



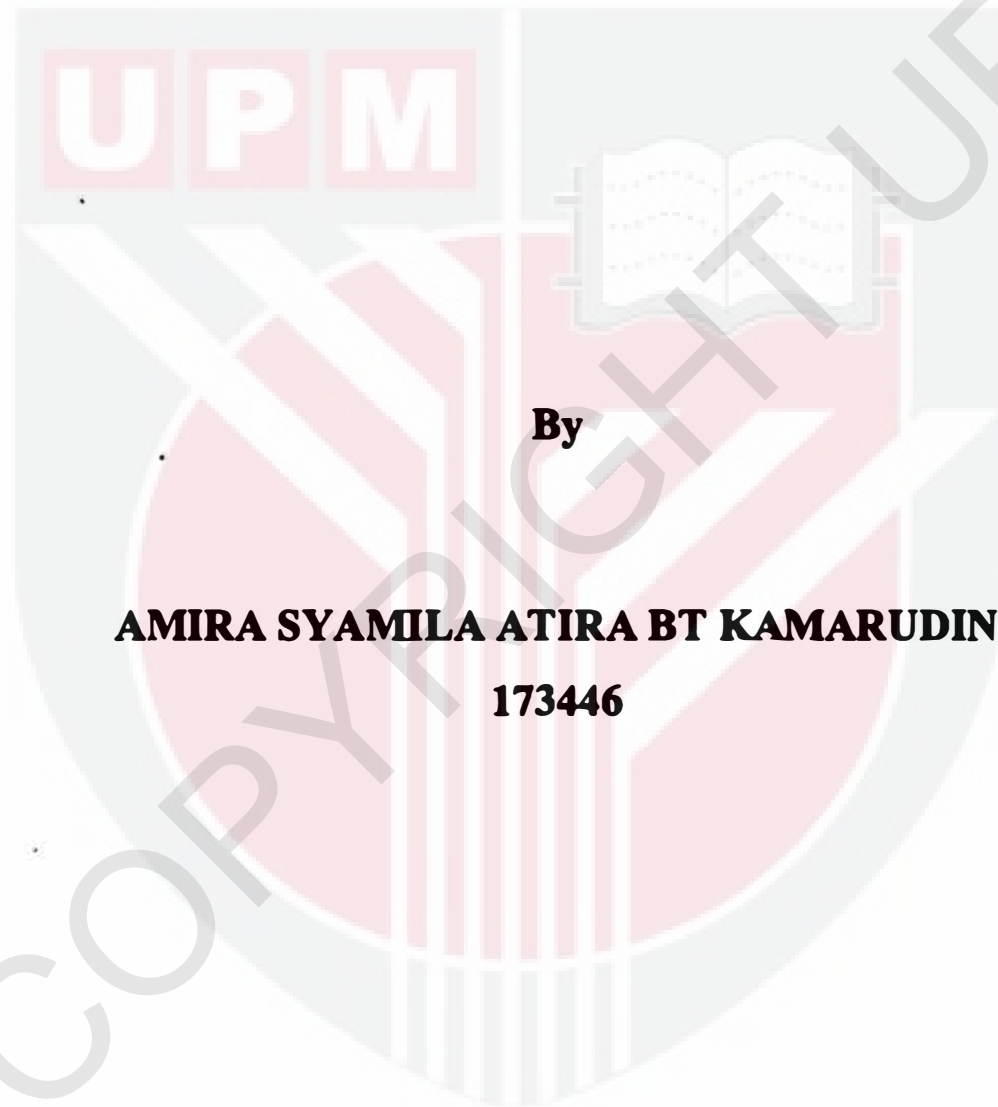
UNIVERSITI PUTRA MALAYSIA

***NONDESTRUCTIVE CONCRETE CHARACTERIZATIONS SYSTEM FOR
CONCRETE STRUCTURES BY ULTRA-PULSE VELOCITY (UPV)***

AMIRA SYAMILA ATIRA BT KAMARUDIN

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By

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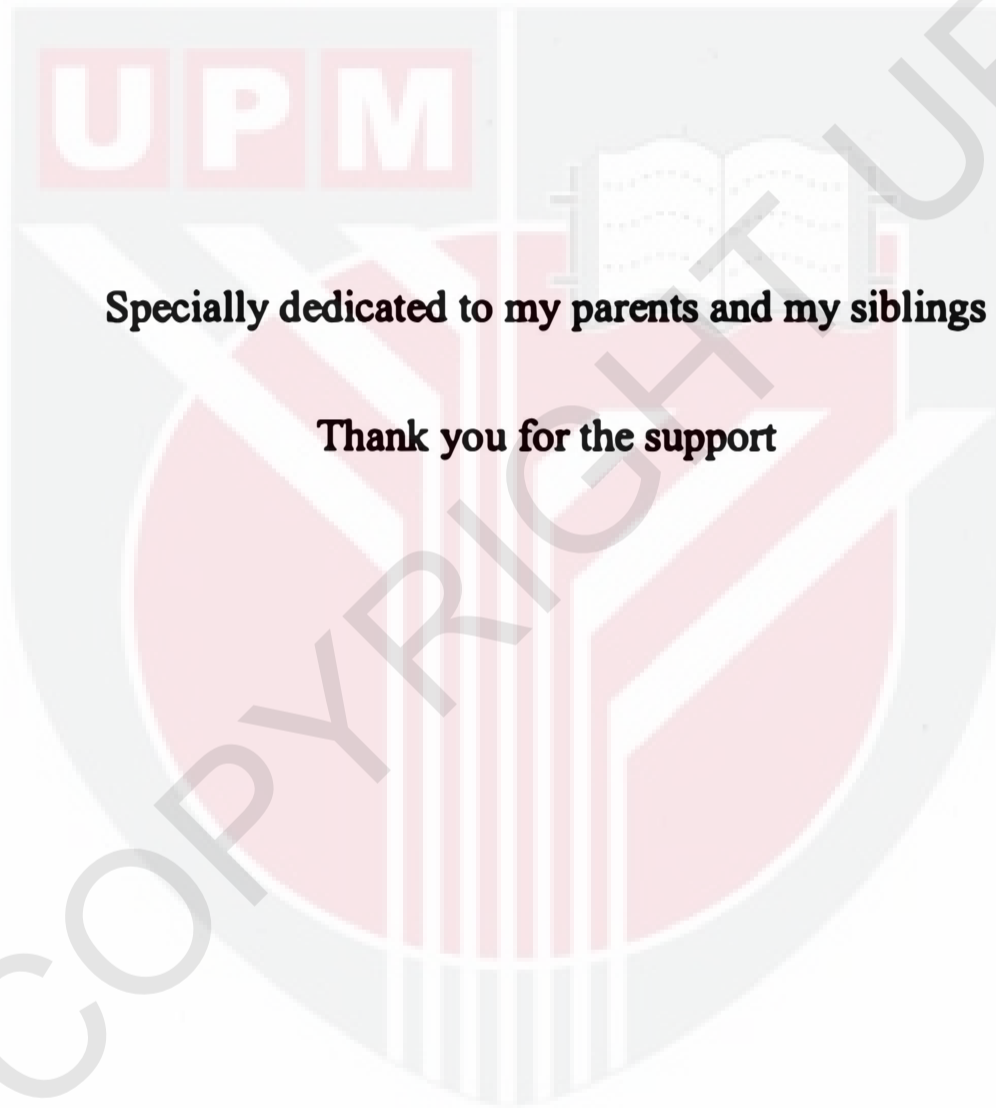
**Report Submitted to the Faculty of Engineering, Universiti Putra
Malaysia, in Partial Fulfilment of the Requirement for the
Degree of Bachelor of Engineering (Civil)**

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DEDICATION

Specially dedicated to my parents and my siblings

Thank you for the support



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ABSTRACT

The aim of this research is to establish the characterization of concrete by using the Non Destructive Test (NDT) of Ultrasonic Pulse Velocity (UPV). NDT is the process of examining or evaluating materials or components without destroying the function, serviceability and product structure test. NDT is used in industrial, manufacturing, and fabrication and inspection services widely to ensure product quality.

