IFERP connecting engineers...developing research
ISSN (Online): 2456-1290
International Journal of Engineering Research in Mechanical and Civil Engineering (IJERMCE)
Volume 2, Issue 4, April 2017

Infrared Thermography for Building Inspection: A Non-Destructive Method

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Abstract :- **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 inside and outside as well. 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 mould, moisture is growing in an area and it is also used in conservation field to detect hidden characteristics or degradations of building structures. Infrared thermography is equipment or method, which detects infrared energy emitted from an object, converts it to temperature, and displays image of temperature distribution. In Construction Industries, the application of infrared thermography is not limited to passive investigations but active investigation too. Some defects like voids in concrete or masonry, delaminations at interfaces of an object which have a different density or heat conductivity can also be detected and characterised. Infrared thermography, due to its non-contact character that allows for quick 2D 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 are taken for inspection on the campus of Veermata Jijabai Technological Institute, Matunga, Mumbai, and at the same location traditional methods of NDT are also performed and the results are compared. Thus, temperature measurement must be completed during a short elapsed time after the pulse heating. The infrared thermography is useful in detecting invisible defects non-destructively, extensively and safely.**

Keywords: - **2D surface mapping, Non-destructive testing, thermograms, Global Positioning System.**

I. 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 [3].

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 [5].

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. [7]. Notwithstanding this, Infrared thermography is still not completely exploited. In contrast to the conventional use where natural temperature gradients are utilized, the NDT

ISSN (Online): 2456-1290
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applications take an active approach.

II. PARAMETERS THAT AFFECT 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 envelope/surroundings and radiation reflected by the envelope/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:

– Emissivity is a highly material-dependent surface property, which defines the material's capacity to emit energy. There are published studies which provide tables giving the emissivity values of different materials in accordance with surface temperature and wavelength. 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. If a quantitative analysis is required, the emissivity of each material should be assessed.

– Reflections on metal or glazed surfaces may distort the interpretation of the thermogram.

– 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.

– The distance between the camera and object may attenuate thermal radiation for distances over 10 m.

– The specifications of the camera also affect results. There is at present a broad range of cameras on the market. For this reason, it is vital to choose the right specifications for the application required, namely: resolution, spectral sensitivity, precision and pixels.

– 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), reflection calibration (to adjust the temperature detected) and background compensation (compensates for background reflection).

III. 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.

IV. 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.

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 cause 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.

V. 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

ISSN (Online): 2456-1290
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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 [9].

Specification of Infrared Thermal Camera

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

The rebound hammer is a 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 indicates lesser strength that corresponds to lower moisture content).

VI. 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.

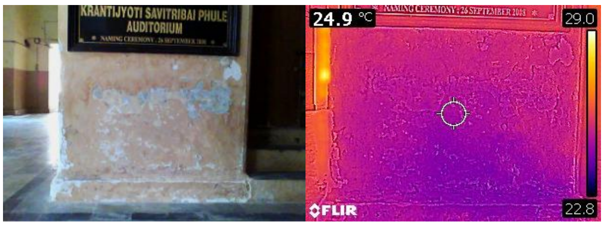


Fig (a): Auditorium Main Door

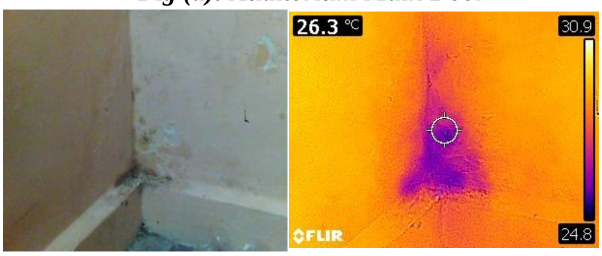


Fig (b): Computer Department Class room

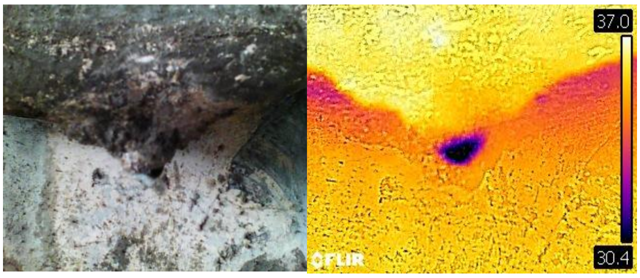


Fig (c): Water Tank no. 24 at terrace (Front)

