APPLICATION OF INFRARED THERMOGRAPHY IN CIVIL ENGINEERING

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ABSTRACT

Just as doctors use temperature in disease diagnosis, infrared thermography allows us to diagnose and pinpoint problems based on the temperature differential of areas. It is the ability of the thermal camera to "see" these early stages of increasing temperature that makes thermography such a valuable technology.

Keywords – *Active, Infrared thermography, Passive, Photograph, Radiation, Electromagnetic*

I.INTRODUCTION

Infrared thermography is a powerful tool to investigate structural condition and equally useful for damage assessment. It is a non-contact and non-destructive method that enables rapid investigations. Highly efficient infrared cameras and versatile software have simplified thermography considerably over the years While infrared thermography has wide applications in process industries, it is not yet extensively adopted in the investigation of buildings. The paper presents a brief historical account of infrared thermography, the phenomenon of electromagnetic radiation, thermal imaging and applications in civil engineering.

Numerous other applications of thermal imaging are also discussed briefly along with the advantages and limitations. Infrared thermography (IRT) can be defined as the science of acquisition and analysis of data from non-contact thermal imaging devices. The process of thermal imaging has simplified over the years with the availability of efficient, high resolution infrared cameras that convert the radiation sensed from the surfaces into thermal images. Thermography literally means ‘writing with heat’, just as photography implies ‘writing with light’. The invisible infrared radiation emitted by bodies is converted into temperature and displayed as thermal images (thermographs).The recent developments in thermography and image processing has made the technique a valuable addition to the repertoire of non-destructive testing methods.

II. ELECTROMAGNETIC RADIATION

The electromagnetic spectrum of radiant energy is spread over a wide range of wavelengths, and is divided into various bands depending upon the wavelengths. The wavelength band less than 0.1 nm pertains to gamma rays, X-rays are of 0.1 - 10.0 nm bandwidth, ultraviolet radiation is of wavelength 0.01 – 0.1 µ m, visible light has wavelengths between 0.4 – 0.7 µ m, while the infrared waves lie in the bandwidth of about 1.0 – 14 µm;

farther beyond are microwaves in the band 1.0 – 10.0 mm, and radio waves thereafter in the band extending from 10.0 mm to a few kilometers. Infrared band comprises near infrared waves of about 1.0 µm, short waves of 2 – 5 µm and long waves of 8 – 14 µ m. Not all waves are capable of transmitting thermal energy; the waves somewhere in the ultraviolet band extending to infrared wave bands through the visible band alone can transfer thermal energy. These wave travel at a very high velocity (at about 2, 99,792.5 km / s, the speed of light in vacuum). Energy of different wavelengths is perceived by human eyes as (visible) light of diffrent colors.

Radiant over 300 m away. energy of 0.4 µm wavelength is perceived as violet light while that of 0.7 µm wavelength as red colour with the wavelengths in between showing up as other colours of a rainbow. While the colour of an object indicates its ability to reflect more of the specific radiation of the wavelength pertaining to that colour than any other energy, visible white light is a mixture of wavelengths. The short and long wave bands are adopted in infrared thermography. The thermal energy transmitted by the atmosphere depends upon the wavelength of radiant energy. The transmissivity is high in the bands 0.7 - 5 µ m and 8 – 14 µ m; the band between 5 – 8 µ m does not transmit thermal energy.

