INFRARED BASED TECHNOLOGY
TO
DETERMINE STRENGTH OF CONCRETE

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Bachelor of Engineering Technology
(Infrastructure Management) with Hons.

UNIVERSITI MALAYSIA PAHANG

SUPERVISOR'S DECLARATION

I hereby declare that I have checked this thesis and in my opinion, this thesis is adequate in terms of scope and quality for the award of the Bachelor Degree of Engineering Technology (Infrastructure Management)

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I hereby declare that the work in this thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at Universiti Malaysia Pahang or any other institutions.

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ABSTRAK

Thermografi Inframerah adalah alat alternatif untuk mengukur kekuatan konkrit selain menggunakan kaedah mampatan oleh mesin mampatan. Kajian ini adalah mengenai kaedah ujian tidak terganggu dengan menggunakan teknologi berasaskan inframerah untuk mengukur kekuatan konkrit bagi mengekalkan permukaan struktur daripada terganggu. Thermografi Inframerah adalah teknologi yang terkenal dalam bidang Kejuruteraan Awam disebabkan oleh ciri-cirinya yang tidak memerlukan sentuhan dengan objek yang mahu diuji. Ia membenarkan pengguna mengesan perubahan suhu pada permukaan objek. Objektif kajian ini adalah untuk manghasilkan kaedah ujian tidak terganggu yang dapat mengesan kekuatan konkrit dengan menggunakan teknologi inframerah dan untuk menentukan hubungan antara inframerah, kekuatan, dan keliangan konkrit. Kaedah ini akan memberi impak positif kepada kejuruteraan awam dan bidang seni bina kerana ia mengekalkan nilai estetika sesuatu struktur itu untuk menentukan kekuatan konkrit tanpa perlu menghancurkan konkrit. Kaedah ini bermula dengan menghasilkan gred konkrit yang berbeza (Gred 30, Gred 35, Gred 40, Gred 45, Gred 50, Gred 55 dan Gred 60) dengan saiz 150mm x 150mm x 150mm untuk diuji menggunakan ujian tidak terganggu dan ujian terganggu Proses menghasilkan sampel imej inframerah dilakukan pada hari ke-7 dan hari 28 konkrit direndam. Terdapat 3 imej inframerah yang diambil dari 2 permukaan kiub konkrit untuk setiap gred konkrit. Langkah seterusnya ialah menukarkan imej haba ke dalam imej plot kontur menggunakan perisian MATLAB dan kemudian plot kontur tersebut akan dianalisis menggunakan AutoCAD dengan memilih fungsi bulatan 3-titik untuk menentukan diameter setiap warna termal diatas imej inframerah. Terdapat 3 warna termal yang diutamakan dalam kajian ini iaitu Putih. Kuning, dan, Oren. Warna termal putih adalah warna yang mempunyai suhu tertinggi di antara dua warna termal yang lain kerana haba digunakan terus ke kawasan tersebut sebelum tersebar ke kawasan kuning dan oren. Ujian terganggu dilakukan sejurus selepas proses ujian tidak terganggu selesai. Analisis keputusan daripada imej kontour plot diteruskan dengan mengetahui batas bawah, tengah, dan batas atas bagi warna termal kuning dan oren. Akan tetapi, bagi warna termal putih yang berada di tengah-tengah imej inframerah, ia hanya mempunyai had atas sahaja. Hasil menunjukkan bahawa warna haba yang paling boleh dipercayai dan yang mempunyai korelasi tertinggi antara diameter warna termal dan gred konkrit adalah warna termal putih dengan nilai R^2, 0.9877. Tetapi bagi korelasi antara diameter warna termal dan keliangan konkrit, warna termal putih menunjukkan korelasi terendah dengan nilai R^2, 0.7673. Ini disebabkan apabila objek berada dalam keadaan suhu yang tinggi, zarah-zarah objek bergerak lebih cepat, oleh itu tidak kira betapa poros konkrit tersebut, hasilnya akan menunjukkan nilai yang kurang berkesan. Dibandingkan dengan warna termal kuning dan oren, haba mula merebak di permukaan konkrit dan pergerakan zarah mula menjadi stabil. Oleh kerana warna termal oren terletak di bahagian paling luar dalam imej inframerah, ia menunjukkan nilai R^2 tertinggi. Hasil dari AutoCAD kemudian dianalisis untuk mencari korelasi antara gred konkrit, keliangan, dan diameter plot kontur. Hubungan antara ketiga-tiga mereka dapat diterima dan objektif kajian ini tercapai. Analisis keputusan menunjukkan bahawa gred konkrit yang tinggi, berada dalam keadaan kurang berliang, bermakna ia lebih padat, dan memindahkan haba lebih cepat pada permukaan konkrit, dengan itu membuat diameter setiap warna termal lebih besar pada imej inframerah.

