STUDY OF CONCRETE GR IAGE PROVIDES BY

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MOHAMAD FARHAN BIN ABU SAMAH

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ABSTRACT

Infrared thermography (IRT) has been used in the civil engineering field for different applications such as highway, bridge and concrete structures. Infrared have been using worldwide in non-destructive methods to evaluate bridges, building, highway pavement and airport. Previous research has shown that IRT can detect cracking, void and leaking on the structure. IRT systems provide a new non-destructive method to test every failure that occurs in the structure of building. Besides easy to perform, IRT also accurate and detail if the data required are supplied enough. With nowadays technological advances it is required to find a new method that are more users friendly. The main advantage of IRT than the others destructive testing techniques is that big scale areas can be scanned easily and practically with no need to destroy any building structure during testing. These will results to the main reduce in time, worker, work and machinery. The IRT device is no risky, as it does not release any radiation; it only records the infrared radiation release by the material that is under testing. The procedure is to scan the concrete cube under same stress and produce the infrared thermography image. This procedure will use different concrete's grade which are 25, 30, 35, 40, 45 and 50. Every changes of colour due to the load apply and difference grade of concrete will be recorded. Test was performed in the lab to have more quality image. All the data that been gather must be analysed using Colour Detector software and the result should be shown by using IRT analysis system.

ABSTRAK

Termografi inframerah telah digunakan dalam bidang kejuruteraan awam bagi aplikasi yang berbeza seperti di lebuhraya, jambatan dan struktur bangunan konkrit. Inframerah telah digunakan di seluruh dunia dalam kaedah tanpa musnah untuk menilai jambatan, bangunan, kaki lima lebuhraya dan lapangan terbang. Kajian sebelum ini menunjukkan bahawa IRT boleh mengesan keretakan, kelembapan dan kebocoran di struktur bangunan. Infrared Termografi (IRT) merupakan kaedah tanpa musnah yang baru untuk menguji setiap kegagalan yang berlaku di dalam struktur bangunan. Selain daripada mudah untuk dilaksanakan, IRT juga menghasilkan data yang tepat dan terperinci jika data yang diperlukan mencukupi. Dengan kemajuan teknologi pada masa kini, IRT amat diperlukan untuk mencari kaedah baru yang lebih kepada mesra pengguna. Kelebihan utama IRT daripada teknik-teknik ujian tanpa musnah ialah kawasan berskala besar dan luas boleh diimbas dengan mudah dan praktikal tanpa perlu untuk memusnahkan mana-mana struktur bangunan semasa ujian. Ini dapat mengurangkan masa, pekerja, kerja dan jentera. Peralatan IRT tidak berisiko, kerana ia tidak melepaskan sebarang radiasi, ia hanya mencatat pelepasan radiasi inframerah. Kajian ini adalah untuk mengimbas kiub konkrit di bawah tekanan yang sama iaitu 50 kN dan menganalisis data imej termografi inframerah yang terhasil. Prosedur ini menggunakan gred konkrit yang berbeza seperti berikut gred konkrit 25, 30, 35, 40, 45 dan 50. Setiap perubahan warna disebabkan oleh tekanan pada gred konkrit yang berbeza direkodkan. Ujian dilaksanakan di dalam makmal untuk menghasilkan imej yang lebih bermutu. Semua data yang telah terkumpul dianalisis menggunakan perisian pengesan warna dan hasilnya dipaparkan dengan mengunakan'IRT analysis system'.

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μm	Micrometre
°C	Celsius
λ	lambda

LIST OF ABBREVIATION

NDT	Non Destructive Method
kN	Kilo Newton
mm	Millimetre
m	Meter
RGB	Red, Green, Blue
IRT	Infrared Thermography
ITAR	International Traffic in Arms Regulations
NETD	Noise-equivalent temperature difference
MRTD	Minimum resolvable temperature difference
CPWD	Central Public Works Department of India
PT	pulsed thermography
PPT	pulsed phase thermography
TM	thermal modelling

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

In the early 19th century, an astronomer William Herschel discovers the concept of an infrared radiation. Herschel showcased the outcome of his experiment in 1800 in front of the Royal Society of London. Herschel took a prism to deflect light from the sun and identified the infrared that got past the red part of the spectrum with the support of an enhancement in the temperature displayed on a thermometer. He was astonished with the outcome and termed them "Calorific Rays". The word 'Infrared' failed to prove its significance and it was only after late 19th century, people gradually came to know the term after understanding its manifold applications in diverse industry verticals (Rao, 2008).

