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NURUL LYANA BINTI AL-ZAHABA

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Faculty of civil Engineering and Earth Resources

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ABSTRACT

Active infrared thermography (IRT) has been knowing and been established as a reliable non destructive and faster tools to investigates structure building. Application of infrared thermography in non destructive method is well known in civil engineering to detect voids in concrete, to check the concrete strength and material composition of concrete and grade of concrete. With help of image processing using colour detector software and IRT analysis system to assess and evaluate the concrete become more accurate and easier. Infrared thermography can be use in application of concrete studies because concrete has very small thermal conductivity and mostly limited to passive investigations quality of thermal insulation in structural building. Normal concrete cube specimens size (150mm x 150mm) were prepared with varying grade which is grade 25, grade 30, grade 35, grade 40, grade 45 and grade 50. The concrete cube condition must be in clean and free from dirt and IRT camera will be place opposite the concrete cube with computer to evaluate the data analysis. Using the IRT Camera to record and scan the concrete cube and set the equipment controls so that an adequate temperature image is viewed and recorded. This procedure need to be repeated for all concrete grade 25, concrete grade 30, concrete grade 35, concrete grade 40, concrete grade 45, concrete grade 50 and every concrete grade need two sample for each concrete grade. The concrete cube need to heating up 24 hours (110^{o}) before test begin. The tests and image captured using IRT Camera right after the concrete come out from oven and after four (4) hour later to see the if that any change of the concrete image cause by the thermal insulation. Every changes of colour due to the thermal insulation should be recorded. Once data are collected, the results should be shown as visual image and analysed using colour IRT analysis system based on colour detector software.

ABSTRAK

Thermografi inframerah aktif (IRT) adalah kaedah dan peralatan yang dipercayai tidak merosakkan dan berfungsi dengan lebih cepat untuk menyiasat struktur bangunan. Penggunaan thermografi inframerah dalam kaedah tanpa musnah adalah bagus dalam bidang kejuruteraan awam untuk mengesan lompang di dalam konkrit, untuk memeriksa kekuatan konkrit, komposisi bahan konkrit dan gred konkrit. Dengan bantuan perisian pemprosesan imej pengesan warna dan 'IRT analysis system' untuk menilai konkrit menjadikan data lebih tepat dan lebih mudah. Thermografi inframerah boleh digunakan dalam aplikasi kajian konkrit kerana konkrit mempunyai kekonduksian haba yang sangat kecil dan kebanyakannya terhad kepada siasatan pasif kualiti penebat haba dalam bangunan struktur. Normal konkrit saiz kiub spesimen (150mm x 150mm) telah disediakan dengan pelbagai gred koniakrit itu gred 25, gred 30, gred 35, gred 40, gred 45 dan gred 50. Keadaan kiub konkrit mestilah bersih dan bebas daripada kotoran dan kamera inframerah ditempatkan bertentangan kiub konkrit bersama-sama dengan peralatan lain seperti komputer untuk menganalisis data. Thermografi inframerah kamera digunakan untuk merakam, mengimbas kiub konkrit dan menetapkan kawalan peralatan supaya imej suhu dapat dilihat dan direkodkan. Prosedur ini perlu diulangi untuk semua gred konkrit 25, gred konkrit 30, gred konkrit 35, gred konkrit 40, gred konkrit 45 dan gred konkrit 50 . Sebanyak dua ke tiga sampel konkrit digunaakan untuk kajian ini. Kiub konkrit perlu dipanaskan 24 jam (110°) sebelum ujian bermula. Ujian dan imej yang diambil menggunakan kamera IRT sejurus selepas konkrit keluar dari ketuhar dan selepas empat (4) jam kemudian untuk melihat jika berlaku sebarang perubahan imej konkrit yang disebabkan oleh penebatan haba. Setiap perubahan warna disebabkan oleh penebatan haba hendaklah direkodkan. Setelah data dikumpul, keputusan hendaklah ditunjukkan sebagai imej visual dan dianalisis menggunakan IRT sistem dan analisis berdasarkan perisian pengesan warna.