ABSTRACT

Infrared Thermography is an alternative tool to measure concrete strength apart of using compressive machine method. This study is about developing a Non-Destructive method using infrared-based technology to measure the strength of concrete in order to preserve the structure's surface. Infrared Thermography is a technology that becomes well-known in the Civil Engineering field due to its non-contact characteristics. It allowed users to detect change of temperature on an object surfaces. The objectives of this study are to develop a non-destructive testing method that able to detect high strength concrete by using infrared technology and to determine the correlation of infrared thermography, strength, and porosity of the concrete. This method will be a positive impact to civil engineering and architectural field as the method promote an aesthetics finishing to determine concrete strength without having to crush the concrete. This method started by producing different concrete grade (Grade 30, Grade 35, Grade 40, Grade 45, Grade 50, Grade 55 and Grade 60) with size 150mm x 150mm x 150mm to be experimented using the Non-Destructive Testing (NDT) and Destructive Testing (DT). The infrared thermal images sampling was done on Day 7 and Day 28 of concrete curing. There are 3 thermal images taken from 2 surface of concrete cubes for each grade of concrete. The step afterward was to convert the thermal images into contour plot image using MATLAB software and then the contour plot will be analysed using AutoCAD by selecting the 3-point circle function to determine the diameter of each thermal colour on the infrared images. There are 3 main thermal colour focus in this study which are White. Yellow, and, Orange. The white thermal colour indicate the highest temperature among the other two thermal colour since the heat was applied directly on to that area before spread to the yellow and orange area. The DT were done right after the NDT process. The analysis of result is continued by finding out the lower, middle, and upper limit of yellow and orange thermal colour. However, since the white thermal colour is at the middle of the infrared images, it only had the upper limit only. The result shown that the most reliable thermal colour that have the highest correlation between the diameter of thermal colours and concrete grade is the white thermal colour with an R^2 value of 0.9877. While for the correlation between the diameter of thermal colours and porosity of concrete, the white thermal colour show the lowest correlation with an R^2 value of 0.7673. This is due to when an object is in high temperature state, the particles of the object move faster, thus no matter how porous the concrete is, the result will be less effective. Compare to the yellow and orange thermal colour, the temperatures start to spread across the concrete surface and the particle movement start to stabilize. Since the orange thermal colour is the most in the most outer side, it shows the highest R^2 value. The result from AutoCAD then gather and analyse to find the correlation between the concrete grade, porosity, and the diameter of the contour plot. The correlation between the three of them are acceptable and the objectives are considered achieved. The analysis of result show that higher concrete grade, is in a less porous state, means it is denser, and transfer the heat faster on a concrete surface, thus making the diameter of each thermal colour bigger on the infrared images.

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INTRODUCTION

1.1 Research Background

Infrared thermography had been used broadly in the application fields. It used for many different purposes indeed. Any processes which are a temperature dependent process may get benefit from the use of an infrared device. Infrared thermography can be said as one of the methods that becoming more popular in civil engineering and architecture. This is mainly due to its non-contact character which includes two great advantages. First, it prevents the object under inspection from any alteration or destruction and the second one is the personnel in charge of testing the concrete strength can be far away from any hazard. Both of these advantages complies with worthwhile value especially in the presence of precious works of art that could not be disturbed and provide safety at work regulations.

Infrared thermography testing is one of a non-destructive method to test the strength of existing concrete. A wide range of concrete in Malaysia is made from Portland cement. Portland cement concrete is a composite material made up of the hydrated cement matrix, fine aggregate, and coarse aggregate. A major factor determining the strength of the material is the bond at the interface of the matrix and the aggregates. This factor has big influences on character and evolution of concrete cracking.

1.2 Problem Statement

Concrete is one of the crucial items in the construction field. Therefore, it is important for us to test the strength of the concrete in order to ensure whether it is strong enough and safe to be applied to the construction of building or infrastructure. The most common method to test the concrete is by coring a cylindrical shape from the finished structure using the rotary cutting tool and put the specimen in the compression testing machine. The machine will compress the specimen of the concrete and show its strength on the screen. The only problem with this method is it will ruin the aesthetical value of the structure itself.

Thus, an alternative is taken, an infrared thermography tool was introduced to improve the method of concrete strength testing without having to destruct the structure. This method can be identified as one of the Non-Destructive testings. However, this method has not yet familiar with the practice we have in Malaysia. The idea of this tools is it will intelligently detect the strength of concrete by just capture the photo concrete surface using the technology of infrared thermography. By using this method, we will be able to maintain the aesthetical value of the structure constantly.

1.3 Objectives

The objectives of this study are as follows:

1) To develop a non-destructive method that able to detect the strength of concrete by using infrared technology.

2) To determine the correlation of infrared thermography, strength, and porosity of concrete

1.4 Scope of Study

The scope of this study shall be confined to the following:

- This study focuses on infrared thermography as one of non-destructive testing on concrete.
- The concrete used in this study is made of OPC type of cement, tap water, crushed stone as coarse aggregate, and sand as fine aggregate.
- The concrete strength used in this study are 30MPa, 35Mpa, 40MPa, 45MPa, 50MPa, 55Mpa, 60Mpa.
- The software used during the analysis process in this study are MATLAB, AutoCAD, and MS Excel.
- Compressive strength testing of those concrete cubes sample was on Day 3, Day 7, and Day 28 or curing process.
- Infrared thermal images samplings were on Day 7 and Day 29 of concrete curing.
- This study also observes the porosity of the concrete on Day 7 and Day 28.

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