A thermal imaging device gives the ability to see targets in darkness or smoke. During an interview at the International Robots & Vision Show, Dr Austin Richards (Indigo Systems) stated that thermal imaging is a technology that creates a photographic image or video sequence of light emitted by an object at terrestrial temperatures. Infrared thermography is not the same as night vision. Night vision operates on the principle of light amplification, so in a totally dark environment light amplification would yield no image where as a thermal imager would (Rao, 2008).

Infrared thermography is equipment or method, which detects infrared energy emitted from 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 literatures show tendency not to pay attention to such appellative. The equipment call as infrared thermography considering such generalization of the terminology. Thermal imaging devices were first developed for military purposes. According to Bullard Thermal Imaging, "In the late 1950s and 1960s, Texas Instruments, Hughes Aircraft, and Honeywell developed single element detectors that scanned scenes and produced line images. These basic detectors led to the development of modern thermal imaging (Cannas, 2012).

Most materials absorb infrared radiation over a wide range of wavelengths, causing an increase in their temperature. All objects with a temperature greater than absolute zero emit infrared energy, and even glowing objects usually emit far more infrared energy than visible radiation. Thermal imaging is a technique for converting a thermal radiation pattern, which is invisible to the human eye, into a visual image. To achieve this, an infrared camera is used to measure and image the emitted infrared radiation from an object. Since this radiation is dependent upon the object surface temperature, it makes it possible for the camera to calculate and display this temperature. However, radiation measured by the camera does not only depend on the temperature of the object, but also its emissivity and its absorption by the atmosphere. Further radiation (e.g. reflected from the sun) may be introduced by the surroundings, which may be reflected on the object (Wild, 2007).

Infrared thermography (IRT) is a modern tool for examination of nondestructive structural building. Thermography is determination surface temperature of objects with help of infrared camera. Infrared camera provides a visual of temperature measurement in building from inside and outside. IRT used to check the concrete condition during the concrete under stress using the image and visual that provided by the IRT. The measurement presented performed by using compression machine given certain load to the concrete. Image from IRT show several of colour's pattern causes of the stress happen on the concrete. Difference colour on the image show difference load react to the concrete's structure, IRT image been taken before the compression test, during the compression test and after the compression test to achieve good result and data (Rao, 2008).

It captures as a temperature distribution on a surface, and it can display as a visible information. Temperature can be measured from a distance without contacting an object. Temperature can be measured in real time. Relative comparison of distribution of surface temperature can be made over a wide area. Temperature can be measured easily for a moving object or an object which is dangerous to get close to. Temperature of small object can be measured without confusing the temperature. Temperature of food, medicine or chemicals can be measured in a sanitary fashion. Temperature of an object with drastic temperature change or a phenomenon during a short period of time can be measured.

1.2 PROBLEM STATEMENT

Infrared thermography is contactless measurement for analysis of building structures. By using IRT that can be used in real situation with non-destructive method to check the stress happen on structural of the building. The method more accurate, easy and economical since only use IRT that can be handling by single person than using destructive method that can damage the structure or need to operate by skill worker.

1.3 OBJECTIVES

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

i. To determine concrete grade under stress using image provides by Infrared thermography Camera (IRT).
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 these five (5) scopes of study.

i. Determine concrete grade under stress of 50 kN by image provides by using Infrared Thermography IRT.
ii. Determine concrete grade under stress for concrete grade 25, 30, 35, 40,45 and 50.
iii. Using Compression Test for concrete cube testing.
iv. Sample using 2 (two) to 3 (three) concrete cube for each concrete's grade.
v. Develop set of data from image captured by infrared camera by using IRT Analysis System based on Colour Detector software.

1.5 RESEARCH SIGNIFICANCE

Within recent years there has been an increase in the use of Non-Destructive Technique (NDT) methods to detect defects and anomalies in various civil engineering structures. Infrared thermography, which has been successfully used in the United State of America (USA) in civil engineering applications, is being increasingly applied in the United Kingdom(UK) as a NDT. For example, the technique is now included in the Building Regulations for the assessment of thermal insulation for all new non-domestic buildings from April 2002. One of the perceived limitations of infrared thermography is that in temperate climates it is too cold to use this technique since there is rarely the extreme solar exposure that has enabled the successful use of thermography to detect render deboning and concrete spilling utilizing solar heating. However, with the advancements in modern technology it is now possible to detect smaller changes in temperature,(down to 0.08°C to8°C). This paper shows that even with the low ambient temperatures experienced in Europe it is possible to use infrared thermography to identify correctly known areas of delimitation in a concrete bridge structure and also to investigate the internal structure of a masonry bridge (Maldague, 2002).