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LIST OF SYMBOLS

μm	Micrometre
%	Percentage
°C	Celcius

LIST OF ABBREVIATION

mm	Millimetre
m	Meter
IRT	Infrared Thermography
2D	Two Dimension
NDT	Non Destructive Method
psi	Pound Per Square Inch
RN	Rebound Number
PT	Pulse Thermography
SH	Step Heating
LT	Lockin Thermography
VT	Vibrothermography
RGB	Red, Green, Blue
MPa	Mega Pascal

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

Infrared radiation discovered by an astronomer, William Herschel while searching for new optical filter materials to reduce the brightness of sun image in telescopes during solar observations in 1800 and in 1821. Thomas Johanna Seeback discovered thermoelectric that lead the scientist to research long wave radiation. Great knowledge development in third of 20th century produced a camera that can measure radiation and after that camera with temperature measurement. Nowadays, with help of new technology infrared camera is widely uses in civil engineering. It can be applied at any condition where process inside the object can lead to changes of temperature on its surface. Infrared camera only can sense temperature received from the surface of object and not from the visible light reflected to the object's surface. (Rao, 2008)

The infrared camera (IRT) consist an infrared permeable 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 thermography appears on the screen. IRT 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. The focal length and lens opening govern the quality of image generally. Wide angle lenses used to cover large spaces and telescopic lenses to obtain images from a distance are available for any model by according to (Wild, 2007)

In civil engineering, IRT is a effective tool to investigate and evaluating the condition of building structure. It gives faster result and information, easy to handling low cost. The application of infrared thermography is non destructive method (NDT) that using temperature as measurement to produce of image and visual not limited to passive investigations of the quality of thermal insulation of building envelopes. IRT is widely used for no-contact measurement of surface temperatures through infrared radiation emission. IRT measures the radiated electromagnetic energy in the infrared zone of the electromagnetic spectrum between 8 to 14 μm and produces 2D-images that represent heat wave contour. IRT is used for detecting subsurface characteristics such as subsurface thermal properties, presence of subsurface anomalies or defects. An infrared camera is generally used for creating fully analyzable images from the thermal radiation given off by the objects surface. A defect in the subsurface of the object can be revealed by a thermal anomaly in the distribution of temperature. IRT can be applied through active or passive approaches, depending on whether the inspected part is in thermal equilibrium or not. In construction thermography gains importance because it quickly discovers heat losses of building envelopes. (Cannas, 2012)

IRT are useful in electrical engineering, chemical and manufacturing industry and also pavements in road. IRT also used to locating sources of fire in case of fire ravaged building, fire potential of stored materials as well as surveillance. They are used in the food processing industry, wild life studies and diagnostics such as cancer detection. Several types of infrared cameras suitable for various applications are available commercially.

1.2 PROBLEM STATEMENT

Existing methods of measuring structure in composite materials are often categorized into two broad groups, destructive and nondestructive. The disadvantage of destructive method implies damaging or removing a section of material so that the specimen may no longer be usefully employed meanwhile non destructive method relatively simple and quick to perform and provide the advantage of using the same samples again and again. NDT techniques are also of particular value in quality control testing. One of the method in NDT is Infrared thermography (IRT) that can provides an invaluable service to civil engineering and concrete technology. By using this tools that can produce image and visual to check the characteristic of concrete such as concrete grade using IRT and based on set of data that produce from image processing without damage the structure. IRT also in situ faster method to check the thermal insulation of the difference concrete grades and only need one or two person to conduct the test. Data produce from the image processing can be used in other application and condition.

1.3 OBJECTIVE

Based on research problem statement, this research aims to achieve two (2) objectives.

i. To determine characteristics of concrete by different type of concrete grades on thermal insulation based on image provide form IRT Camera.
ii. To produce and come out set of data by using Colour Detector and IRT analysis system.

