as a useful method which can be used for building inspection.

Due to advance in science and technology in the field of GPS (Global Positioning System), there will be chances that in coming era the satellite will take the thermograms as Google Earth takes the photos of physical features now and the results can be interpreted in the office itself. This will ultimately reduce the time and effort. Also with this, the major cost reduction i.e., the cost of an instrument has reduced to zero as the thermograms are directly taken by the satellite. This GPS technology will help to record the location information of where each thermal image was taken.

Acknowledgement

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