



**UNIVERSITI PUTRA MALAYSIA**

**EFFECTIVENESS OF ULTRASONIC PULSE VELOCITY  
AND IMPACT- ECHO NDT TECHNIQUES TO ASSESS  
THE QUALITY OF CONCRETE**

**SHIBLI RUSSEL HJ. MOHIUDDIN KHAN**

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**By**

**SHIBLI RUSSEL HJ. MOHIUDDIN KHAN**

**Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia,  
in Fulfillment of the Requirements for the Degree of Master of Science**

**July 2002**



*Specially dedicated to my mother Haja Begum Rokeya  
and my Late Father Haji Mohiuddin Khan*



Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfillment of the requirement for the degree of Master of Science

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The deterioration of concrete in structure is a result of several internal or external degradation mechanism and which results in distress of the structure i.e. decrease in strength and integrity of the structure. The state of distress is often hidden from view and is only evident at a stage where there is significant reduction in strength of the structure. Defects are often introduced during construction and are viewed during in-service life. Some deterioration is viewed physically in the early age or during the service life of the structure in terms of spalling, surface crack, swelling and honeycombing. This deterioration collectively or individually results in reducing the load carrying capacity in terms of the distress of the structure.

In this project, the common defects in the concrete structures and mapping techniques by nondestructive test are presented. Among the various techniques of the nondestructive tests, the Ultrasonic Pulse Velocity (UPV) and DOCTOR's Impact-echo were chosen for their effectiveness. The UPV is used to estimate the concrete strength, detecting flaws such as voids and cracks and also to investigate the effects of smaller diameter bar in the concrete. In detecting various sizes of voids by the



Impact-echo test techniques a format was suggested to identify them from the frequency spectrum. In the bridge condition assessment by nondestructive test techniques most common problem encountered were correlation of cube crushing strength to the UPV values, in order to determine residual strength of the structure in different environmental conditions. Also the other defects such as cracks and voids in the concrete, which does not have any standard guideline to identify them by the above NDT techniques to use in the bridge condition assessment. This project has dealt with large number of specimens between the actual condition and those of the values given by the NDT results. A number of beam specimens were also cast with known defects in the concrete in order to obtain and suggest standard investigation procedure. 108 standard cubes with different grades and environmental conditions were cast. Also eight beams and a slab were cast having known common defects.

From the strength-UPV correlation nine numbers of regression equations were suggested. A standard transducers spacing has been suggested for detecting crack depth of 50 to 125mm range. The effect of bar sizes on UPV test results was also obtained. Reinforced concrete slabs or decks having bar diameter greater than 10mm diameter will be affect the readings of UPV. Based on the obtained results a computer database system for NDT has been made to accommodate and fulfill necessary requirements of knowledge base system. Hence this knowledge base system will be used for bridge condition assessment.



Abstrak tesis yang dimukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Master Sains

**KEBERKESANAN KAEDAH HALAJU DENYUT ULTRASONIK (UPV)  
DAN KESAN GEMA DOCTOR'S UJIAN TANPA MUSNAH (NDT) BAGI  
MENILAI KUALITI SESUATU STRUKTUR KONKRIT**

Oleh

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Kerosakan konkrit pada sesuatu struktur adalah disebabkan oleh pelbagai mekanisme penurunan dalaman dan luaran yang menyebabkan berlakunya kehilangan tegasan seperti penurunan di dalam kekuatan dan integrasi sesuatu struktur. Tahap kehilangan tegasan ini selalunya tersembunyi dari pandangan penglihatan dan hanya boleh dilihat sewaktu jangka hayat khidmat (service). Kebanyakan kecacatan boleh dilihat secara fizikal di awal usia pembinaan dan boleh dilihat sewaktu jangka hayat khidmat sesuatu struktur dari segi kesan tanggal, retak pada permukaan, pengecutan dan lubang (honeycomb). Kecacatan ini secara kolektif atau secara individu telah menyebabkan pengurangan dari segi keupayaan menanggung beban disebabkan oleh kehilangan tegasan pada sesuatu struktur.