Fig (d): Water Tank no. 24 at terrace (Bottom)

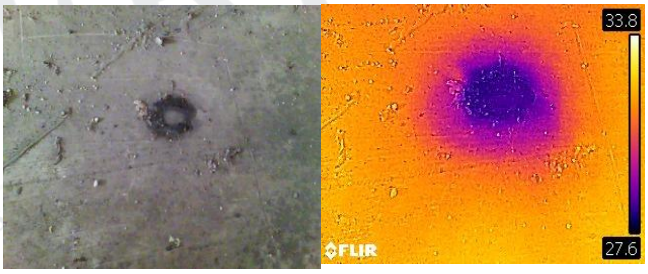


Fig (e): Spread of water on terrace

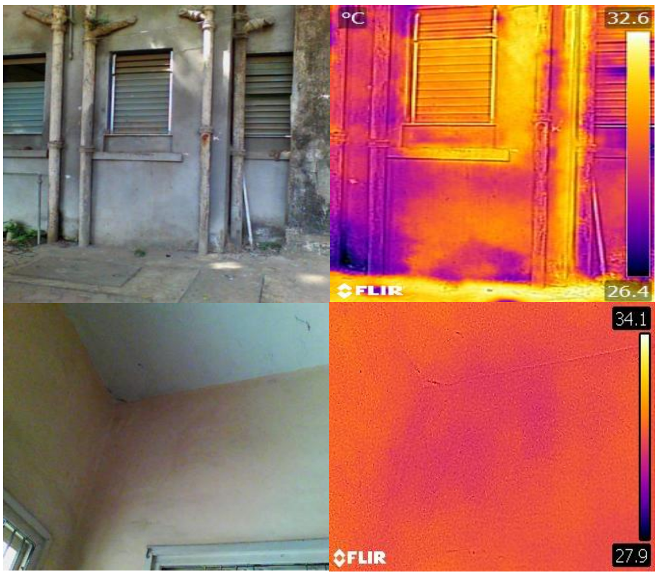


Fig (g): Electrical Department at Second floor

ISSN (Online): 2456-1290
International Journal of Engineering Research in Mechanical and Civil Engineering (IJERMCE)
Volume 2, Issue 4, April 2017

Fig (h): Air leakage through Meeting room

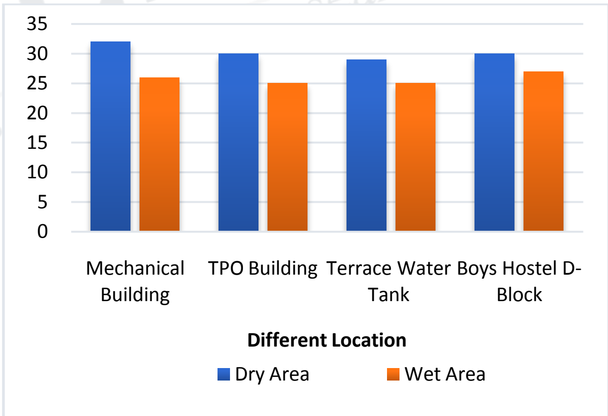
Fig (i): Roof Top at Civil Building

In fig (a) the moisture gets accumulated due to the ground water source and creates the dampness on the wall.
In fig (b) 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.
Fig (c) and (d) are the thermogram of the water tank at the terrace of the building showing the leakage at the in the dark violet color which has not seen in naked eyes.
In fig (e), 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.
Fig (f) 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.
Fig (g) shows the improper insulation at the top corner of the building which can be seen with the pink color in the vertical pattern.
In fig (h) the air leakage of the door has shown even though the door is closed the cool air is leaking between the door and the casing.
In fig (i) the roof top moisture can be seen in pink color. This thermography is called as active thermography because the source of heat i.e., the sun is heating the subject uniformly.