A general series of tests which are compression test, and UPV was carried out at laboratory to obtain a correlation of the NDT results with compressive strength. 27 concrete cubes of sizes 100 x 100 x 100 mm and 9 concrete prism of size 100 x 100 x 500 mm has been made and subjected to water curing for 28 days for concrete grade of G30, G35 and G40 with three different water cement ration which is 0.4, 0.6 and 0.8 for each concrete grade. To get the exact result of the strength, compression test applied to the concrete cube. Before the compression testing applied, the cube strength checked by using UPV. The data obtained from each test has been evaluated and analysed. From this research, the data that only consider are grade concrete of G30; w/c 0.6 and G40; w/c 0.4. The result shown that the concrete strength of concrete grade G30 with w/c 0.6 are too high for experimental data (36.71 MPa) compare to the laboratory data that achieve the target strength (28.80 MPa) and concrete grade G40 with w/c 0.4 too lower than the laboratory work, 35.80 MPa which is 25.04 MPa. However, for UPV test result, data shown that the cumulative results of the testing of ultrasonic pulse velocity (UPV) is greater than 4.5 km / s except for concrete prism of grade G40 with w/c: 0.4 but for all the result for concrete grade G30; w/c: 0.6, are in the range of excellent quality.

ABSTRAK

Tujuan kertas ini ditulis adalah untuk memeriksa pencirian konkrit dengan menggunakan Ujian Tanpa Musnah (Non Destructive Test) oleh “Ultrasonic Pulse Velocity (UPV)”. Ujian Tanpa Musnah (Non Destructive Test) adalah proses pemeriksaan atau bahan menilai atau komponen tanpa memusnahkan fungsi, kebolekhidmatan dan struktur produk ujian. Ujian Tanpa Musnah digunakan dalam industri, pembuatan, dan fabrikasi dan dalam pemeriksaan perkhidmatan secara meluas untuk memastikan kualiti produk.

Satu siri umum ujian iaitu ujian mampatan, dan UPV telah dijalankan di makmal untuk mendapatkan korelasi keputusan Ujian Tanpa Musnah dengan kekuatan mampatan. 27 kiub konkrit bersaiz 100 x 100 x 100 mm dan 9 prisma konkrit bersaiz 100 x 100 x 500 mm telah dibuat dan tertakluk kepada pengawetan air selama 28 hari untuk gred konkrit G30, G35 dan G40 dengan berbeza tiga nisbah air simen iaitu 0.4, 0.6 dan 0.8 bagi setiap gred konkrit. Untuk mendapatkan hasil yang tepat dari kekuatan, ujian mampatan digunakan untuk kiub konkrit. Sebelum ujian mampatan digunakan, kekuatan kiub diperiksa dengan menggunakan UPV. Data yang telah diperolehi akan di evaluasi dan dianalisis. Dari kajian ini, data yang hanya dipertimbangkan adalah konkrit gred G30; w / c 0.6 dan G40; w / c 0.4. Hasil kajian menunjukkan bahawa kekuatan konkrit gred konkrit G30 dengan w / c 0.6 terlalu tinggi untuk data eksperimen (36.71 MPa) berbanding dengan data makmal yang mencapai kekuatan sasaran (28.80 MPa) dan gred konkrit G40 dengan w / c 0.4 juga Lebih rendah daripada kerja makmal, 35.80 MPa iaitu 25.04 MPa. Walau bagaimanapun, bagi keputusan ujian UPV, data menunjukkan bahawa keputusan kumulatif ujian kelajuan ultrasonik (UPV) melebihi 4.5 km / s kecuali prisma konkrit gred G40 dengan w / c: 0.4 tetapi untuk semua hasil konkrit Gred G30; W / c: 0.6, berada dalam pelbagai kualiti yang sangat baik.

ACKNOWLEDGEMENTS

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CHAPTER 1

INTRODUCTION

1.0 Introduction

Concrete is used in many structure that are generally large in size such as airfield runaways, highways, pavements, building etc. and also have some surface roughness associated with them. Cracks in concrete structure mainly occur due to disbanding between layers, voids within layer, excess loading, temperature changes, etc. As we know, the construction of the modern structure need a concrete quality with a sufficient strength and durability. In recent years, many accidents occur involving public construction, which was reported by the media. The accident was caused by the low craftsmanship and less monitoring during construction. Based on this fact, monitoring the quality of concrete structures become increasingly important subject. Besides that, instead of new building, maintenance of existed building such as historical building also important as it is a proof of the existing of certain culture of community. The purpose of maintaining the existing building not only for historical value, but also saving cost for construct new building, multiple usage of the building example house turns into a kindergarten, avoiding wasting of the building, aesthetic value if the building were left unused, and not including some individual does this for their own sentimental value.

