UNIVERSITI PUTRA MALAYSIA

PREPARATION AND ULTRASONIC CHARACTERIZATION OF FRESH CONCRETE

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PREPARATION AND ULTRASONIC CHARACTERIZATION OF FRESH CONCRETE

By

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May 2009

Chairman : Prof. Sidek bin Haji Abdul Aziz, PhD

Faculty : Science

An ultrasonic based device has been developed to estimate the age of fresh concrete. The concrete that used in this study is grade 30 concrete. The mix design of concrete samples is calculated using software called Calcrete. All concrete samples used throughout the study was Grade 30 concrete with water to cement ratio (w/c) 0.5 apart for the effect of casting time on concrete strength test, there were two different mixtures used. Mixture 1 (Mix 1) is concrete grade 30 with the w/c ratio of 0.5 and for the Mixtures 2 (Mix 2), the w/c ratio is 0.65. The slump value of each mixed concrete was successfully measured. There were three types of moulds prepared for ultrasonic fresh concrete testing namely Mould 1, Mould 2 and Mould 3. Pre-testing of each fabricated moulds was conducted in order to select the appropriate mould for fresh concrete testing. The velocity of each fresh concrete was monitored within 4 hours using Mould 3. The preparation of same grade of concrete was repeated using

the same method and left for 1 to 4 hour before the slump value was measured. The concrete samples cured in room temperature for 28 days. After 28 days, all concrete samples were tested for an ultrasonic property such as ultrasonic pulse velocity, acoustic impedance and acoustic modulus. The compression test was performed to obtain the strength properties of each sample. The experimental result shows that the slump value and ultrasonic pulse velocity of concrete decreased with the increasing of casting time. The slump tests indicate that concrete at 4 and 5 hour of casting time have no workability. Ultrasonic pulse velocity obtained is in the range of 1900 to 2400 m/s. The density, acoustic impedance and acoustic modulus of concrete also vary with the casting time. The density of concrete samples is between 1800 to 2300 kg/ m^3. The acoustic impedance of concrete samples that were produced throughout project is in the range of 7 to 9 MRayl while the acoustic modulus is in the range of 26 to 35 GPa depending on time of casting.

Abstrak tesis yang dikemukakan kepada senat Universiti Putra Malaysia sebagai mematuhi keperluan untuk ijazah Master Sains

PENYEDIAAN DAN PENCIRIAN KONKRIT BASAH MENGGUNAKAN ULTRASONIK

By

MOHD NOORUL IKHSAN BIN MOHAMED @ AHMAD

Mei 2009

Pengerusi : Prof. Sidek bin Haji Abdul Aziz, PhD

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Sebuah peralatan yang berasaskan ultrasonic telah dibangunkan bagi menganggar umur konkrit basah gred 30. Rekabentuk campuran bagi sampel konkrit yang digunakan di dalam kajian ini telah disediakan dengan menggunakan perisian komputer yang dinamakan Calcrete. Semua sampel konkrit yang digunakan sepanjang kajian ini adalah gred 30 dengan nisbah air terhadap simen adalah 0.5 kecuali untuk kajian kesan masa tuangan terhadap kekuatan mampatan dimana dua campuran dengan nisbah campuran air terhadap simen yang berbeza telah digunakan. Campuran 1 (Mix 1) adalah konkrit dengan nisbah air tehadap simen 0.5 manakala Campuran 2 (Mix 2) adalah konkrit dengan nisbah air terhadap simen 0.65. Sebaik sahaja sampel konkrit telah siap sedia dibancuh, nilai turunannya telah diukur. Sepanjang kajian, 3 acuan yang berbeza telah disediakan dinamakan Mould 1, Mould 2 dan Mould 3. Ujian kesesuaian telah dijalankan ke atas ketiga-tiga acuan bagi memilih acuan yang paling sesuai untuk digunakan di dalam kajian konkrit

basah. Di dalam kajian konkrit basah menggunakan ultrasonik, halaju denyut ultrasonik bagi konkrit tersebut telah diukur selama 4 jam dengan menggunakan Mould 3. Kaedah penyediaan sampel bagi gred yang sama telah diulangi dan kemudiannya dibiarkan selama 1 hingga 4 jam sebelum ujian turunan dan ujian halaju denyut ultrasonik dijalankan. Bagi setiap parameter yang diuji, tiga bongkah kubus konkrit disediakan dan dibiarkan selama 28 hari pada suhu bilik. Ujian ultrasonik telah dijalankan ke atas semua sampel yang telah disediakan pada hari ke-28 bagi mendapatkan nilai impedance akustik dan modulus akustik. Ujian mampatan juga telah dijalankan bagi mengukur kekuatan bagi setiap sampel. Keputusan ujikaji menunjukkan nilai turunan dan nilai denyut ultrasonik menurun dengan bertambahnya masa tuangan. Ujian turunan menunjukkan sampel konkrit dengan masa tuangan 4 dan 5 jam tidak boleh dimampatkan dengan baik. Ujian ultrasonik pula menunjukkan halaju denyut ultrasonik adalah sekitar 1900 hingga 2400 m/s. Keputusan ujikaji juga menunjukkan nilai ketumpatan, impedance akustik dan modulus akustik dipengaruhi oleh masa tuangan. Ketumpatan yang diperolehi adalah sekitar 1800 hingga 2300 kg/ m^3 manakala nilai impedance akustik dan modulus akustik adalah bergantung kepada masa tuangan, masing-masing sekitar 7 hingga 9 Mrayl dan 26 hingga 35 GPa.