III. DEVICES USED (INFRARED CAMERA)

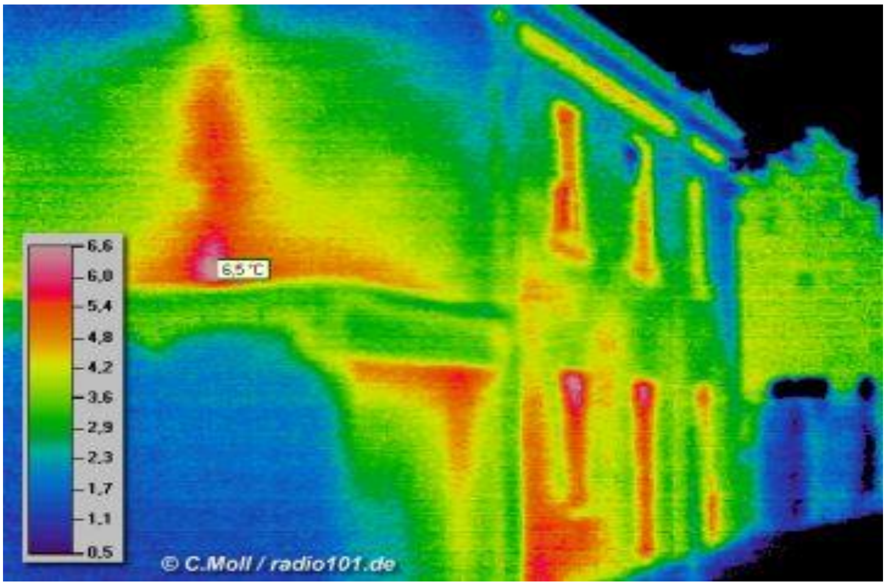
Bodies emit thermal radiation as a consequence of their temperature. While thermal radiation is transmitted by most gases, including atmosphere, it is blocked by most liquids and solids. All the bodies emit and absorb thermal energy besides reflecting a part of the incident energy. The thermal radiation emitted by the bodies depends on their temperature basically, surface condition and thermal properties of the material.

A black body absorbs all the radiant energy (coefficient of thermal absorption = 1.0), and emits 100 percent of its energy. Such an ideal body does not exist in reality, but the concept is useful in comprehending the concepts of thermal radiation. The radiation on a body is partly absorbed, transmitted and reflected. Similarly, exitant radiation from the surface of a body comprises components of energy emitted, that reflected from the surface and the energy transmitted through the body by a source behind it. The components of exitant energy depends on the emissivity and reflectivity of the surface, and thermal properties (specific heat and conductivity) of the body. Steel elements have uniform temperatures because of high conductivity, while temperatures on a concrete element are likely to vary over its surface. The infrared camera senses the exitant (radiated, reflected and transmitted) thermal energy from the body, converts into temperature and displays thermal images. While thermal images provide useful data, the exitant energy should be considered in analysing and interpretng the images.It should also be appreciated that infrared camera senses only the radiant energy received from the surfaces, and not the visible light reflected from the surfaces Thermal images are vastly different from visual

IV. TYPE OF INFRARED THERMOGRAPHY

Passive Infrared Thermography.

The exitant energy from the surface of a body depends primarily on its temperature. The quality of thermal image depends on the variation in surface temperatures; the greater the contrast in temperatures, the better will be the images. Thermal images can usually be obtained under ambient conditions. When the body is heated by ambient conditions (solar radiation), it implies passive thermography.



Active Infrared Thermography

Sometimes the body is heated by an external source to obtain temperature contrast. Such a process is known as active thermography. The former process is adopted while assessing large bodies, while active thermography is generally adopted in laboratory investigations. Other procedures adopted are impulse thermography (local heating), lock in thermography (exposed to infrared radiation) and pulse phase thermography (repeated heating at short intervals of time).

V. APPLICATION OF PASSIVE IRT

Moisture Penetration.

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 colors or shades, depending upon the palette selected. Figure indicates the thermal image of a canopy. The image was taken late in the evening on a hot summer day in May.

