

100000 21229

**ELECTROMAGNETIC PROPERTIES OF PORTLAND
CEMENT CONCRETE USING MICROWAVE
NONDESTRUCTIVE TESTING TECHNIQUES**

FOTOSTAT TIDAK DIBENARKAN

By

Hashem Mohd Ali Al-Mattarneh

Thesis is submitted in fulfillment
of the requirements for the degree of
Master of Science in Civil Engineering

**UNIVERSITI TEKNOLOGI MARA
MAY 2000**

ACKNOWLEDGEMENTS

I would like to thank my supervisors Professor Dr. Ir. Wan Mahmood B. Wan A. Majid and Associated Professor Dr. Deepak Kumar Ghodgaonkar for their support and encouragement during the duration of my study. This work would not have been possible without their guidance and input. Also I would like to thank the post graduate committee in the faculty of civil engineering, Universiti Teknologi MARA, Assoc. Prof. Dr. Mohd Salleh Mohd Noh and Dr. Mohd Yusuf for their advice and assistance during the completion of this work.

My sincere and special thanks to The examiners of this thesis Prof. Dr. L. F. Boswell, Director, Ocean Engineering Research Center, City University, London, UK, and Assoc. Prof. Dr. Khafilah Din, Universiti Teknologi MARA, Malaysia for their advices and comments during the completion of this work.

My sincere and special thanks to all lecturers and staff of microwave lab, Faculty of Electrical Engineering, UiTM for their support and providing access to the required materials and instruments for the completion of this study. Also special thanks for staffs of the concrete lab, Faculty of Civil Engineering, UiTM for their support and help during the study.

Finally I would like to express my deepest thank to my family, especially my parents (Mohd & Mariam) and my wife Siti Hafsa for their understanding, support and encouragement during the study.

TABLE OF CONTENT

TITLE	i
ACKNOWLEDGEMENT	iii
LIST OF TABLES	viii
LIST OF FIGURES	x
ABBREVIATIONS AND SYMBOLS	xv
ABSTRACT	xvi
CHAPTER ONE: INTRODUCTION	1
1.1 Background	1
1.2 Problem Statement	2
1.3 Objectives	3
1.4 Scope of Research	4
CHAPTER TWO: PORTLAND CEMENT CONCRETE, STRUCTURE AND PROPERTIES	6
2.1 Portland Cement Concrete	6
2.1.1 Cement	6
2.1.2 Aggregate	9
2.1.2.1 Types of Aggregate	9
2.1.2.2 Properties of Aggregate	11
2.1.2.3 Effect of Aggregate on PCC	15
2.1.3 Water	15
2.1.4 Transition Zone	16
2.2 Hydration of Portland Cement	17
2.3 Water Cement Ratio	19
2.4 Curing of Concrete	22
2.4.1 Methods of Curing	23
2.4.2 Effects of Curing on PCC	24
2.5 Permeability of Portland Cement Concrete	24
2.6 Moisture Content	26

ABSTRACT

The use of electromagnetic waves as a nondestructive evaluation technique to evaluate Portland cement concrete (PCC) structures is based on the principle that the change in structure, composition, condition, or basic properties of PCC results in a change in its electromagnetic properties. The near field open-ended rectangular waveguide is one of the few devices that can make accurate measurements of the electromagnetic properties of PCC in the frequency range of 7.0 GHz to 13.0 GHz. A microwave measurement system using open-ended rectangular waveguide developed at Universiti Teknologi MARA was used to measure the electromagnetic properties of PCC. Also, a study was conducted to investigate the effect of the basic properties and conditions of PCC, namely, curing time, water cement ratio (w/c), moisture content, curing type, compressive strength, cement type, cement content, aggregate type, aggregate ratio and maximum aggregate size on the electromagnetic properties of PCC.

Measurements were conducted in the frequency domain. The research found that, the electromagnetic properties decrease with increasing curing age. The electromagnetic properties of PCC with lower w/c ratio is lower than the PCC with higher w/c ratio at early age of curing, this is reversed after hydration (curing) is completed. The electromagnetic properties of PCC increase with increasing moisture content. There is a significant difference in the electromagnetic properties of PCC cured using different type of curing methods such as, submerged in water, cover by wet cotton and cured in air and ambient humidity. The microwave nondestructive testing using near field open-ended rectangular waveguide can be used for determination of w/c ratio, compressive strength and moisture content from the measurement of reflection coefficients, dielectric constants, loss factors and conductivity. There is no significant difference between the electromagnetic properties of PCC mixes using different type of Portland cement (Type I and Type II). Mixes containing limestone aggregate had a lower reflection coefficient than those containing granite. Also, mixes containing limestone had a greater dielectric constant and loss factor than those containing granite.

CHAPTER ONE

INTRODUCTION

1.1 Background

Portland Cement Concrete (PCC) is a widely used man-made building and construction material. The construction of large public works and infrastructure systems has almost been completed in many countries. Also, a large number of these PCC structures are currently deteriorating. Before any repairs can be undertaken on PCC structures, an evaluation to determine the existing conditions and to understand the mechanism of deterioration needs to be undertaken. This has effectively shifted the emphasis from the construction of new structures to system preservation, maintenance and rehabilitation. For maintenance and rehabilitation purposes, information should be gathered by destructive and nondestructive methods depending on the measurement requirements. Destructive methods are mostly less expensive and time consuming. On the other hand, nondestructive testing usually does not require removal of material, and allows the user to test more extensively. These considerations may increase the use of nondestructive technique. The demand for the development of reliable nondestructive testing for construction materials and constructed facilities is ever increasing.

Among the nondestructive testing (NDT) methods, microwave NDT seems to be promising for the evaluation of PCC. Electromagnetic properties of materials represent the interaction of a material with the propagation of electromagnetic fields through the material. Out of many electromagnetic properties of PCC, the one that are interesting to study are, the reflection and transmission coefficients, the dielectric