Di dalam projek ini, kecacatan biasa di dalam struktur konkrit dan teknik melakar oleh Ujian Tanpa Musnah diperkenalkan. Di antara pelbagai teknik Ujian Tanpa Musnah, Halaju Denyut Ultrasonik (UPV) dan Kesan Gema Doctor's dipilih bagi mengetahui tentang keberkesanannya. Ujian UPV digunakan bagi

menganggarkan kekuatan konkrit, mengesan kecacatan seperti terdapat liang (void) dan retakan dan juga bagi menyelidik kesan diameter tetulang keluli yang lebih kecil di dalam konkrit.. Di dalam mengenalpasti pelbagai saiz liang (void) dengan menggunakan teknik Ujian Kesan Gema satu format telah dicadangkan bagi mengenalpasti kecacatan ini melalui spectrum frekuensi. Di dalam penilaian keadaan jambatan oleh teknik Ujian Tanpa Musnah kebanyakan masalah yang timbul berkaitan dengan pemecahan kekuatan sesuatu struktur di dalam keadaan persekitaran yang berbeza. Kecacatan lain seperti retakan dan liang di dalam konkrit yang mana ianya belum lagi mempunyai garis panduan piawai bagi mengenalpasti kecacatan-kecacatan ini dengan teknik NDT yang dinyatakan di atas yang digunakan di dalam penilaian keadaan jambatan. Projek ini melibatkan jumlah spesimen yang besar di antara keadaan sebenar dan nilai yang diberikan oleh keputusan NDT. Sebilangan spesimen rasuk telah disediakan dengan kecacatan yang diketahui di dalam konkrit bagi memperolehi dan mencadangkan penyelidikan tentang prosedur penyiasatan. Sebanyak 108 kiub piawai dengan gred yang berbeza dan keadaan persekitaran yang berbeza telah disediakan. Sebanyak lapan rasuk dan sebuah papak telah disediakan bagi mengetahui beberapa kecacatan yang biasa.

Menerusi korelasi kekuatan UPV sembilan persamaan regresi telahpun dicadangkan. Satu jarak transduser piawai telahpun dicadangkan bagi mengesan kedalaman retak dari julat 50 hingga 125 mm. Kesan saiz tetulang keluli di dalam keputusan ujian UPV juga diperolehi. Papak konkrit bertetulang mempunyai diameter tetulang keluli yang lebih besar daripada 10 mm diameter akan memberi kesan kepada bacaan ujian UPV. Berdasarkan kepada keputusan yang diperolehi, satu sistem pengkalan data berkomputer untuk ujian NDT telah dihasilkan bagi memudahkan dan memenuhi keperluan sistem pengkalan data maklumat. Sistem pengkalan data maklumat ini akan digunakan bagi penilaian keadaan jambatan.

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## TABLE OF CONTENTS

DEDICATION	ii
ABSTRACT	iii
ABSTRAK	v
ACKNOWLEDGEMENTS	vii
APPROVAL	viii
DECLARATION	x
LISTS OF TABLES	xiii
LISTS OF FIGURES	xvi

### CHAPTER

1	INTRODUCTION	1.1
1.1	Background	1.1
1.2	What are NDT and its Limitations	1.1
1.3	Classification of NDT and their Commercial Name	1.2
1.3.1	Nondestructive Test	1.3
1.3.2	Semi-destructive Test	1.4
1.4	Objective	1.4
1.5	Scope of Study	1.5
2	LITERATURE REVIEW	2.1
2.1	Nature of Distress	2.1
2.2	Ultrasonic Pulse velocity Test	2.2
2.2.1	History and Development	2.2
2.2.2	Test Principle	2.3
2.2.3	Feature of equipment	2.4
2.2.4	Limitations	2.5
2.3	Impact-Echo Test	2.7
2.3.1	History and Development	2.7
2.3.2	Test Principle	2.7
2.3.3	Feature of equipment	2.8
2.3.4	Limitations	2.9
2.4	Previous Research	2.19
3	METHODOLOGY	3.1
3.1	Experimental Set-up	3.1
3.2	Concrete Strength Estimation	3.1
3.2.1	Preparation of Cube Specimen	3.1
3.2.2	Test Technique	3.2
3.2.3	Destructive Test	3.3
3.3	Estimation of Crack depth	3.4
3.3.1	Preparation of Beam Specimen & Test Technique	3.4