1.4 SCOPE OF STUDY

In particular, this research will be conducted following this four (4) scopes of study.

i. Characteristics of concrete based on normal concrete grade 25, grade 30, grade 35, grade 40, grade 45 and grade 50 cured in water for 28 days.
ii. Concrete cube size 150 mm x 150 mm
iii. Sample using two (2) to 3 (three) normal concrete cube for each concrete's grade.
iv. Develop set of data from image from image captured by infrared camera by using IRT analysis system based on colour detector software.

CHAPTER 2

LITERATURE REVIEW

2.1 TESTING FOR HARDENED CONCRETE

The deterioration of concrete structures in the last few decades calls effective methods for condition evaluation and maintenance. Testing and quality checkup are important at different stages during the life of a structure to properly maintain the civil infrastructures and as civil engineers required new methods of inspection The traditional method of evaluating the quality of concrete in civil structures is to test specimens casted simultaneously for compressive, flexural, and tensile strengths; these methods have several disadvantages such as results are not predicted immediately, concrete in specimens may differ from actual structure, and strength properties of a concrete specimens depend on its size and shape (Verma, 2013).

Therefore to overcome above limitations several NDT methods have been developed. NDT methods depend on the fact that certain physical and chemical properties of concrete can be related to strength and durability of structures. These methods have been used for more than three decades for evaluating the condition of a structure; now in the present century NDT has become more sophisticated, as it has developed from a hammer to Impact Echo and Impulse response. This resulted in development of several destructive and nondestructive testing techniques for monitoring civil infrastructures.

Both of destructive and non destructive method can uses to ensure the quality of the material, to minimize the maintenance cost and to spare or reduce the involved parties in the construction from facing problem at later stage(Verma, 2013).

2.2 DESTRUCTIVE METHOD

These tests are generally much easier to carry out, yield more information, and are easier to interpret than non-destructive testing. Destructive testing is most suitable, and economic, for objects which will be mass-produced, as the cost of destroying a small number of specimens is negligible. It is usually not economical to do destructive testing where only one or very few items are to be produced for example, in the case of a building. Analyzing and documenting the destructive failure mode is often accomplished using a high-speed camera recording continuously (movie-loop) until the failure is detected. Detecting the failure can be accomplish using a sound detector or stress gauge which produces a signal to trigger the high-speed camera (Oussama, 2008).

These high-speed cameras have advanced recording modes to capture almost any type of destructive failure. After the failure the high-speed camera will stop recording. The capture images can be played back in slow motion showing precisely what happen before, during and after the destructive event, image by image (Oussama, 2008). There are three type of destructive method which is compression strength concrete using cube test, tensile strength of concrete using direct tension test, split-cylinder test and flexural test and flexural strength. Building structures or large non building structures such as dams and bridges are rarely subjected to destructive testing due to the prohibitive cost of constructing a building.

2.2.1 Compression Strength of Concrete using Cube Test

For cube test two types of specimens either cubes of 150 mm X 150 mm X 150 mm or 100 mm X 100 mm x 100 mm depending upon the size of aggregate are used. For most of the works cubical moulds of size 150 mm X 150 mm X 150 mm are commonly used. Concrete cube testing is a primary quality compliance check on the specified design characteristic compressive strength of concrete mix supplied to the site. Concrete is poured in the mould and tempered properly so as not to have any voids. Concrete cube is prepared by placing 3 layer of concrete in the mould. Each layer is compacted using rod for 35 times. The top surface of these specimen should be made even and smooth. This is done by putting cement paste and spreading smoothly on whole area of specimen. Then it is cured in a tank of water for 7, 14 and 28 days. These specimens are tested by compression testing machine after 7 days curing or 28 days curing. Load should be applied gradually at the rate of 140 kg/cm^2 per minute till the specimens fails. Load at the failure divided by area of specimen gives the compressive strength of concrete (Ephraim, 2012).