Therefore, in order to know how and when maintenance can be done, the condition and performance of the building must be evaluated first. Thus, suitable

method must be appropriate choose so that a test can be done. However, the important thing is, the test must not damage the existed structure because it will increase the cost of maintenance and repairing. Furthermore, it will decrease the strength of the building and threat the building user safety. Then, for that, the suitable test that can be applied to facilitate the needs of maintenance system is a non-destructive test.

By choosing the suitable method of non-destructive test, the problem that had occurs or might occurs can be determine. From here suitable repair material or repair technology can be verify. However, maintenance needs to be characterization or management so that maintaining operation can be start. This is what paper will be discussed about including what have being said above. The title Non-destructive Concrete Characterizations System for concrete structures is chosen for the research to answer the exactly pinpoint the level of strength with different water cement ratio that has led to the deterioration.

1.1 Background of Study

Non-destructive testing have been known in many name such as NDT, Non-Destructive Evaluation (NDE) and Non-Destructive Inspection (NDI). Nowadays, there are a lot of construction to achieve the government's goal of becoming a rapidly developing country. Thus, in construction, non-destructive tests are in great variety in worldwide use to detect variations in structure, minute changes in surface finish, the presence of cracks and other physical discontinuities. Besides that, it also helps to avoid design failures, prevent accidents and save human life. Most of civil engineer will have to consider about this matter because in involving the life or death of the

building user. Furthermore, it can make a profit for the user as the longer the building is useful to the user the better profit can be made. As a result, it will ensure the client satisfaction and maintain the consultant or contractor reputation.

There are many methods in non-destructive test such as Surface Hardness Test, Rebound Hammer, Radioactive and Nuclear Methods and Ultrasonic Pulse Velocity. Every method of non-destructive test have its own boundary and which mean the method cannot afford an accurate and consistence result for difference cases and to detect different defect.

As we know, concrete is a multiphase materials consisting of coarse aggregate, fine aggregate, and cement. Therefore, the Ultrasonic Pulse Velocity can be used to assess the quality and uniformity of the material. It will go through a material is a function of the elastic modulus and density of the material. The method is also useful for measuring the composition of the mixture material such as monitoring during construction, and estimation of the degree of devastation caused by the fires. Besides, it also can determine estimating strength, determination homogeneous, modulus determination, the determination of the age of the concrete and flaw detection. (Mohamad Pauzi Ismail, 2015). The Profometer is used in order to accurately locate reinforcing bars and welded wire meshes. Besides that the Profometer also used to measures the concrete cover and determines the diameter of the bars. The most easiest and simple method for non-destructive test is Schmidt Hammer. A Schmidt Hammer, also known as a Swiss hammer, is a device to measure the elastic properties or strength of concrete or rock. The hammer measures the rebound of a spring loaded mass impacting against the surface of the sample.

1.2 Problem Statements

The role of engineering investigation is to determine the condition of the existing structure and predict the past and future of the structure. In addition, each building should be evaluated for performance after the construction.

The assessment should be done periodically to detect any defects or failures in the structure. Check the deterioration of the structure after a period of service is required to know the life of the building.

However, no particular method prescribed by JKR and consultants to assess the building. The choice of method is up to the resident engineer.

By using non-destructive testing there are many methods that can determine defects or failures in the structure and each method has its own parameters. Furthermore, every single technique that always used to have a limited boundary which means the method is not capable of precise and consistent results for case differences and to detect different defects.

Because there are methods that are offered for Non-Destructive Testing, then, there seems to be a lot of arguments to the best method of Non-Destructive Testing for evaluation.

Therefore, it is important to conduct research and increase knowledge of non-destructive testing and find the best way to avoid testing methods that can damage existing construction.

1.3 Objective

The objective of this research are:

- i. To apply the *Non-Destructive Test (NDT)* to evaluate the strength of concrete structure by using different water cement ratio.
- ii. To review the accuracy of the Ultrasonic Pulse Velocity methods of Non-Destructive.
- iii. To get details of the structure with respect to its design, features, and past performance by using Non-Destructive Characterization.