3.4	Effect of Steel Bar Size	3.5
3.4.1	Preparation Of Beam & Slab Specimen & Test Technique	3.5
3.5	Void Detection	3.7
3.5.1	Preparation of Beam Specimen & Test Technique	3.7
4	RESULTS AND DISCUSSION	4.1
4.1	Standardize Strength Determination Equation by UPV	4.1
4.1.1	Discussion of Results	4.1
4.2	UPV to Map Crack Depth	4.13
4.2.1	Discussion of Results	4.13
4.2.2	Crack Depth 125mm	4.15
4.2.3	Crack Depth 100mm	4.16
4.2.4	Crack Depth 75mm	4.17
4.2.5	Crack Depth 50mm	4.18
4.3	Effect Of Steel Bar Size In Concrete By UPV	4.23
4.3.1	Discussion of Results	4.23
4.4	Effect Of Void Size In Concrete By UPV	4.31
4.4.1	Discussion of Results	4.31
4.5	Effect Of Void Size In Concrete By Impact-Echo	4.43
4.5.1	Discussion of Results	4.43
4.6	Knowledge-Base System For Bridge Condition Assessment	4.64
4.6.1	Introduction	4.64
4.6.2	NDT Results for Database	4.64
4.6.3	Conclusions	4.68
5	CONCLUSION AND RECOMMENDATIONS	5.1
5.1	Concrete Strength Estimation	5.1
5.2	Concrete Crack Depth Estimation	5.2
5.3	UPV Effect on Steel Bar Size	5.2
5.4	Effect Of Void Size In Concrete By UPV	5.3
5.5	Effect Of Void Size In Concrete By Impact-Echo Test.	5.3
5.6	Recommendations.	5.4
	REFERENCES	R.1
	APPENDIX A	A.1
	APPENDIX B	A.9
	BIODATA OF THE AUTHOR	V.1



## LISTS OF TABLES

<b>Table</b>		<b>Page</b>
2.1	Possible Distress in Reinforced Concrete and corresponding NDT techniques	2.11
3.1	Schedule for Concrete Test Cube specimen	3.2
4.1	Schedule of Test Specimen 150×150×150mm Test cubes	4.2
4.2	Correlation expression for individual data of oven dry, air dry and saturated conditions	4.4
4.3	Correlation Expression for combined data of oven dry, air dry and saturated conditions	4.9
4.4	Summary of recommended equations for grade 10 to 40Mpa concrete for three physical conditions (oven dry, air dry and saturated)	4.9
4.5a	Percentage of error for the selected equation to estimate the compressive strength of concrete by Direct mode of measurement.	4.11
4.5b	Percentage of error for the selected equation to estimate the compressive strength of concrete by Indirect mode of measurement.	4.12
4.6	Schedule of Transducers spacing and corresponding Transit Time for Crack Depth 125mm	4.15
4.7	Schedule of Transducers spacing and corresponding Transit Time for Crack Depth 100mm	4.16
4.8	Schedule of Transducers spacing and corresponding Transit Time for Crack Depth 75mm	4.17
4.9	Schedule of Transducers spacing and corresponding Transit Time for Crack Depth 50mm	4.18
4.10	Transducers spacing and corresponding crack depth with percentage of error.	4.19
4.11	Transducers spacing and corresponding minimum predicted crack depth with percentage of error.	4.21