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 table shows that the reading collected on site testing using rebound hammer testing. 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/mm2 while on wet area, it's strength comes to 26 N/mm2 in case of Mechanical Building, which shows that the strength comes more on dry area rather than wet area. 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 areas, the test was conducted to make sure that the result obtained from the thermal camera was absolute.

Result of Rebound Hammer Test



VII. 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 = 30ºC). 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

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30cm from the cube so that the source of leakages can be detected preciously in the cube sample.

As seen from the figure (k), 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. Fig (j) is the thermogram prior to pouring the water. 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.

Fig (j): Before pouring the water in the block

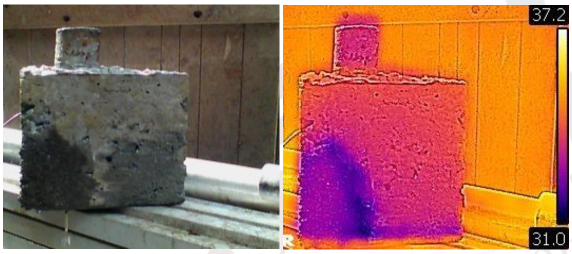

Fig (k): After pouring the water in the block

Infrared Thermography Inspection cost nearly INR 20,000/- per day 8 hours shift. But the cost of infrared thermal camera stats from INR 50,000/- to beyond. Once the instrument has purchased it can be used for a life time and the cost of inspection has reduced abruptly. This is that type of case in which the initial price is high and during the service, its nil. So, to sum up the inspection cost will be mitigated.

VIII. CRITICAL ANALYSIS OF METHODOLOGY

This study has successfully demonstrated infrared thermography's potential for diagnosing anomalies in the building. One of its main advantages is that it is a non-destructive technique, and so may be used as a preventive maintenance tool to detect problems without having to directly access the surface. The methodology consists of using solar radiation effect to obtain thermograms for rooftop moisture inspection. The best period for inspection was found to be during the hours of exposure to sunlight. However, the inspection may also take place after sunset or during the night, although defects will be less evident as the temperature contrast is less marked. A qualitative analysis was adopted as it was enough to detect these defects, avoiding more complex procedures that would be necessary for a quantitative approach, and reducing some uncertainties such as the thermal influence of the surrounding surfaces. Great attention is required during the measurements due to the variability of environmental conditions and other parameters that may impact the final results.

IX. TIME MANAGEMENT

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.

It is highly recommended that the IRT should be adopted as far as Non-destructive testing is concern. It gives the precise and pristine results then other methods of NDT, which ultimately emerges as a one of the best method for heritage building inspection.

X. 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 thermographic testing non-destructive technique has the main purpose to provide information by analyzing the real characteristics of the existing buildings for determined surface anomalies. Thermal irregularities, air leakage, moisture intrusion and the building's structure produce different models of superficial temperature that have characteristic shapes in a thermal image. The high variations of temperature on the thermal images it often indicates structural changes, structural abnormalities, the lack of insulation, degradation, air leakage sources, heat losses, moisture. The infrared measurements give a qualitative image of the thermal protection level of buildings envelope and identify the week zones hidden from eye visual contact. Thus, temperature measurement must be completed during a short-elapsed time after the pulse heating especially for the detection of smaller delamination. The infrared thermography is useful in detecting invisible defects non-destructively, extensively and safely.

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.

XI. ACKNOWLEGEMENT

This work was supported by Transportation Engineering Laboratory of Civil and Environmental Engineering Department, VJTI. The authors gratefully acknowledge their financially support and their cooperation.

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