INFRARED THERMOGRAPHY AND ITS APPLICATION IN BUILDING CONSTRUCTION

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Abstract - *Thermography technique relies on variation in temperature to identify in homogeneities in the test medium. Infrared thermography is a non-destructive testing method being used for the detection of shallow depth defects in concrete structures. Infrared thermography technique relies on the infrared rays emitted by the test object to assess its surface temperature. In the present work, the recent research works on infrared thermography technique are reviewed in detail. Later, the possibility of employing thermocouple sensors to identify defects in concrete is explored. Towards this, an experiment is conducted to assess temperature variations in a concrete block of size 0.4×0.4×0.15 m. The block is cast with a defect of size 0.1×0.1×0.05 m. For the identification of the defect using the thermography technique, the characteristics of the heating source play an important role. Hence, it is proposed to explore the influence of two heating sources on the non-destructive evaluation process. The oven heating and solar heating are considered in the present study. While the oven heating simulates an ideal source with uniform heating of the test surface, the solar heating is uncontrolled. Thus, the influence of these two heating sources on the interpretation of the data for the nondestructive evaluation is discussed in detail. The encouraging results inspire further research on the thermography technique.*

***Key Words*: Infrared Camera1, Thermography Technique2, Non-Destructive Technique3, Solar heating4, Oven heating5.**

1. INTRODUCTION

In the recent years, the application of Non-destructive Testing (NDT) methods for identification of defects is becoming more popular. Many NDT methods are presently available, such as impact-echo method, ultrasonic pulse echo, ground penetrating radar and infrared thermography. Of these, the first three techniques work based on wave propagation. The characteristics of the reflected wave are used for the evaluation of the concrete properties or the location of the defects. These methods are useful in the identification of internal voids, honeycombs, delimitations, cracks and other subsurface defects . Recently, the infrared thermography technique is gaining popularity for moisture detection and shallow depth defect identification. Infrared thermography technique (IRT) relies on the variation in the temperature caused by the presence of air packets in concrete. This information is used for the identification of defects. This method uses the infrared rays emitted by the investigated object to assess its temperature gradient on the surface of the test object / specimen. An infrared camera is used for capturing the infrared rays from the object. The data is then processed into a thermo gram revealing the temperature variations on the assessed face of the test object . The non-contact nature of this technique makes it an attractive option for non-destructive testing. Also, while other methods collect data at a series of points to evaluate a structure, the infrared thermography technique is capable of monitoring the temperature variations on an area at every time instant. Thus, the IRT method has the characteristics of an efficient non-destructive testing method. Thermography is the determination of surface temperatures of objects and bodies with the help of infrared photography. A special-purpose camera captures what the human eye cannot see. The camera consists of an infraredpermeable lens, a transmission line and a sensitive detector. The detector converts radiation into electric signals. After processing they are transformed into pixels so that the thermogram appears on the screen.

1.1 Thermography And Infrared Camera:

Bodies emit the thermal radiation as a consequence of their temperature .While thermal radiation is transmitted by the most gases, including atmosphere it is blocked by most liquids and solid. All bodies emit and absorb thermal energy besides reflecting a part of the incident energy. The thermal radiation emitted by the bodies depends on their temperature basically, surface condition thermal properties of material. The infrared camera senses extant (radiated, reflected and transmitted) thermal energy from the body, converts into temperature and displays thermal images. while thermal images provides useful data ,the exitant energy should be considered in analyzing and interpreting the thermal images. While the exact value of thermal properties (surface and body) are not always required to assess thermograph, the sources of radiation from the body (emitted, reflected, transmitted) help in correct assessment . A sources of radiant thermal energy close to a body may leads to incorrect interpretation of the image. It should also be appreciated that infrared cameras senses only the radiant energy received from the surface and not the visible light reflected from the surfaces. Thermal images are vastly different from visual images and do not require visible lights. Thermal images can be obtained in total darkness. The thermal images of light bulb appears to glow as brightly in the total darkness after it is switched off.

Fig -1: A typical infrared camera

The cameras are often application specific: cameras for application on structure have lower ranges and precision than those for electrical equipment (motors and transformers).Sources of radiation on the body should be shielded from the object for valid result. It is advisable not to take thermal images in bright sun or when the body is exposed to radiation from any sources to heat (glowing light). An infrared camera should be handled with considerable care. The lens should be protected from scratches and should never be wiped or touched by hand to protect its sensitivity.