<b>Table</b>	<b>Page</b>
4.12a Pulse velocity in Reinforced concrete with bar diameter 10mm and cover 50mm	4.25
4.12b Pulse velocity in Reinforced concrete with bar diameter 10mm and cover 30mm	4.26
4.13a Pulse velocity in Reinforced concrete with bar diameter 12mm and cover 50mm	4.26
4.13b Pulse velocity in Reinforced concrete with bar diameter 12mm and cover 30mm	4.27
4.14a Pulse velocity in Reinforced concrete with bar diameter 16mm and cover 50mm	4.27
4.14b Pulse velocity in Reinforced concrete with bar diameter 16mm and cover 30mm	4.28
4.15a Pulse velocity for (test on side with long depth for direct transmission) beam with same size of voids at different levels of concrete.	4.33
4.15b Pulse velocity for (indirect mode of test on long depth side) concrete with same size of voids at different position in the beam.	4.33
4.16a Pulse velocity for (test on side of shallow depth for direct transmission) beam with same size of voids at different levels of concrete.	4.35
4.16b Pulse velocity for (test on side of shallow depth for indirect transmission) beam with same size of voids at different levels of concrete.	4.35
4.17a Pulse velocity for (test on side with long depth for direct transmission) beam with different size of voids at same depth of concrete.	4.37
4.17b Pulse velocity for (test on side of long depth for indirect transmission) beam with different size of voids at same depth of concrete.	4.37
4.18a Pulse velocity for (test on side of shallow depth for direct transmission) beam with different size of voids at same depth of concrete.	4.39
4.18b Pulse velocity for (test on side of shallow depth for indirect transmission) beam with different size of voids at same	

<b>Table</b>	<b>Page</b>
depth of concrete.	4.39
4.19 Recommended pulse velocity range for different size of voids	4.42
4.20 Impactors, their corresponding diameters, approximate duration impact (contact time) and the frequency generated by the impact. (the values are valid for concrete only)	4.44
4.21 Summary results for beam-1 with orientation-A – (Void size 75x25x20mm, 100x25x20mm, 125x25x20mm)	4.62
4.22 Summary results for beam-1 with orientation-B – (Void size 75x25x20mm, 100x25x20mm, 125x25x20mm)	4.62
4.23 Summary results for beam-2 with orientation-A – (Void size 25x20x50mm)	4.63
4.24 Summary results for beam-2 with orientation-B – (Void size 25x20x50mm)	4.63

## LISTS OF FIGURES

<b>Figure</b>	<b>Page</b>	
1.1	Schedule of NDT techniques and the related Instruments	1.3
2.1	A simplified schematic diagram for the PUNDIT instrument	2.6
2.2	Simplified diagram of the Impact-echo method	2.9
2.3	Crack depth measurement by Indirect method	2.24
2.4	Pulse velocity correction factor by BS 4408 and Chung H. W	2.25
2.5	Reinforcement Parallel to the Pulse Path	2.26
2.6	Layer thickness Measurement	2.30
3.1	Arrangement of the transducers of UPV	3.3
3.2	Position of the transducers to obtain reading	3.3
3.3	Schedule of different crack depth 150×150×750mm long Prism beam	3.4
3.4	Schedule of 100×100×500mm long prism beam with 10mm, 12mm and 16mm diameter steel bar	3.6
3.5	Slab of size 1200×400×100mm depth with 10mm, 12mm & 16mm diameter steel bar	3.6
3.6	125×200×1200mm long beam with 25×50×20mm depth voids at different level of the concrete	3.8
3.7	125×200×1200mm long beam with 25×50×20mm depth voids at same level of the concrete	3.8
4.1	Schedule of test specimen	4.3
4.2a	UPV vs. $f_{cu}$ graph for concrete at OD condition (Direct method)	4.6
4.2b	UPV vs. $f_{cu}$ graph for concrete at AD condition (Direct method)	4.6
4.2c	UPV vs. $f_{cu}$ graph for concrete at SAT condition (Direct method)	4.6
4.3a	UPV vs. $f_{cu}$ graph for concrete at OD condition (Indirect method)	4.7
4.3b	UPV vs. $f_{cu}$ graph for concrete at AD condition (Indirect method)	4.7