Infrared thermography and impulse radar have been used together on a number of occasions in the civil engineering industry for different applications such as concrete structure sand on highway bridges in the USA. Weil has shown that bridges, highway and airport pavement have been tested with both infrared and radar finding a variety of faults ranging from cracks on airport pavements to delimitation on concrete bridges. Infrared Thermography (IRT) systems provide a new nondestructive method to test every failure that occurs in the structure of building. Besides easy to perform, IRT also accurate and detail if the data required are supplied enough. With nowadays technological advances it is required to find a new method that are more users friendly that even unskilled worker can conduct the test (Maldague, 2002).

CHAPTER 2

LITERATURE REVIEW

2.1 TESTING FOR HARDENED CONCRETE

The standard method of determining strength of hardened concrete consists of testing concrete cubes in compression. The quality of entire concrete of a structure cannot be fully assessed by testing a few concrete cubes. The results obtained in testing cubes do not always reflect the actual strength of concrete in construction. In a whole day, concreting work cubes are cast in a few batches, the differences (unintentional and intentional) in the composition are not uncommon, their compaction and their hardening conditions always differ more or less from those of the structure. In addition, the number of test cubes is generally so small that they can only be considered as random tests. Sometimes, in case of failure of cubes, doubtful concrete, cracks, deterioration of concrete, etc. it becomes necessary to assess the quality and strength of concrete of the structure. As far back as early thirties, the necessity was felt to develop instruments by which in-situ strength of concrete may be obtained (Verma, 2013).

Various non-destructive methods of testing concrete have been developed, which include, Rebound hammer, Pull out techniques, Windsor probe, Ultrasonic pulse velocity methods, Radioactive and nuclear methods, Magnetic and electrical methods. In all these methods of tests, due to simplicity, rebound hammer test based on surface hardness becomes most popular in the world for non-destructive testing of in-situ concrete.

2.2 DESTRUCTIVE TEST

In destructive testing, tests are carried out to the specimen's failure, in order to understand a specimen's structural performance, composition of structure or material behavior under different loads and stress. 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 (Oussama, 2008).

Detecting the failure can be accomplished using a sound detector or stress gauge which produces a signal to trigger the high-speed camera. 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. 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 (Oussama, 2008).

2.2.1 Compression Strength of Concrete using Cube Test

Compression test of the concrete specimen is most widely used test to measure its compressive strength. Two types of concrete specimen: Cubes & Cylinders are used for this purpose. Cubes of size 150mm are more common in Asia, Russia & European countries while Cylinders of 150mm in diameter & 300mm high are common in U.S and Australia. Cubes for compression test are casted in a steel or cast-iron mould of prescribed dimensions. BS 1881: Part 108: 1983 requires filling the mould in layers of approximately 50 mm. Compaction of each layer is achieved by not less than 35 strokes for 150mm cubes or 25 strokes for 100 mm cubes. A standard tamping bar of a 25mm square of steel section is used for this purpose. Compaction by vibration may also be used (Ephraim, 2012).

After finishing the cube, it should be stored at a temperature of 150°C to 250°C, when the cubes are to be tested at or more than 7 days. When the test days is less than 7 days the temperature to be maintained is 180°C to 220°C. Also, relative humidity of 90 percent is to be maintained always. The cube is remolded just before testing at 24 hours. For greater ages at test, remolding takes place between 16 to 28 hours after adding water in a concrete mix and the specimens are stored in a curing tank at 180°C to 220°C until the required age (Ephraim, 2012).

The most common age at testing is 28 days, but tests can be made at 1, 3, 7 & 14 days also. At the time of testing the specimen is placed in a "Compression Testing Machine" with the position of cubes at right angles to the position of cast. The load is applied at a constant rate of stress within the range of 0.2 to 0.4 MPa/sec. Under pure uniaxial compression loading, the failure cracks generated are approximately parallel to the direction of applied load with some cracks formed at an angle to the applied load. Practically, the compression testing system rather develops a complex system of stresses due to end restraints by steel plates (Ephraim, 2012).

2.2.2 Tensile Strength of Concrete Using Direct Tension Test

The measured tensile strength of concrete is dependent on the test method used. Compared with indirect methods, the direct tension test method gives results closer to the true tensile strength under pure tension condition. Herein, a new direct tension test method for prismatic specimens that uses bonded steel end plates to apply tension load to the concrete has been developed (Zheng, 2001). A three-dimensional finite element analysis of the test assembly showed that the tensile stresses transmitted to the specimen are very evenly distributed. The random distribution of the fracture location indicated that there was no preferred fracture location and no significant end effect. The dependence of direct tensile strength on specimen length revealed that there might be significant size effect.