1.2 IMAGES PROCESSING:

Infrared camera is a simple device and can be handled with usual precaution like an ordinary photographic camera. The image have to be focused and composed to same way. The focus, composition and ranges of temperature chosen cannot be altered later, though brightness and contrast can be adjusted in the image to highlight the required details. It is essential to focus the camera for sharp images compose the significant details being monitored , and set the temperature ranges for useful result. The images are processed by software to yield thermal images. Various thermal pattern can be obtained from by varying the palette (colour pattern), brightness and contrast of the image for locating details and correct interpretation of the image. Various colour palette can be selected, including grey palette. Thermal images appear as zone of different colours or shades depending upon temperature ranges and mean temperature selected. It should be mentioned here that the visual colours do not necessarily reflect the temperature pattern (thermal images).The bright region in a thermal images indicate the high temperature ,while the dark region indicated the low temperature and intermediate region marked by colours ranging from white to black through yellow , orange ,red and indigo. On a grey palette, various shades ranging from white (high temperature) to black (low temperature) distinguish the region of reducing temperature. Figures indicated a typical example; the visual images show the seepage of water from a flower pot beneath a window of an apartment building. The water left a long streak all along the balcony wall .However thermal images shows a much shorter streak, barely reaching the bottom of the flower pot.The presence of moisture lowered the temperature in the region, that showed up as a dark band, while the brown streak in the visual image is caused by the deposits due to water seepage. These aspect should be considered while analyzing thermal images. Similarly, some dark patches of low temperature may be due to local effect (changes in emissivity or spray of water).The effect of surface features (curvature, colour and roughness) on exitant radiation should be assessed properly while interpreting thermal images.

2. CASE STUDY

A case study is nothing but a process of research into development of project over a period of time. To fulfill the objective of this research, site has to be selected. For the same, the garden city township, mogara building Amravati is the ideal one. Table 1shows the detail site information which is taken as case study of the project. It is a residential project site which is located at Nagpur bypass, near maharshi school, Amravati.

Table -1: Site Information (Source : Mogara Building,GardenCity)

Project Name	Mogara Building, Garden City Township
Address	Akola Nagpur Bypass, near maharshi school, Amravati
Building Type	Residential
Name of Client	Nilesh Thakare
Name of Contractor	Raju Thakare
Site Engineer	Aditya Lohiya
Construction Started	June-2016
Expected Date of Completion	Aug-2018
Total cost of Project in Rs.	60 crore
No of floor	G+7 2 BHK
Area of project	4 acres

3. METHODOLOGY

3.1 Uses Of It Camera And Its Application:

The technique has numerous applications in condition assessment of structures, locating the source of distress, assessment of damage potential in concrete and masonry structures, identifying moisture ingress and flow through pipes. Thermal images are widely used in branches of engineering including computer systems where it is especially used to locate components of excessive heat generation. The information regarding the number of position of organization is obtained from mogra building garden city Some of the applications with typical images are discussed here briefly.

1. Moisture penetration

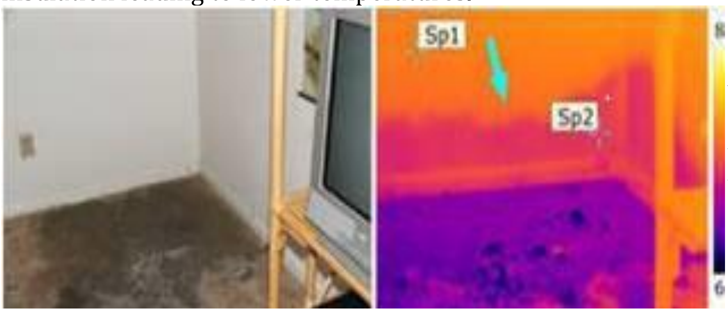
2. Plumbing

3. Concrete structures

4. Tension tests on reinforcement bars

3.1.1 Moisture penetration:

Figure 3.1.1 shows that Presence of moisture causes lower temperatures due to ambient evaporation, and consequent cooling of surfaces. Thermal images indicate the regions of temperatures distinguished by various colours or shades, depending upon the palette selected. Figure3.1.1 indicates the thermal image of a canopy. The image was taken late in the evening on a hot summer day in May of in mogara building garden city amravati. Most of the structure is at a high temperature of about 47C due to the absorption of solar radiation, but for two bands of about 43C on the soffit. On closer examination, it was found that the structure has a brick lining on the three free sides and rainwater stagnated along the two bands. Subsequently, dust an muck got deposited along a the bands, providing some degree of insulation leading to lower temperatures.