<b>Figure</b>	<b>Page</b>
4.3c UPV vs. $f_{cu}$ graph for concrete at SAT condition (Indirect method)	4.7
4.4a Pulse velocity vs. concrete strength combined graph of OD, AD & SAT (Indirect method)	4.8
4.4b Pulse velocity vs. concrete strength combined graph of OD, AD & SAT (Direct method)	4.8
4.5 Beam with 125, 100, 75 & 50mm depth crack	4.14
4.6 Beam with different transducer position by interposing Crack	4.14
4.7a Transducers spacing standardization graph with respect to Crack depth 125 & 100mm	4.20
4.7b Transducers spacing standardization graph with respect to Crack depth 75 & 50mm	4.20
4.8 UPV indirect test for concrete with different diameter rebar and cover range 30 to 50mm.	4.24
4.9 UPV indirect test on slab with different diameter rebar and cover range 30 to 50mm.	4.24
4.10 Effect of Pulse velocity for different bar size in concrete beam	4.29
4.11 Correction factors for Pulse velocity in reinforced concrete For different sizes of bar.	4.29
4.12 Beam with 25×50×20mm thick voids at different level of the concrete	4.32
4.13 Beam with 75×25×20mm, 100×25×20mm and 125×25×20mm thick voids at same level of the concrete	4.32
4.14a Different mode of UPV test performed on the beam from long depth orientation side	4.34
4.14b Different mode of UPV test performed on the beam from shallow depth side	4.36
4.15a Different mode of UPV test performed on the beam from long orientation depth side for different size of voids at same levels of beam	4.38
4.15b Different mode of UPV test performed on the beam from shallow depth side for different size	



<b>Figure</b>	<b>Page</b>
of voids at same levels of beam	4.40
4.16 Pulse velocity vs. transit length graph for various void size	4.41
4.17 Beam-1 orientation 'A' with 75x25x20mm, 100x25x20mm and 125x25x20mm thick voids at different level of concrete	4.45
4.18a Solid thickness frequency spectrum and waveform for the beam-1 with orientation-A	4.46
4.18b 75mm deep void at depth 72.5mm in concrete, frequency spectrum and wave form for the beam-1 with orientation-A	4.46
4.18c 100mm deep void at depth 60mm in concrete, frequency spectrum and wave form for the beam-1 with orientation-A	4.47
4.18d 125mm deep void at depth 47.5mm in concrete, frequency spectrum and wave form for the beam-1 with orientation-A	4.48
4.19 Beam-1 orientation 'B' with 75x25x20mm, 100x25x20mm and 125x25x20mm thick voids at same level of concrete	4.49
4.20a Solid thickness frequency spectrum and waveform for the beam-1 with orientation-B	4.49
4.20b 25mm deep void, frequency spectrum and wave form for the beam-1 with orientation-B	4.50
4.20c 25mm deep void, frequency spectrum and wave form for the beam-1 with orientation-B	4.51
4.20d 25mm deep void, frequency spectrum and wave form for the beam-1 with orientation-B	4.52
4.21 Beam-2 orientation 'A' with 25x20x50mm thick voids at different level of concrete	4.53
4.22a Solid thickness frequency spectrum and waveform for the beam-2 with orientation-A	4.53
4.22b 25mm deep void at depth 62.5mm in concrete, frequency spectrum and wave form for the beam-2 with orientation-A	4.54
4.22c 25mm deep void at depth 87.5mm in concrete, frequency spectrum and wave form for the beam-2 with orientation-A	4.55

<b>Figure</b>	<b>Page</b>
4.22d 25mm deep void at depth 137.5mm in concrete, frequency spectrum and wave form for the beam-2 with orientation-A	4.56
4.23 Beam-2 orientation 'B' with 50×20×25mm thick voids are at same level of the concrete from the impact surface	4.57
4.24a Solid thickness frequency spectrum and waveform for the beam-2 with orientation-B	4.58
4.24b 50mm deep void-1 at 35mm depth in concrete frequency spectrum and waveform for the beam-2 with orientation-B	4.58
4.24c 50mm deep void-2 at 35mm depth in concrete frequency spectrum and waveform for the beam-2 with orientation-B	4.59
4.24d 50mm deep void-3 at 35mm depth in concrete frequency spectrum and waveform for the beam-2 with orientation-B	4.60
4.25 First page of programme for NDT and the selected test technique – UPV	4.65
4.26 Data key-in form for UPV to estimate strength	4.66
4.27 Output result from the programme for the UPV test	4.66
4.28 Data input form for crack depth estimation by UPV	4.67
4.29 Output form for the crack depth estimation by UPV	4.68

# CHAPTER 1

## INTRODUCTION

### 1.1 Background

Nondestructive test (NDT) is the branch of engineering concerned with methods of detecting and evaluating flaws in materials. Flaws can affect the serviceability of the material or structure. NDT is useful tool to indicate performance of structures throughout its service life.