2.2.2 Tensile Strength of Concrete using Direct Tension Test, Split-Cylinder Test, and Flexural Test.

Tensile strength of concrete should be high enough to resist cracking from shrinkage and temperature changes. There are three types of tests to measure strength using the following test, direct tension test, split-cylinder test and flexural test. Normally tensile strength is assessed using flexural or split-cylinder test. Tensile strength test has been well established that the simplest and the most reliable method, which generally provides a lower coefficient of variation, is the splitting tensile test of a cylindrical specimen. In this test, a cylindrical specimen is loaded in compression diametrically between two plates. According to the theory of elasticity, this loading generates almost uniform tensile stress along the diameter, which causes the specimen to fail by splitting along a vertical plane (Arıoglu, 2006).

2.2.3 Flexural Strength

Most common method for measuring the tensile strength of concrete. A concrete beam with span length equal to 3 times the beam depth the length of the beam should be at least 0.50 cm larger than the span is subjected to 3rd point loading (ASTM C78-94).
This produces tensile stresses at the bottom of the beam and compressive stresses at the top. Since concrete is weaker in tension than compression, the specimen fails where it breaks into two following the formation of a nearly vertical crack called a flexural crack, near the section of maximum moment. Beam samples measuring 500×100×100mm were molded and stored in water for 28 days before test for flexural strength that using automatic universal testing machine for the test according to BS1881-118. Three similar samples were prepared for each mix proportion. The casting was made by filling each mould with freshly mixed concrete in three layers. Each layer was compacted manually using a 25mm diameter steel tamping rod to give 150 strokes on a layer. The hardened beam was placed on the universal testing machine simply supported over a span 3times the beam depth on a pair of supporting rollers. Two additional loading rollers were placed on top the beam (Ukpata, 2012).

2.3 NON DESTRUCTIVE METHOD

Non-destructive techniques (NDT) are useful for evaluating the condition of structure, by performing indirect assessment of concrete properties. These techniques have been improved in last few years and the best part is that NDT avoids concrete damage for evaluation. Several researchers perform NDT tests to evaluate the condition of concrete structures. Methods range from very simple to technical depending on the purpose. Non-destructive normally carried out to periodically to evaluate the performance of building, to gather information on old building in order to ascertain the methods of repair or to demolish and to ascertain the strength of concrete if cube tests failed (Shaw, 1998). NDT has been defined as comprising methods used to examine objects, materials, or systems without impairing their future usefulness, that is, inspect or measure without harm. NDT methods are now considered as powerful tools for evaluating existing concrete structures with regard to their strength and durability. NDT methods have been drawing more and more attention, in the sense of reliability and effectiveness. The importance of being able to test in situ has been recognized, and this trend is increasing as compared to traditional random sampling of concrete for material analysis. NDT methods may be categorized as penetration tests, rebound tests, pull out tests, dynamic tests, and radioactive methods.

2.3.1 Rebound Hammer Test

Rebound hammer test is known as Schmidt hammer test. It can be used to determine the in-place compressive strength of concrete within a range of 10 to55 MPa and very useful in the assessment of uniformity of concrete within a structure. This is test can be used to establish whether the rebound number has reached a value known to correspond to the desired strength. Measure the distance of rebound of a spring-loaded plunger after it struck a smooth concrete surface with a quick and simple mean of checking concrete uniformity. Results of the test can be affected by factors such as smoothness of concrete surface, size, shape, rigidity of specimen, age & moisture condition, type of coarse aggregate & the carbonation of the surface. The rebound hammer is useful in the assessment of uniformity of concrete with in a structure. The test can also be used to establish whether the rebound number has reached a value known to correspond to the desired strength. This is of the help in deciding when to remove false work or to put the structure into service.

Rebound hammer test is one of the oldest non-destructive tests and still commonly used owing to its simplicity. It is based on the principle that the rebound of an elastic mass depends upon the surface hardness, against which the mass impinges. A spring loaded mass having a fixed amount of energy is released and the distance traveled by the mass is expressed as a percentage of the initial spring extension. It is called as rebound number (RN) generally indicated by a rider moving along a graduated scale. The measured rebound numbers are very sensitive to local variations in concrete. For example, presence of large pieces of aggregate just under the plunger may result in abnormal higher values, conversely, presence of a crack or void under the plunger will cause lower rebound numbers. Moreover, the rebound numbers also depend on the type and the properties of the aggregate, mix proportions, surface texture and surface wetness of the concrete. It is clear that the rebound number reflects only the concrete surface properties (Arioz, 2008).