1.4 Scope of Study

This type of Final Year Project is about case study. This study will take place at Engineering Faculty of University Putra Malaysia (UPM), Serdang, Selangor. A case study will be carried out on a Laboratory Materials of Engineering Faculty, UPM.

For this study, Non-Destructive Test method mainly Ultrasonic Pulse Velocity (UPV) will be employed. For the Ultrasonic Pulse Velocity (UPV) method, it will use BS 1881: part 203: 1986 for British Standard.

All the collected data must be analyse and make comparison in order to know which water cement ratio gives the most accurate result. The structure to be evaluated is cubic and block concrete. Besides that some of laboratory test also need to be done in order to compare with the test that carried out. For the test of 24 concrete cubes and 9 concrete block will be made which for 28 days. The concrete will be test using UPV for Non-Destructive Test methods include cube test for destructive methods that using BS 1881: part 116:1983.

1.5 Significant of Study

Significance of this study is to determine any deterioration in the structure or any failure that may contribute to damage. In addition, non-destructive testing basically refers to all test methods that allow the test or examination material without affecting future use. Non-destructive testing methods are particularly valuable in assessing the state structures, such as bridges, buildings, and highways.

Because there is current emphasis on recovery and structural adjustment, there is a critical need for the development of non-destructive testing methods that can be used to assess the condition of the structure so that repair work following the correct procedures. In addition, a significant study is to suggest the best method of valuation structure.

Basically the purpose of non-destructive testing is to determine material property. In addition, it is also to detect, characterization, defects, determine the quality of the manufacture or fabrication of components or structures and lastly is to examine deterioration after a period of service to the structure. Of all non-destructive testing purposes, so it is important to learn about non-destructive testing and be able to apply to work as a civil engineer.

1.6 The Purpose

The purpose of this research is to compare the condition of water cement ratio of concrete in the transport that carrying the ready mixed concrete to the site with the allowable water cement ratio. Usually on this transport, there will mix the water for make the concrete didn't dry before arrive the destination of site. If this happened, the water cement ratio will change and also make the strength of concrete also change. Therefore, if the strength of concrete change to low, it will affect the design and also the quality of structure. The structure will crack and crush if the strength are not same as design that have been calculated before. So, by using this data, in future, we will know the condition of the concrete in the carriage.

CHAPTER 2

LITERATURE REVIEW

2.0 Introduction

The aim of the work of engineering investigation is to determine the conditions existing at the relevant structures and predict the situation in the past and the future of the structure. Some options investigation, for example removing the brick veneer to see what is behind is significantly alter the conditions found in the field. Therefore, the method that has little effect on the conditions, such as existing the non-destructive methods, is highly desirable.

2.1 Definition of Non – Destructive Test (NDT)

The American Society have been define the *Non-Destructive Test (NDT)* as “The determination of the physical condition of an object without affecting that object’s ability to fulfil its intended function. Non-destructive testing techniques typically use a probing energy form to determine material properties or to indicate the presence of material discontinuities (surface, internal or concealed).” However, the Standard British was defined it as “a test that does not affect the performance of elements or members is expected.”

According to Mark Wilcox and George Downes (2000-2003), non-destructive testing is the testing of materials, for surface or internal flaws or metallurgical

condition, without interfering in any way with the integrity of the material or its suitability for service. Besides that, the others defines it as the process of inspecting, testing, or evaluating materials, components or assemblies for discontinuities, or differences in characteristics without destroying the serviceability of the part or system. In other words, when the inspection or test is completed the part can still be used.

Therefore, the non-destructive testing methods are very valuable in assessing the state structures, such as bridges, buildings, and highways. Due to the current emphasis on analysis and structural adjustment, there is a critical need for the development of non-destructive testing methods that can be used to assess the condition of the structure so that repair procedures that can be implemented effectively.