Nondestructive methods have been of considerable value in the testing of concrete. They are most useful in the testing of in situ concrete structures. In the laboratory, their special usefulness lies in the repetitive testing of the same specimen when evaluating the influence of time. These are the two aspects of testing in which the nondestructive test methods are better suited than the destructive methods. It is however, essential to understand the limitations of nondestructive testing methods in view and to exercise due caution in interpreting the results of these methods because they are normally not deterministic.

### 1.2 What are NDT and its Limitations?

Nondestructive test technique is a descriptive term used for the examination of materials and components in such a way that allows materials to be examined without changing or destroying their usefulness.



The subject of NDT has no clearly defined boundaries; it ranges from simple techniques such as visual examination of surfaces to the well-established methods available in the structural field.

Many research have already been performed to detect the various defects of the concrete structure, especially concrete bridges. To detect the distress of bridge structure such as delaminations, voids, honeycombs, cracks, corrosion in the reinforcement and also the chemical attack / content e.g. chloride in the concrete structure the various technique of NDT are used. The details of nondestructive test technique, their strength and limitations, purpose of each NDT test e.g.- mechanical properties i.e. strength, elastic modulus etc. - physical properties i.e. density, permeability, uniformity etc. - chemical properties i.e. chloride content, alkali-aggregate reaction are described in related section of this thesis.

### **1.3 Classification of NDT and their Commercial name**

The non-destructive test can be categorized as follows:

- ◆ Non-destructive test
- ◆ Semi-destructive test

### 1.3.1 Nondestructive test

Each non-destructive test can be carried out using several equipments with different commercial name. The test procedure for each equipment is also different although they have similar test objective. Most commonly used non-destructive test techniques can be summarized as shown in **Figure 1.1**.