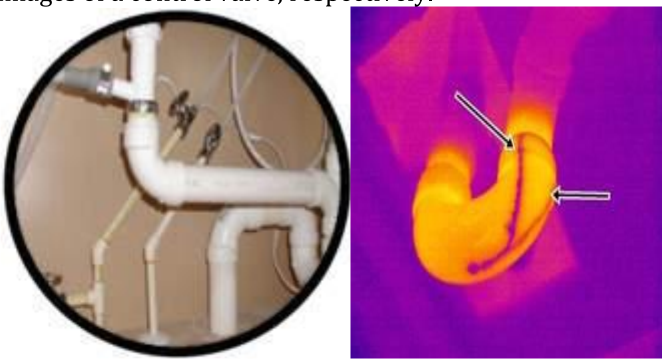
(a) Visual images (b) Thermal images

Fig 3.1.1:- Moisture penetration in a canopy

The dark regions underneath the windows in Figure3.1.1 indicate moisture penetration. The image was taken two days after brief showers in the summer month of May in mogara building garden city amravati. The rest of the wall is more or less of the same temperature of about 34C, while the dark regions are at temperatures lower than 31C, indicating the presence of moisture.

3.1.2 PLUMBING:

Infrared camera also helps assess plumbing and flow through pipes. Figure3.1.2 is the thermal image of sewage pipes in an apartment building. The flow of warm sewage flowing in the pipes is discernible in the thermal image taken in the morning at about 8.00 am before the pipes were exposed to sunlight in mogra building garden city amravati . The bright band along the inclined pipe indicates that the pipe is not running full and is not choked and there is no sedimentation. It may also be noticed that the pipe is enclosed in a recess below the cantilever beam. The dark patch on the beam soffit indicates leakage from the pipe and accumulation of moisture. Repairs can be planned to seal the couplings in the regions of seepage suggested by thermal images. Concealed pipes are difficult locate in a structure and require removal of plaster and masonry to expose them. Figure3.1.2 (a) and (b) indicate the visual and thermal images of a control valve, respectively.



(a) Visual images (b) Real images

Fig3.1.2:- Images of a sub-surface pipe

The images were taken on a hot day in the month of May, when the water flowing in the pipe system was heated by the sun as the tank is located on the terrace of the building. The trace of the concealed pipe inside the wall can be noticed by the light band of temperature higher than the wall. The wall is at a temperature less than 31C, while the concealed pipe is at about 32C and the exposed pipe is at about 33C. The small differences in temperatures help locate the concealed pipes.

3.1.3CONCRETE STRUCTURES:

Thermal images help determine the state of fresh as well as hardened concrete Figure3.1.3 is the thermal image of a ready mix concrete truck delivering at a site on a hot summer afternoon. The tyres of the truck are at about 46C, and the pump at a temperature over 50C, while the drum is at about 3C. The uniform colour of the drum, with no patches of variation, indicates good mixing and concrete of uniform quality.

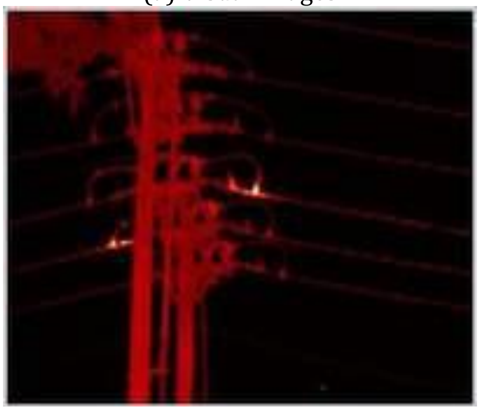
Fig 3.1.3:- Carbon fiber reinforcement of concrete structure