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I certify that a Thesis Examination Committee has met on 27 May 2009 to conduct the final examination of Mohd Noorul Ikhsan Bin Mohamed @ Ahmad on his thesis entitle " Preparation and Ultrasonic Characterization of Fresh Concrete" in accordance with the Universities and University Colleges Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U.(A) 106] 15 March 1998. The Committee recommends that the student be awarded the Master of Science.

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This thesis was submitted to the senate of University Putra Malaysia and has been accepted as fulfillment of the requirement for the degree of Master of Science.

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Date: 11 September 2009

DECLARATION

I hereby declare that the thesis is based on my original work except for quotations and citations, which have been dully acknowledge. I also declare that it has not been previously or concurrently submitted for any other degree at UPM or other institutions.

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(**MOHD NOORUL IKHSAN**)

Date: 1 July 2009

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CHAPTER 1

GENERAL INTRODUCTION

Introduction

Concrete is a hard and solid material made from a mixture of cement, water and aggregates. In 1756 John Smeaton, made the first modern concrete that is recently known as hydraulic concrete by adding pebbles as a coarse aggregate and mixing powdered brick into the cement (Pauzi, 1996). Joseph Aspdin, in 1824 has invented Portland cement, which has remained the dominant cement used in concrete production today (Pauzi, 1996). Besides being a hard and firm structure, concrete also long lasting and cheap. On top of that, concrete is widely used in civil construction including buildings, bridges, dams, tunnels and towers. Since it is a very important material, the quality assessment of concrete has become a new area of interest for researchers all around the world. One of the most important areas that have been widely used in concrete testing is non-destructive testing (NDT). In 1969 Civil Engineering Institute (UK) has organized the first conference NDT Concrete that discussed comprehensively about the applications of NDT in concrete assessment.

Problem Statement

A significant amount of today's infrastructure is partially or completely made out of cementitious materials. To meet the constantly increasingly expectations of the industrial community, concrete structures are required to be highly serviceable, durable and flexible. The properties of concrete are solely determined by the composition of its ingredients and conditions during setting and hardening process or the condition while the concrete still in fresh concrete (Voigt et al., 2003).

The most important properties of fresh concrete are rheology, setting and hardening. Rheology will determine the workability of the concrete meanwhile setting and hardening responsible for strength gain and stiffness development of the concrete (Reinhardt et al., 1996). The workability of fresh concrete is a function of the total water content where it increases with water content. Voigt et al. (2003) described setting and hardening process of concrete as the most critical time period during the life of a concrete structure. It is essential to have reliable information about early age properties of a concrete in order to assure the concrete quality meet the required specifications and avoid problem performance throughout the life of the material.

While requirements regarding the quality control of fresh concrete are nowadays increasing, the methods used for in-situ concrete monitoring at site is still limited to

certain conventional method only. There are widely used portable, easy and low budget techniques such as flow test, slump test, vebe test and penetrometer. Reliability of these techniques is very limited and very close related to the experience of the tester. Herb (1996) has suggested that reliability statements about the quality or the effect of admixtures and additions in terms of material characterization could not be expected using these methods. Many researchers are interested in developing new method that can overcome the problems occur using conventional testing methods.

Fresh Concrete and Time

In modern construction technology, the ability to determine the composition and potential strength of fresh concrete as soon as possible is becoming more and more important. Since much of today's construction is very rapid, by the time the concrete quality for a project is deemed inferior, it may be too late. If the structure has not collapsed, the inferior concrete may still be buried deep inside the structure where it is very difficult or practically impossible to replace. It would be ideal to analyze concrete before it is placed in the formwork. Determining the water-cement ratio of the concrete at a very early stage could determine whether or not the concrete meets the job specifications. Also, checking the uniformity of the concrete (within or between batches) is another possible method for estimating the concrete's strength potential. The water-cement ratio is one of the key factors in determining the quality of a given concrete, and, at the same time, it is the most difficult parameter to measure.