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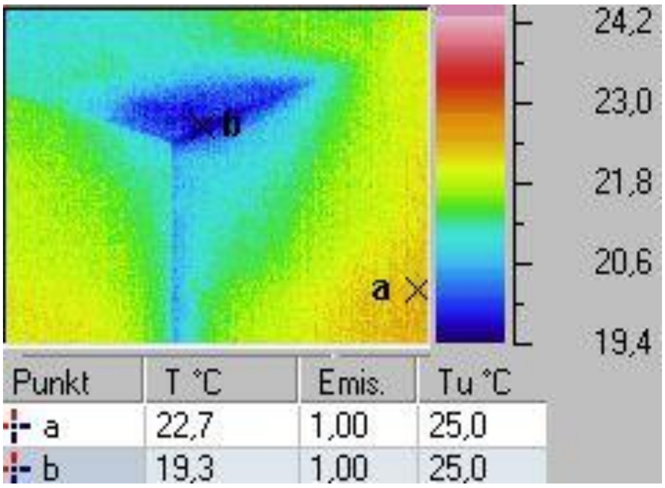
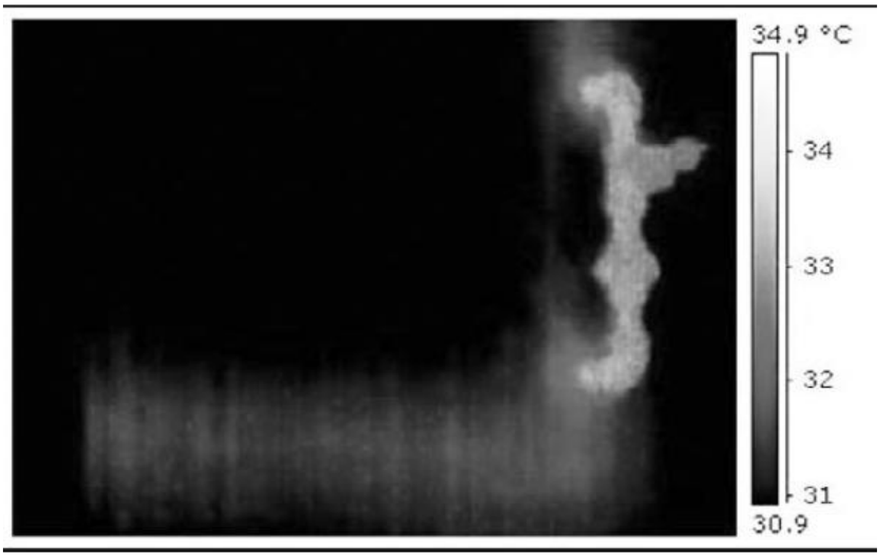


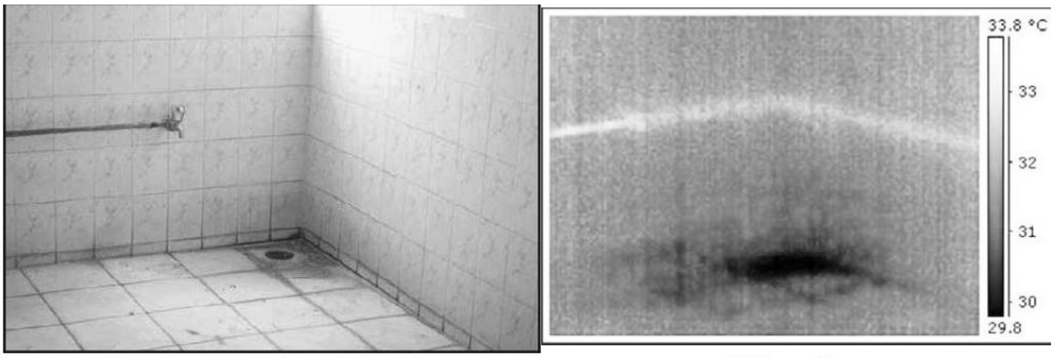
Most of the structure is at a high temperature of about 47ºC due to the absorption of solar radiation, but for two bands of about 43ºC on the soffit. On closer examination, it was found that the structure has a brick lining on the three free sides and rainwater stagnated along the two bands. Subsequently, dust and muck got deposited along the bands, providing some degree of insulation leading to lower temperatures.Further, the soffit along the bands sounded hollow when struck by a small hammer indicating delamination of plaster and a small hammer indicating delamination of plaster and possibly of concrete. The temperature differences caused by the muck deposited and delamination manifested in the form of dark bands.

Plumbing.

Infrared camera also helps assess plumbing and flow through pipes. Figure 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. 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.