Figure 3.1.3shows asegment of pipe delivering concrete; the leakage of slurry at the joints is discernible in the image. Any obstruction to flow can be observed from the temperature patterns of the thermal image. However, the dark patch on the pipe after the second joint from the left corner is not an obstruction in the flow, but, water spilled on the pipe, Figure3.1. 3.The thermal image of concreting of a slab is shown in Figure 3.1.3. The concrete was cast on a hot day with temperature of about 40C. The concrete poured is cooler than the forms as can be seen from the colour pattern. The forms are at temperatures of about 40 – 44Cdue to exposure to direct sun, while the concrete is cooler at 32 – 34C due to evaporation. The reinforcement bars of the column in the image are at about 38C. A person with a needle vibrator can also be seen in the image. The effectiveness of curing procedure adopted can be assessed by the camera. Figure3.1.3 shows the concrete columns of a structure being cured. The image was taken at about 6.00 am (before sunrise) in summer. The bright columns at the right are at temperatures of 29 – 30C with little curing, while the columns with gunny bags wrapped around are cured better with surface temperatures at about 25C. However, the upper parts of the columns are not wrapped properly, and appear to have dried out with a surface temperature of about 28C.

3.1.4 TENSION TESTS ON REINFORCEMENT BARS:

Reinforcement bars tested for their tensile strength fail at a section after necking. However, tensile tests do not reveal the yield point precisely, or the critical section until after failure. Figure 3.1.4 indicates the thermal patterns in a deformed bar during tensile tests. The temperature of the bar increases with load and generally the temperature rise is uniform along the bar length in the elastic region. During the post-elastic loading, the temperatures start increasing locally, in the region of failure, Figure4 .The temperature in the critical (brightest) region is about 45C, while in the vicinity of the critical section the temperature is about 43C, and the temperature away from the critical section is about 40C. Figure 3.1.4(b) shows the bar after failure, with the tips of the failed section at a higher temperature than the rest of the bar.

(a) Visual images



(b) Real image

Fig3.1.4 :-Reinforcement bars

Thermal image can be useful in determining the yield point more accurately than by conventional strain measurements .Figure shows a set of tested bars after failure. The bar in the foreground, tested last, is at the highest temperature, while the other bars at lower temperatures can be seen in the background. The temperature pattern in a bar under bend test is shown in Figure 3.1.4. The rise in temperature of the bar at the bent section is discernible. It can also be seen that the bar is at a higher temperature along the outer radius than on the inside. The formation of plastic hinge at the bent section can also be noted in the figure3.1.4.

4. CONCLUSIONS

1. Thermal images provide an excellent tool for rapid assessment of structures.

2. Non-contact and non-destructive method is useful in rapid condition survey of structures without requiring any access.

3. Thermography is particularly useful in assessing the condition of historical structures.

4. Thermal images of chimneys and cooling towers provide a rapid method of determining surface temperatures for condition surveys.

5. Thermal images can also assessed by deterioration due to corrosion of reinforcement, and damage due to fire.

6. Thermography also helps the food processing industry in maintaining suitable temperature conditions.

7. Thermal images can be used to locate the regions of heat so as to direct the extinguishing jet effectively.

REFERENCES

[1] Rao, D.S. Prakash, "Advanced non-destructive testing methods, Workshop on emerging trends in construction", International Journal of Economics, Business and Management Research, Vol. 2, No. 01, 2006.

[2] Bryson, F. "IR thermography finds missing grouts in block walls, Inframation, Infrared Training Centre", International Journal of Envinmental Research and Development, Volume 4, Number 1 (2014), pp. 21-26.

[3] V.K.Divya1, K.Sivasubramanian2, D.Suji3, Defect "Identification in Concrete Using Active Thermography Technique", International Journal of Innovative Research in Science, Engineering and Technology, Vol. 4, Issue 6, June 2015.

[4] Sakagami, T., and Kubo, S., "Development of a new non-destructive testing technique for quantitative evaluations of delamination defects in concrete structures based on phase delay measurement using lock-in thermography", Infrared Physics & Technology, Vol.43, pp.311-316, 2002.

[5] Taylor, T. Counsell, J., Gill, S., Combining thermography and computer simulation to identify and assess insulation defects in the construction of building facades. Energy and Buildings, 2014.

[6] Dr. Khaled N. Alshuwairekh, (2016), "*The Effectiveness Of The Training Programs On Employees Performance: An Empirical Study At Private Sector Companies",* International Journal of Business and Management Review, Vol.4, Issue 9, November 2016, pp.1-23.

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