Concrete cracking strength can be defined as the tensile strength of concrete subjected to pure tension stress. However, as it is difficult to apply direct tension load to concrete specimens, concrete cracking is usually quantified by the modulus of rupture for flexural members. In this study, a new direct tension test setup for cylindrical specimens (101.6 mm in diameter and 203.2 mm in height) similar to those used in compression test is developed. Double steel plates are used to obtain uniform stress distributions. Finite element analysis for the proposed test setup is conducted. The uniformity of the stress distribution along the cylindrical specimen is examined and compared with rectangular cross section. Fuzzy image pattern recognition method is used to assess stress uniformity along the specimen. Moreover, the probability of cracking at different locations along the specimen is evaluated using probabilistic finite element analysis. The experimental and numerical results of the cracking location showed that gravity effect on fresh concrete during setting time might affect the distribution of concrete cracking strength along the height of the structural elements (Zheng, 2001).

2.2.3 Tensile Strength Of Concrete Using Split-Cylinder Test

Due to the difficulty in applying direct tension to concrete, the split-cylinder tensile test has gained wide popularity. In this test, a cylinder is in compression diametrically between two platens. According to the theory of elasticity, this loading produces a nearly uniform maximum principal tensile stress along the diameter, which causes the cylinder to fail by splitting. Although the stress state is not uniaxial (there is a significant compressive normal stress in the transverse direction), the tensile stress value in the cylinder at failure has proven to be a useful measure of the tensile strength. Like all brittle failures of concrete, split-tensile failure can be expected to exhibit size effect. It has been well established that the simplest and the most reliable method, which generally provides a lower coefficient of variation, is the splitting tensile test7-9 of a cylindrical specimen. In this test, a cylindrical specimen is loaded in compression diametrically between two platens (Arıoglu, 2006).

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. The splitting strength can be used to estimate direct tensile strength by multiplying by a conversion factor of $\lambda = 0.9$. The splitting tension tests were performed on cylinders with varying geometries and concreting methods. On site, the characteristic values of existing concrete structures can only be determined by taking core samples (Arıoglu, 2006).

2.2.4 Tensile Strength Of Concrete Using Flexural Test

Flexural strength provides two useful parameters, which is the first crack strength, which is primarily controlled by the matrix, and the ultimate flexural strength of modulus of rupture, which is determined by the maximum load that can be attained. In China the flexural properties of cement stabilized macadam reinforced with polypropylene fiber has been studied. Flexural properties of structural materials are generally important to design engineers to guide appropriate selection of materials. It has been argued that the flexural strength property of concrete is important particularly when the concrete structure has no steel reinforcement. For example, unreinforced concrete roads and runways rely on their flexural strengths to safely distribute concentrated loads over wide areas. This appears to be also true for tensile strength property of concrete. Hence, findings from this research will have great significance in providing relevant data for the analysis and design of structures by consultants and practitioners in the construction industry. It will also open many questions that will trigger further research on the appropriate use of these abundant resources to reduce construction costs and tendencies for building failures (Ephraim, 2012)

2.3 NON DESTRUCTIVE TEST (NDT)

The NDT of concrete in today's scenario has received a great importance in terms of practical and engineering value. The subject has received a growing attention during recent years, especially the quality characterization of damaged structure made of concrete using NDT testing (Jain, 2013).

The advantages of NDT as reduction in the labor consumption of testing, a decrease in labor consumption of preparatory work, a smaller amount of structural damage, a possibility of testing concrete strength in structures where cores cannot be drilled and application of less expensive testing equipment, as compared to core testing. These advantages are of no value if the results are not reliable, representative, and as close as possible to the actual strength of the tested part of the structure. Rebound hammer is useful to detect changes in concrete characteristics over time, such as hydration of cement, for the purpose of removing forms or shoring. This test is based on the principle that the rebound of an elastic mass depends on the hardness of the surface against which the mass impinges (Malhotra, 1976).

The test procedure is described in IS:13311 Part 2 : 1992 and BS1881 202 (1986). It is portable, easy-to-use, low-cost, and can quickly cover large areas but it is valuable only as a qualitative tool since it measures the relative surface hardness of the concrete. Other tests, such as a compression test, must be used to determine the actual strength of the concrete. The rebound measurement is governed by several factors including the size, age, and finish of the concrete, as well as the aggregate type and the moisture content. A handy non-destructive testing instrument should be cheap, easy to operate and should have reproducibility for, fairly accurate results. In 1948, a Swiss Engineer, Ernst Schmidt developed a test hammer for measuring the hardness of concrete by the rebound principle (Malhotra, 1976). .

