RELIABILITY IN INTERPRETING NON-DESTRUCTIVE TESTING (NDT) RESULTS OF CONCRETE STRUCTURES

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A project report submitted in partial fulfilment of the requirements for the award of the degree of Master of Engineering (Civil - Structure)

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APRIL 2006

Say, “Indeed, my prayer, my rites of sacrifice, my living and my dying are for Allah, Lord of the worlds.”

(Al Qur’an 6: 162)

ACKNOWLEDGEMENTS

I wish to express my sincere appreciation to my supervisor, Associate Professor Dr. Mohammad Ismail, for encouragement, guidance, critics and friendship. Without his continued support and interest, this thesis would not have been the same as presented here.

I am also indebted to Mr Chai Ko Nyim for helping me during the laboratory work. My sincere appreciation also extends to Ms Tan Pui Lai and her colleagues for their assistance.

My fellow postgraduate student Tan Yu Chai should also be recognized for his support.

I am grateful to all my family members.

ABSTRACT

This research was carried out to study the reliability in interpreting non-destructive testing results of concrete structures for assessing concrete strength, concrete uniformity, and concrete cover. An experimental research was carried out, involving both destructives and non-destructive testing methods applied to different concrete mixes ranging from 20 to 55 MPa. The specimens consisting of cubes, slabs, and columns were casted for the correlation purposes and as testing samples. Statistical analysis was used to establish a relationship between destructives and non-destructive readings. Direct and predicted values were made on the testing samples and compared. For the strength estimation, the interpretation by cores calibration is more reliable than calibration by cubes. This interpretation can improve by taking calibration specimens from the same batch and cure them in the same conditions as the structures to be investigated. It also appears that the combined pulse velocity and rebound index method has no effect on the accuracy of the interpretation. The interpretation of covermeter data by calibration is reliable and that of the concrete uniformity also; and the use of more than one test method for the latter will increase the confidence on the interpretation.

ABSTRAK

Projek ini dijalankan untuk mengkaji dalam menggambarkan keboleh percayaan bagi tafsiran yang diperolehi melalui ujian tanpa musnah bagi struktur konkrit dalam penilaian kekuatan konkrit, keseragaman konkrt dan penutup konkrit. Suatu kajian makmal yang melibatkan kaedah ujian musnah dan tanpa musnah telah dijalankan ke atas adunan konkrit yang berlainan kekuatan antara gred 20 ke gred 55. Specimen-specimen yang mengandungi kiub, papak, dan tiang ini dibina bagi tujuan mewujubkan pertalian antara satu sama lain dan juga sebagai specimen ujian. Analisis statistik digunakan untuk menentukan hubungan antara bacaan ujian musnah dan tanpa musnah. Data terus dan data jangkaan dibandingkan seterusnya. Bagi jangkaan kekuatan, penentukuran teras didapati memberikan tafsiran yang lebih tepat daripada penentukuran kiub. Tafsiran ini boleh dimajukan dengan menentukur specimen daripada kumpulan yang sama dan diawetkan dalam keadaan sebagaimana struktur yang akan dikaji. Ketepatan keputusan adalah didapati tidak dapat ditingkatkan melalui ujian gabungan UPV dan "*rebound index method"*. Tafsiran yang diperolehi dengan menggunakan "*covermeter"* boleh dipercayai dan sesuai untuk mengkaji keseragaman konkrit. Walau bagaimanapun, adalah didapati bahawa ujian yang berlainan boleh dijalankan untuk meningkatkan keyakinan pada ketepatan tafsiran yang diperolehi.

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LIST OF SYMBOLS AND ABBREVIATIONS

COV	-	Coefficient of variation
D, D’	-	Depth of reinforcement below the concrete surface
$F_{C'}$	-	Compressive strength from correlation relationship
F_C	-	Compressive strength from direct cores
$F_{cu'}$	-	In-situ characteristic strength
F_{mean}	-	Sample mean strength
FKA	-	Fakulti Kejuruteraan Awam
ICRI	-	International Concrete Repair Institute
k	-	Tolerance factor
Khz	-	Kilohertz
Km	-	Kilometer
KN	-	KiloNewton
Ln	-	Lognormal
Log	-	Logarithmic
LS	-	Least square
MPa	-	MegaPascal
NDT	-	Nondestructive testing
OPC	-	Ordinary Portland Cement

P	-	Covermeter reading
Q	-	Sum of squared deviation
R	-	Rebound number
r	-	Correlation coefficient
R^2	-	Coefficient of determination
REHABCON	-	Strategy for maintenance and rehabilitation in concrete structures
RILEM	-	International Union of Experts in Construction Materials, Systems and Structures
s’	-	Sample standard deviation
sec	-	Seconde
SISD	-	Simplified Index of Structural Damage
UTM	-	Universiti Teknologi Malaysia
V	-	Pulse velocity
ε	-	Random error
σ^2	-	Variance

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Chapter 1

INTRODUCTION

1.1 Background of the problem

Concrete structures as many other engineering structures are subjected to deterioration that affect their integrity, stability and safety. Faced with the importance of the damages noted on the structures, the current choices are directed towards the repair of the existing structures rather than towards the demolition and construction of new ones. But before any repair work being done, it is common practice to determine the causes of the deterioration so that successful repair can be done. Many repair work fail because the exact causes of the deterioration was not adequately identified.