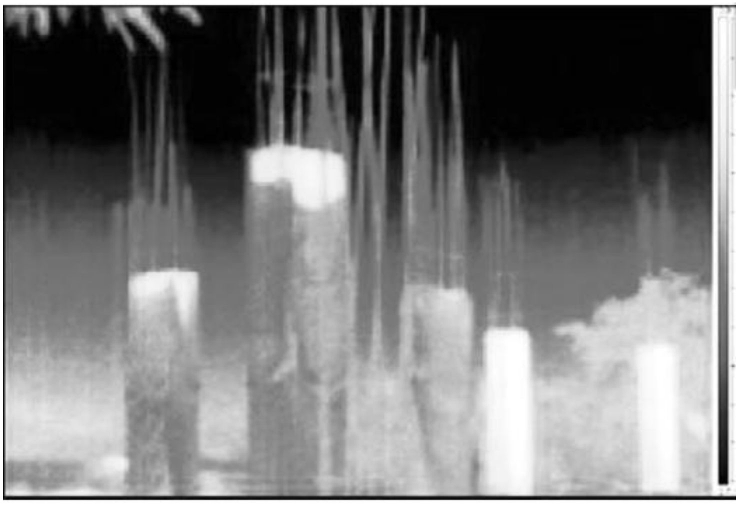
Repairs can be planned to seal the couplings in the regions of seepage suggested by thermal images. Concealed pipes are difficult locate in a structure and require removal of plaster and masonry to expose them. Figure indicate the visual and thermal images of a water supply pipe.. The images were taken 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 31ºC, while the concealed pipe is at about 32ºC and the exposed pipe is at about 33ºC. The small differences in temperatures help locate the concealed pipes.



(a) Visual image (b) Thermal image

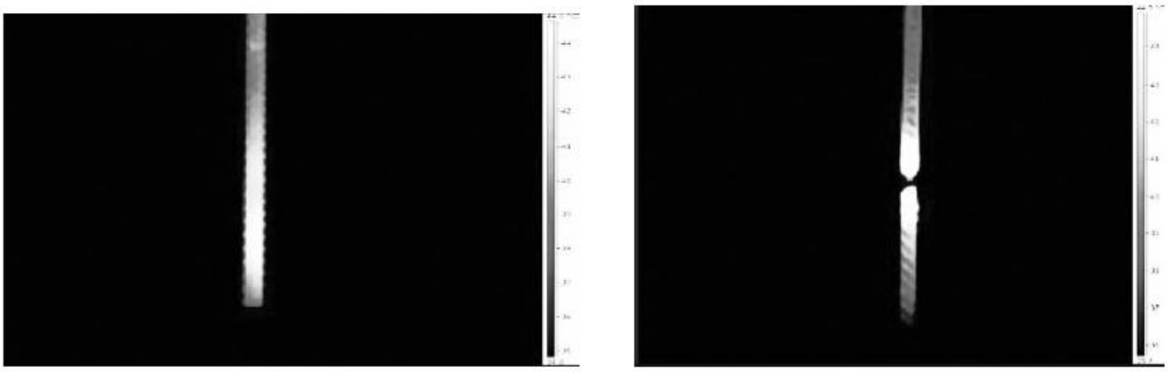
To test effectiveness of curing

The effectiveness of curing procedure adopted can be assessed by the camera. Figure 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 – 30ºC with little curing, while the columns with gunny bags wrapped around are cured better with surface temperatures at about 25ºC. However, the upper parts of the columns are not wrapped properly, and appear to have dried out with a surface temperature of about 28ºC.



Testing Reinforcement bar.

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 indicates the thermal patterns in a deformed bar during tensile tests. The temperature of the bar increases with load and generally the temperature rise During the post-elastic loading, the temperatures start increasing locally, in the region of failure, The temperature in the critical (brightest) region is about 45ºC, while in the vicinity of the critical section the temperature is about 43ºC, and the temperature away from the critical section is about 40ºC. with the tips of the failed section at a higher temperature than the rest of the bar. Thermal image can be useful in determining the yield point more accurately than by conventional strain measurements.



(a) Before failure (b) After failure

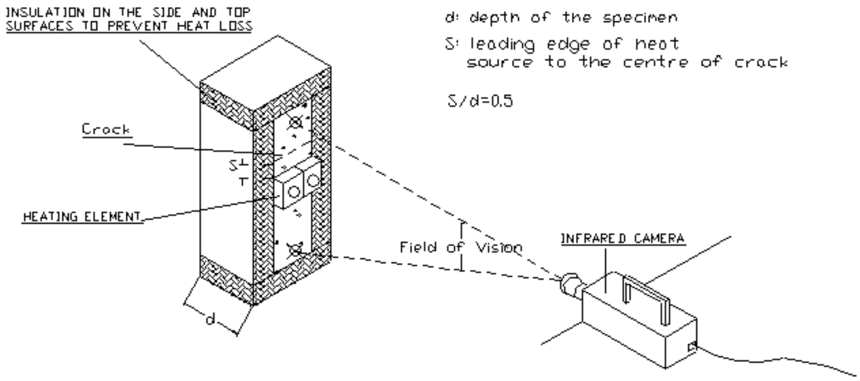
Above Figure shows a set of tested bars after failure. The bar in the foreground, tested last, is at the highest temperature, while the other bars at lower temperatures can be seen in the background . The temperature pattern in a bar under bend test is shown in Figure. The rise in temperature of the 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 figure.