Time is an important parameter for fresh concrete. Concrete strength increases by the increasing of its age. Concrete must be cast as soon as possible after mixing process because the increasing of time before it is placed in the formwork (casting time), will decrease the workability of the concrete and affect strength of the concrete. Casting time also known as pre-cast time or mixing time. Normally limit for casting time is one and a half hour to two hours depending on type of concrete being used and specification or requirement from the client. The use of concrete that has been cast more than 2 hours after mixing is quite risky because it will affect the structure or building that was developed. It is reported, the equipments that can be used for fresh concrete evaluation are less and very limited to some single parameters for material characterization. Until now, there is no special technique that is capable to estimate the concrete age while it is fresh. An ultrasonic based device is being developed to estimate the early age of concrete especially to identify the dead concrete which means the concrete that exceed 2 hours of ages before it has been cast.

Ultrasonic Testing (UT) of Concrete

The evaluation of mechanical properties of concrete by non-destructive technique is one of the most challenging tasks in modern civil engineering. Since 1970's the use of ultrasonic to measure properties in concrete has attracted a number of researcher to explore its potential (Bungey, 1984). Many ultrasonic methods are based on either

through-transmission or pulse reflection methods. Casson and Demone (1982) describe one of the first studies to assess the use of ultrasonic pulse velocity for assessing the setting of early age concrete. They noted that concrete was very lossy material in the fresh state and cannot transmit waves over a long distance. Ultrasonic Testing (UT) technique is one of the most popular NDT methods in concrete testing. It is easy to use in fieldwork since the equipment is lightweight, portable and radiation free. UT technique has been widely used in concrete assessment by measuring the pulse velocity in the material. The application of this technique has been used to check the uniformity of concrete (Tomsett, 1992), thickness measurement of slab (Bungey, 1984) and to estimate the strength of concrete (Galan, 1990; Pauzi, 1996; Grosse & Reinhardt, 2001; Akayya et al., 2003).

Objectives

The main target of this project can be achieved by the following objectives:

1. To study the correlation between sound waves velocity and early age of concrete
2. To evaluate the relationship between the strength of hardened concrete and the casting time

Scope of Study

The aim of this project is to establish the experimental method that can be used to measure the early age of concrete before it being placed into formwork. It is included the study of correlation of the effect of pre-cast duration in relation with the concrete strength. The grade of concrete used in the study is Grade 30 with two different water cement ratio, 0.5 and 0.69. The mix design is based on calculation by commercial software named Calcrete. The cement used in the study is ordinary Portland cement type I. The curing temperature of the samples is maintained at room temperature. The measurement and evaluation of the result was carried out at the Malaysian Nuclear Agency in Bangi, Selangor.

Organisation of the Thesis

The thesis is organized into 6 chapters. Chapter 1 introduces general background of the work being done. Chapter 2 consist of literature review on old and current practices that are related to the research work. The theoretical part of ultrasonic and concrete is explained in Chapter 3. Chapter 4 describes the methodology and apparatus used in this work while result and discussion is in Chapter 5. Chapter 6 will conclude this work and give some recommendations for future work.

CHAPTER 2

LITERATURE REVIEW

Introduction

The evaluation of mechanical properties of concrete by non-destructive technique (NDT) is one of the most challenging tasks in modern civil engineering. However there are several techniques that meet this demand which are currently in use. Mostly the methods are based on acoustical, electrical, magnetic, mechanical, optical, radiation, and thermal properties of the tested materials.

Ultrasonic is one of the NDT methods that are widely used all over the world. Many ultrasonic methods are based on the through-transmission of longitudinal waves in various frequencies. However in examining the hydration of cementitious materials, both longitudinal and transverse waves (T-waves) has been applied. This thesis reports a through transmission method based on ultrasonic wave propagation for studying the early age of fresh concrete. In the following section, a short overview is given about the development of the related methods and various applications of this technique.

Ultrasonic Techniques

Ultrasound is acoustic (sound) energy in the form of waves having a frequency above the human hearing range. Ultrasound inspection methods are powerful tools for non-destructive testing and are widely used in the industry because high resolutions are possible depending on the chosen frequency (20 kHz to 40 MHz). In ultrasonic testing, stress waves are injected into the material or component to be examined and then the transmitted/reflected beams have to be monitored. The measurements are relatively easy to perform with commercially available equipments (Ferraro, 2003).

The most successful application of ultrasonic has been in the detection and location of the presence of discontinuities in concrete specimens and structures. Ultrasonic testing has been proven to be capable of detecting various anomalies including rebar, voids, and cracks. The reliability of ultrasonic tests has been confirmed when applied to the testing of concrete and masonry structures.

Recent research has been conducted using array systems and ultrasonic tomography to evaluate concrete specimens and structures. Ultrasonic can be performed by measuring the times-of-flight of a series of stress pulses along different paths of a specimen. The basic concept is that the stress pulse on each projection travels through the specimen and interacts with its internal construction. Variations of the internal conditions result in different times of flight being measured (Martin et al. 2001).