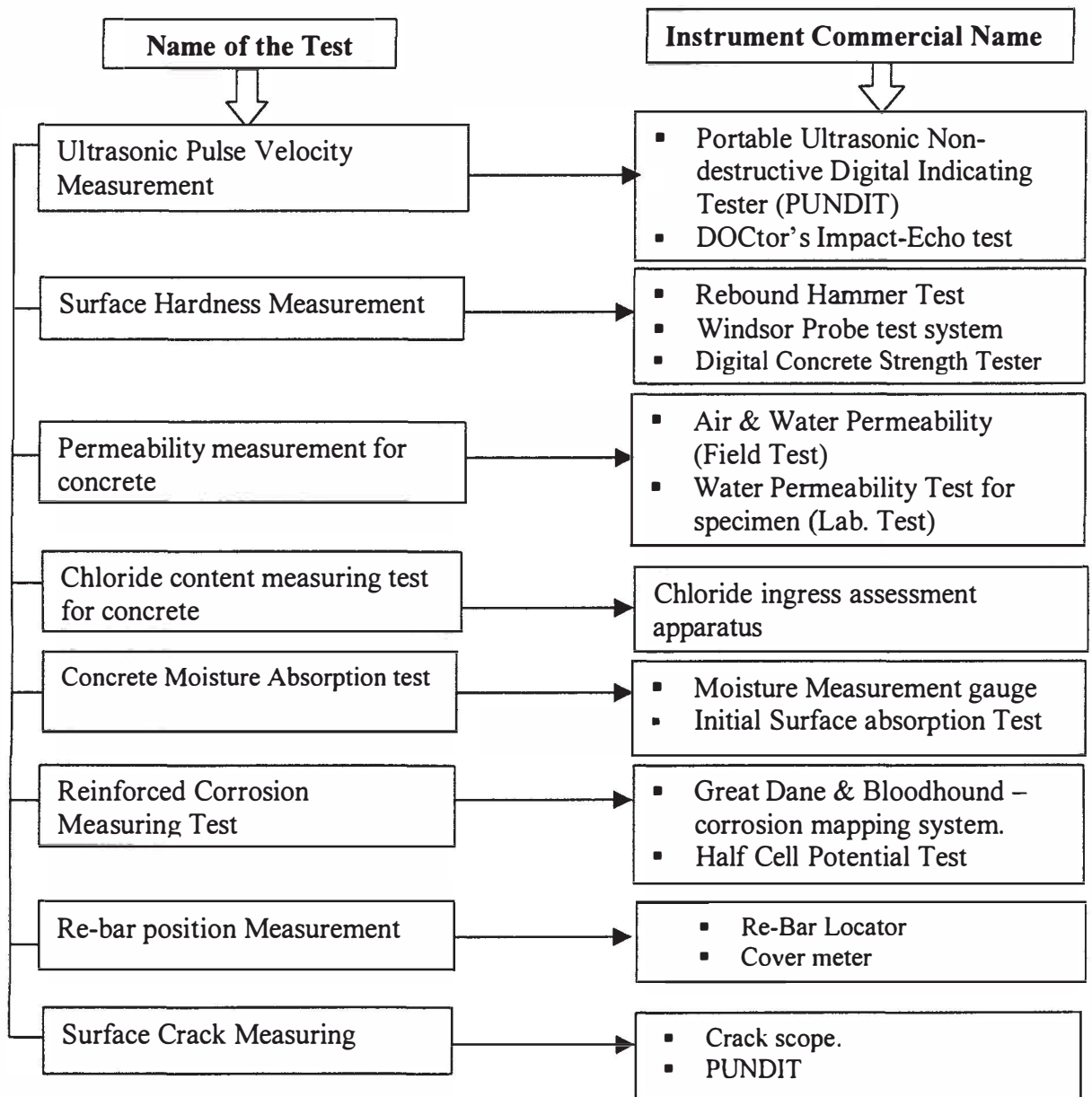


Figure 1.1: Schedule of the NDT techniques and the related Instruments.

### **1.3.2 Semi-destructive test**

Semi-destructive test may be used to confirm some of the test results obtained from the non-destructive test. The accuracy of the NDT varies and is depends on the reliability of the commercially available equipments. Therefore, the semi-destructive test always plays a significant role to confirm reliability of non-destructive test. Hence this reliability brings semi-destructive test to be prominent in the structural field. It also concurrently represents the results of destructive test for the particular location of the structure. For example, Pullout test or concrete coring may be used to obtain in-situ concrete strength or analysis for chemical and physical properties.

### **1.4 Objective**

Distresses of concrete structure are most common in concrete bridges or structures exposed to severe environmental condition. The main cause of these common defects e.g. voids, cracks; corrosion is mainly due to overloading, faulty design and bad construction practice. Early detection and rehabilitation of these common defects may help to limit further distress. The nondestructive tests techniques, which are commonly used includes Ultrasonic Pulse Velocity Test and Impact-echo test for diagnosing such defects. In this regard a study has been conduct with the following objectives.

1. To determine suitable prediction equations in estimating concrete strength by Ultrasonic Pulse velocity method in three different environmental conditions i.e. oven dry (OD), air dry (AD) and saturated (SAT).
2. To determine the optimum transducers spacing for different depths of crack in the concrete beam by Ultrasonic Pulse Velocity Test Technique.
3. To determine the effects of small diameter bar in the concrete beam and slab on the Pulse Velocity.
4. To determine the frequency ranges obtained by the Impact-Echo method on different sizes or locations of voids and cracks.
5. To create a database of UPV and Impact Echo techniques for development an expert system for bridge condition assessment

### **1.5 Scope of Study**

In order fulfill the objectives of this study the scope of work has been limited to the followings.

1. Standard concrete cube specimen prepared in the laboratory condition for grades between 10MPa to 40MPa.
2. Cracks & voids were introduced in the beam, which were cast in the laboratory and the concrete used was grade 30.