VI. APPLICATION OF ACTIVE IRT

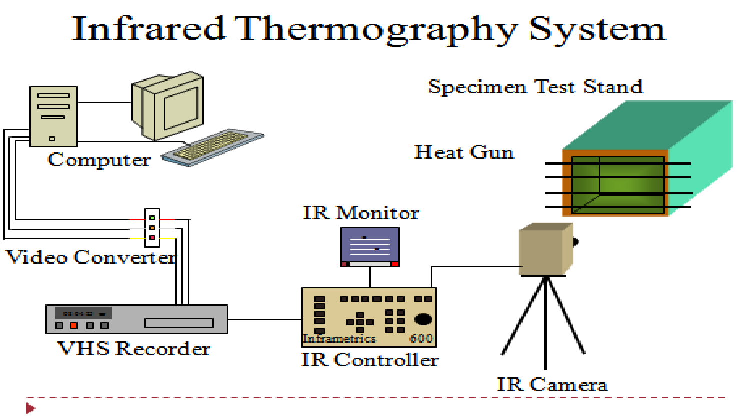
Active infrared thermography (IRT) has established as a fast and reliable tool in many areas of non destructive testing (NDT). It is well known for material testing in several industry branches for the detection of voids and delaminations. Because of its small penetration depth and slow velocity of propagation "Thermal Waves" normally are used for thin materials with high thermal conductivity (e.g. metal plates). As concrete has a very small thermal conductivity the application of infrared thermography in civil engineering (CE) was mostly limited to passive investigations of the quality of thermal insulation of building envelopes. Further developments and applications in civil engineering are using the sun as a natural heat source. Examples are inspections of bridge decks and of paving in general.

Nevertheless, in recent years a lot of investigations have been done to apply active thermography to civil engineering (CE). As shown recently there are certain CE applications where a customized active IRT is reasonable The measurements presented here were performed by external heating of the specimen- surface and further investigation of the cooling down process. The heating up pulse causes a instationary heat flow, describable as propagation and attenuation of thermal waves. The propagation of the thermal wave strongly depends on the material properties like thermal conductivity, heat capacity and mass density. Due to anomalous thermal properties inhomogeneities in the structural element affect the uniform heat flow and thus the surface temperature distribution. While observing the temporal changes of the surface temperature distribution with the infrared camera near surface inhomogeneities will be detected. The differences between temperature transient curves at surface positions above non-defect regions and above inhomogeneities include information about defect parameters like depth, lateral size and the type of material.

VII. EXPERIMENTAL SET UP OF ACTIVE THERMOGRAPHY.



The experimental set-up to perform impulse thermography measurements is shown The thermal heating unit contains three infrared radiators, each with a delivery rate of 2400 W. The heating-up procedure is usually done dynamically by moving the radiators across the specimen surface to obtain the best possible homogeneous heating. Therefore, radiators are mounted in a line array and are moved automatically parallel to the surface at a distance of about 15 cm.The cooling-down process of the surface is observed with a commercial infrared camera (Inframetrics SC1000). The camera contains a focal plane array of 256 x 256 PtSi semiconductor detectors and is able to detect radiation from the surface.



VIII. CONCLUSION

Infrared thermography is a non-destructive and non-contact testing method. All other NDT methods require access to the test element, and surface treatment (Schmidt rebound hammer and ultrasonic pulse velocity tests). Some of them may at the best be termed as semi-destructive (pull out and push off methods) rather than non-destructive. Advanced techniques, such as ground penetrating radar and impulse echo, require direct access and contact with the structural element. Thermography does not need any access and generally no surface treatment and it does not obstruct construction or restrict the use of the structure during investigations.

Infrared thermography has huge scope in investigation and research. It is necessary to use IRT in all type of construction to improve quality of construction. IRT also have best result in quality control of concrete. Throughout study of IRT in civil Engineering is require

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