2.3.2 Ultrasonic Pulse Velocity

The ultrasonic pulse velocity test is a popular NDT. It is fast and easy to perform. Thus, it can be considered as a successful method for quick checking of uniformity of concrete in different parts of the structural member or in different parts of the structure itself, or to indicate the presence of voids or internal cracks and to determine the changes in the properties of concrete in a structure. It uses measurement of the speed of ultrasonic pulses through the concrete through the concrete to correlate concrete strength to standard strength. Ultrasonic pulse velocity allows the determination of compressive concrete strength and location of cracks and it will identify non homogenous condition in the structure such as honeycomb, voids and cracks. The test results are affected by a number of factors such as properties of aggregates, mix proportions of concrete, the presence of steel reinforcement, voids or cracks, surface smoothness, travel path of the pulse, temperature effect on the pulse velocity, moisture content, and age of concrete. Although there are several proposals, it may not be possible to develop a unique relationship between the strength and ultrasonic pulse velocity (Arioz, 2008).

2.3.3 Penetration Test

The Windsor probe is generally considered tube the best means of testing penetration. It consists of a powder-actuated gun or driver, hardened alloy probes, loaded cartridges, a gauge for measuring penetration of probes and other related equipment. A probe is driven into the concrete by means of a precision powder charge. Depth of penetration provides an indication of the compressive strength of the concrete. This apparatus provides a quick means of determining the relative strength and quality of concrete and also useful in determining whether formwork can be removed. Penetration test is designed for in-place testing of compressive strength and quality and can be performed on slabs, floors, ceilings, curved surfaces and pavements. The cost of the test is higher than hammer test and likely to be preferable to drilling small-diameter cores (Malhotra, 2004).

2.3.4 Pull Out Test

Pull out test is a test which measures, by means of a special tension jack, the force required to pull out a previously cast-in-metal insert with an enlarged end. This test is superior to the rebound hammer and to penetration resistance test because a larger volume and greater depth of concrete are involved in the pull out test. Pull out test using post-installed is an alternative to drilled cores to determine the in-place concrete compression strength (Thun, 2009). Pull out test measures, with a special tension ram, the force required to pull-out a specially shaped steel rod whose enlarged end has been cast into the concrete. Because of its shape, the steel rod pulls out a cone of the concrete. The concrete is believed to be simultaneously in tension and in shear, and the shape of the cone is approximately 45 degrees. The pull-out force is related to the compressive strength of companion test cylinders (Malhotra, 1975).

The main advantage of the pull-out test is it provides a direct measure of the in-situ strength of concrete. The method is relatively simple and testing can be done in the field in few minutes. Such correlation depend on the geometry of the pull out test configuration and the coarse aggregates characteristics. A major disadvantage of the pull out test is that minor damage to the concrete surface must be repaired. However, if a pull out force corresponding to a given minimum strength is applied without failure, it may be assumed that a minimum strength has been reached in the concrete and the pull out insert need not be stressed to failure (Thun, 2009).

2.3.5 Infrared Thermography

Infrared thermography (IRT) have been used in the civil engineering industry for different applications to investigate structure. The technique of infrared thermography has been successfully applied in a number of other areas, to measure the conductive heat loss of infants in the medical industry, in the quality assessment and design of semiconductors, in the printing industry to determine when the ink is dry, identification of buried mineshafts, identification of canal seepage as well as various other civil engineering applications. In a number of cases, infrared thermography has been used in collaboration with other techniques and has proved successful. An example of case where infrared thermography was used with digital image processing and fibre optic microscopy to assess and evaluate weathering damage on the Medieval City of Rhodes. Another example involved infrared thermography, electrical resistivity sounding and borehole drilling to determine the seepage of a canal in Nebraska.