This identification process comprises many methods including non-destructive testing methods. Non-Destructive Testing is usually undertaken as part of the detailed investigation to complement the other methods. Sometimes, the conclusions of the investigation are based essentially on these tests.

First developed for steel, it has not been easy to transfer the NDT technology to the inspection of concrete (Carino, 1994). Because of the characteristics of reinforced concrete the non destructive testing (NDT) of concrete structures is more complex than the NTD of metallic materials (Rhazi, 2001).

Since the spread of their application in civil engineering, one of their main disadvantages lies in the processing and interpretation of the data, which is

often not trivial (Colombo and Forde, 2003). In order for the NDT to better achieve its role in structural assessment there must have agreed standards and guidelines on how to do the survey in the field and interpret the data obtained (McCann and Forde, 2001). Unfortunately until now the choice of the best-fitted technique for a specific case is not simple, the relevance of the measurement process not guaranteed, and the question of how to cope with measurement results and how to finally assess the structural properties remains unanswered (Rilem, 2004).

1.2 Statement of the problem

The application of non-destructive testing to concrete structures is sometimes disappointing. There are many NDT techniques, each based on different theoretical principles, and producing as a result different sets of information regarding the physical properties of the structure. Theses properties, such as velocities, electrical resistance and so on, have to be interpreted in terms of the fabric of the structure and its engineering properties.

The interpretation of the data is the most challenging task of the engineer assessing the structure. The recommendations made based on the interpreted result can be very significant. Decision on whether a structure is adequate or not, the standard and specifications are respected or not, and the exact causes of the deterioration, depends on the outcome of the data's interpretation. It is neither desirable that they lead to the condemnation of a structure safe or economically repairable building, nor it is admissible that they provide a false sense of confidence in an otherwise unsafe structure.

Therefore it is vital to study the reliability in interpreting the NDT results of concrete structures. How NDT results are interpreted? What are the factors

affecting these interpretations? What is the reliability of the different interpretations methods?

1.3 Objectives of the study

The objectives of the study are to:

- investigate the reliability in interpreting Non-Destructive Testing (NDT) results of concrete structures,
- determine the factors affecting the interpretation of (NDT) results of concrete structures.

1.4 Scope of the study

The present work focuses on the study of the reliability in interpreting non-destructive testing results of concrete structures. It will be conducted on normal hardened concretes ranging from 20 to 55 MPa, and in laboratory.
The study will be restricted to the following properties: compressive strength, uniformity of concrete and covercrete (concrete cover).

1.5 Limitations of the study

This study will investigate neither human being role in the reliability of NDT nor will it focus on how to improve the reliability of the NDT testing equipments.

It will be based on the assumptions that the testing equipments are adequate and the testing operation done with respect to the procedure from the planning of the testing to the recording of the data.

1.6 Importance of the study

The current way of ensuring accuracy in the interpretation of non-destructive testing (NDT) of concrete structures for the assessment of the compressive strength, is to establish a correlation curve relating non-destructive readings to strength, for a particular mix under investigation, (Bungey and Millard, 1996; Naik and Malhotra, 2004). Regression analysis is used in establishing such curve. By consensus, the accuracy of estimation of compressive strength of test specimens cast, cured, and tested under laboratory conditions by a properly calibrated hammer lies between ±15 and ±20%. However, the probable accuracy of estimation of concrete strength in a structure is ±25%. (Naik and Malhotra, 2004). The accuracy of estimation of compressive strength of test specimens cast, cured, and tested under laboratory conditions by the standard calibrated ultrasonic pulse velocity is ±20% (Popovics, 2001).

In order to improve these estimations, a calibration is developed by combining the readings of the pulse velocity and the rebound number and relates them to the compressive strength. However, there is a wide degree of disagreement concerning the increase of the accuracy of the estimation of strength from the combined method. A combined pulse velocity and rebound index method for a specific aggregate type and a specific age of concrete had been developed and this had shown a good behavior (Samarin and Dhir, 1984). But unfortunately, the results obtained were not compared with a calibration from pulse velocity alone or rebound index alone to state the degree of improvement in accuracy. Certain researchers also claimed that

accuracy of compressive strength can be improved by the combined method of pulse velocity and rebound index (Tanigawa, Baba, and Mori, 1984). For others, analysis of strength estimated from rebound index made along with pulse velocity contributes little, if any, to the increase of accuracy of the ultrasonic strength estimation (Popovics, 1998; Malhotra and Carette, 1980; cited by Popovics, 2001). It is said that calibration curve obtained from cores taken in the structures under investigation will improve the accuracy of the strength estimation. (Bungey and Millard, 1996).

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