2.3.1 Rebound Hammer Test

In spite of its popularity, this testing has not been standardized in any country till 1970 except in Bulgaria. In 1971 the British Standards Institution Standardized this test in recommendation for "Non-Destructive Methods of Test for Concrete" part 4 surface hardness methods (BS 4408 : part 4 : 1971). ASTM issued a tentative standard in 1975 "Tentative Method of Test for Rebound Number of Hardened Concrete" (ASTM C 805 : 75 T), and in 1979 ASTM standard of this test was issued "Test for Rebound Number of Hardened Concrete" (ASTM : C805-1979).

Bureau of Indian Standard did not publish any standard for this test up to 1991. In 1992 they published IS: 13311 (Part 2) for this test. IS: 456-2000 specified the Non-destructive tests are used to obtain estimation of the properties of concrete in the structure, the methods adopted include Rebound Hammer. The Central Public Works Department of India (CPWD) specifications that in case the concrete cubes fails, concrete test hammer may be used to arrive at strength of the concrete and the purpose of Rebound Hammer test results only shall be the criteria.

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 (Neville, 2003).

2.3.2 Ultrasonic Pulse Velocity (UPV)

Longitudinal ultrasonic waves are an attractive tool for investigating concrete. Such waves have the highest velocity so it is simple to separate them from the other wave modes. The equipment is portable, usable in the field for in situ testing, is truly nondestructive and has been successful for testing materials other than concrete. The ultrasonic pulse velocity tester is the most commonly used ones in practice. Test is described in (IS: 13311 Part 1; 1992 and BS 1881-203; 1986). Nevertheless, there are intrinsic and practical factors that may interfere with the determination of concrete strength by ultrasonic means. Concrete is a mixture of four materials: Portland cement, coarse aggregate, fine aggregate and water. This complexity makes the behavior of ultrasonic waves in concrete highly irregular, which in turn hinders non-destructive testing (Popovics, 1998).

In the view of the complexities of the problem it would appear to be overly optimistic to attempt to formulate an ultrasonic test method for the determination of concrete strength. However, considering the seriousness of the infrastructure problem and the magnitude of the cost of rehabilitation, major advancement is desperately needed to improve the current situation. For instance, it has been demonstrated repeatedly that the standard ultrasonic method using longitudinal waves for testing concrete can estimate the concrete strength only with ± 20 percent accuracy under laboratory conditions The use of UPV and rebound hammer has been experimentally investigated by inducing voids in the sample by and result showed the NDT data can be used to make trustworthy guess about concrete condition with damaging structural elements, if the defects are sizeable enough (Lorenzi, 2009).

2.3.3 Penetration Test

The penetration resistance method is well known. The Windsor probe system, introduced in the US in 1960, is based on the determination of the depth penetration of a steel pin fired into the concrete. The depth of penetration of the pins is correlated with the compressive strength of the concrete. Subsequently, in 1970, According to (Arni ,1972) reported the results of a detailed investigation into the evaluation of the Windsor probe. The Windsor probe (Pucinotti, 2005), like the rebound hammer is basically a hardness tester that provides a quick means of determining the relative strength of the concrete. The exposed length of the probe is measured by a depth gauge and related by a calibration table to the compressive strength of the concrete. For each exposed length value of the depth gauge, different values for the compressive strength of concrete are given, depending on the hardness of the aggregate. This hardness is measured by the Mohs' scale. The correlations published by several researchers working upon concrete made with different types of aggregates, but having similar Mohs' hardness values, had, however, shown different relationships (Burt, 1969 and Malhotra, 1971).

A series of non-destructive tests were performed *in situ* with the purpose of investigating the mechanical characteristics of materials of 'ancient' reinforced concrete structures; the correlation between the values of experimental strengths was determined using the Windsor Probe System with satisfactory core strengths. The strength values in the rectangular window refer to a very old concrete, and in this case the tests indicate a higher strength than actually exists in the structure. In this case where the actual strength is less than approximately 15 MPa, the correlation between the probe penetration and in situ strength becomes more uncertain. In fact, the degree of carbonation present considerably affects the accuracy of the probe penetration, and hence indicates the concrete strength for some structural elements in reinforced concrete buildings (Pucinotti, 2005).

2.3.4 Pull Out Test

A pullout test consists of casting a specially-shaped steel insert with an enlarged end into fresh concrete. This steel insert is then pulled-out from the concrete and the force required for pullout is measured using a dynamometer. A bearing ring is used to confine failure to a well-defined shape. As the steel insert is pulled out, a cone of concrete is also removed, there by damaging the concrete surface (which must be repaired after the test).