Infrared thermography, acoustic imaging, radiography tomography have been used together to determine the location and depth of various anomalies in concrete structures. Radar and infrared thermography can be use together to identify cracks in highway bridges in the United State of America (USA) because infrared is a useful tool to test areas, which the radar cannot reach. Various works have been undertaken to quantify infrared images. Infrared thermography is one of many NDT techniques available to the engineer for the non-destructive testing of concrete and masonry bridges. (Clark, 2003)

2.3.5.1 Active and Passive Thermography

IRT can be divided into two approaches, the passive approach and the active approach. The passive approach tests materials and structures which are naturally at different (often higher) temperature than ambient while in the case of the active approach, an external stimulus is necessary to induce relevant thermal contrasts. In many industrial processes temperature is an essential parameter to assess proper operation and passive thermography aims at such measurement. Important applications of the passive approach are in production, predictive maintenance, medicine, fire forest detection, building thermal efficiency survey program, road traffic monitoring, agriculture and biology, medicine, detection of gas by mean of absorbing tracer gas and in NDT (Maldague, 2002).

Interestingly for some applications, knowledge of the work piece fabrication and operation combined with proper thermal modelling opens the door to quantitative extraction of information such as for instance the remaining thickness of refractoriness. Contrary to the passive approach, in the active approach, an external stimulus is required to generate relevant temperature differences not present otherwise. Known characteristics of this external stimulus (example: time to when it is applied) enable quantitative characterization such as for instance the depth of a detected disband. Depending on the external stimulus, different approaches of active thermography have been developed, such as pulse thermography (PT), step heating (SH), lockin thermography (LT), vibrothermography (VT).

2.3.5.2 Theoretical Consideration

Infrared radiation is the region of the electromagnetic spectrum between visible light and microwaves, containing radiation with wave lengths ranging from 0.75 to 10 mm. It can be shown theoretically that peak radiation from a target at room temperature of 300 K occurs at a wave length of 10 mm. Given that bridges in the field may be monitored at lower temperatures than room temperature, it can be seen that a long wavelength camera is required for structural surveys on bridges (Clark , 2003). This equates with the long wave or far infrared zone is shown in Table 2.1.

Table 2.1: The electromagnetic spectrum

Sub Region	Wavelength (μm)
Near infrared	0.75 – 3
Middle infrared	3 – 6
Far infrared	6 – 15
Extreme	15 – 100

The camera captures the thermal information and relays it through the computer or laptop for data storage and processing. By measuring the emitted infrared radiation from an object this camera can measure differences in temperature down to 0.088°C. Radiation is a function of an object's surface temperature, which makes it possible for the camera to calculate and display the temperature. The radiation measured by the camera does not depend only on the object surface temperature but is also a function of the emissivity. Emissivity is a measure of the efficiency of a surface to act as a radiator. The equation for the radiation of an object according to the Stefan–Boltzmann express as in Eq.(2.1)

$$E \text{ ¼ } esT4 \tag{2.1}$$

where E is the radiation (W/m^2), T is the temperature (K), s is the Stefan–Boltzmann constant (5.67 and 1028 W/m^2) and e is the emissivity. Other potential problems can occur when the object reflects radiation originating from the surroundings. Atmospheric absorption of radiation will also affect the measured temperature.

There are three methods of heat transfer, conduction, convection and radiation. An infrared camera is only able to record the amount of radiated heat from an object. The rate of heat transfer through an object, which is dominated by convection and conduction depending on the object's material, determines how much energy can be radiated at the surface. One of the most important factors of each material when talking about heat transfer is the heat capacity of the material.

2.3.5.3 Advantages Of Thermography

No direct contact is required between the camera and the object under investigation. Camera and object separation can range from a few millimetres to several kilometres thus allowing measurements to be made identifying potentially hazardous areas. As no external source of illumination is necessary, both day and night operation is possible. Due to the separation between camera and object, measurement by thermography should not cause interference with the object and, hence, acquired data. In reality, some interference will be caused by the camera shielding the object from some radiation, which would otherwise be incident upon it and by the radiation reflected and emitted from the camera itself. These effects can normally be assumed to be negligible (Clark, 2003).