2.2 Importance of Non-Destructive Test (NDT)

Rao B.P.C (2002) has stated in general terms, the purpose of NDT will happen if it falls into one of the following categories:

1. Determination of material properties
2. Detection, characterization, location and size of discontinuities or defects
3. Determine the quality of the manufacture or fabrication of components or structures
4. Check for deterioration after a period of service to the component or structure

Pratt D. G. and Lawrence J. (1990) has claimed that the non-destructive testing (NDT) is the methods used to obtain information about the structure indirectly. For example, to measure the speed of the pressure wave (sound) moving through objects and study how the waves can reflect the object, therefore, whether there is or is not a weakness in objects that can determine.

For structural engineers, the development of non-destructive testing (NDT) techniques to assess the reinforced concrete structure is very important. At present, practical techniques that can detect cracks in the concrete by the use of acoustic, infrared thermography, and ground penetrating radar.

However, all these methods do not have all the qualities required to crack detection system, which is consistent under a variety of site conditions, the ability to rapidly test a large area and ease of use. Furthermore, every single technique that always used to have a limited boundary which means the method cannot provide accurate and consistent results for cases differences and to detect different defects such as cracks and corrosion, there are different methods. (Rao B.P.C, 2002)

In addition, one important part of the non-destructive testing (NDT) is the management of aging concrete structures. The role of NDT is expected to get a significant development NDT methods to find the correct and most appropriate NDT methods for concrete structures. The existing age structure, effective inspection has become a bigger issue. This problem may occur in all countries of the world. To resolve this issue consistent examination should have been used to detect any

deterioration in its infancy, and afterwards as a result of the decline is expected and can be much lower.

Non-destructive testing (NDT) have potential applications in three key areas in the management of concrete structures related to safety. There are:

- Determination of the as-built (or during) the grain structure
- Detection of weakness
- Characterization and quantification of weakness

Differences in technical non-destructive testing (NDT) for monitoring the aging of concrete have been made between the detection, characterization and quantification of weakness. All requirements for NDT techniques in each application is different. To detect flaws only requires certain techniques have identified that defects are present, and to guide the location and area estimates. For characterization and quantification techniques will be able to measure the nature and grounds of lack of adequate sensitivity further to allow assessment of the impact of disability on engineering safety and serviceability of the structure to be carried out.

In many cases, it is possible to obtain objective data for use in the assessment of engineering. Example point for this assessment include:

- Confirmation of the structure satisfactory performance continues
- Rate of interest identified defect

- Reevaluation of design due to changes in operating conditions (eg increased load design, structural life extension or decommissioning scheme).

However, it should be noted that alternative techniques such as non-destructive testing techniques and partially destroyed is also provided for carrying out the above tasks. However, the pull of NDT techniques is that they do not interfere with or damage the structure and can be less expensive or disruptive to implement. Furthermore, another attraction of NDT is the potential to improve the accuracy and quality of data on the condition and performance of the structure as this can help to avoid more maintenance and unreasonable expenses on the work of monitoring or correction.

2.3 The Methods of Non – Destructive Test

In an era of rapidly developing technology that now, non-destructive testing is also equally build on a par with other technologies. In other words, the development of non-destructive testing technology is also advanced that also creates a variety of methods. Among the non-destructive testing methods are:

2.3.1 Surface Hardness Method

Non-destructive testing methods of surface hardness of the non-invasive procedure that investigated the strength characteristics of the material. There are two categories of techniques that can determine the concrete surface hardness indentation method and the method of recovery. These methods try to exploit the empirical correlation between concrete strength properties and

surface hardness as measured by indentation or rebound. Originating in 1930 (Jones, 1969), the curve is no longer common in the civil engineering industry, while recovering method that is often used to investigate the characteristics of concrete strength by reference to standard guidelines on testing and interpretation.

Procedure surface hardness tests most commonly used are standard hammer recovery. The test was developed in 1948 by Swiss engineer Ernst Schmidt and commonly referred to as the Schmidt Rebound Hammer (Dinghy, 1969). When the impact with the concrete surface, hammer rebounded to record some recovery expand the power of nature with reference established empirical correlation between concrete strength properties (compressive and flexural) and the number of balls that bounce.

A basic understanding of the impacts and recovery related to the theory of wave propagation. A compression wave is propagated and the concrete surface is interrupted by a plunger (σ_i). The reaction force is reflected compression wave propagates through plunger (σ_r). Wave amplitude ratio (σ_r / σ_i) is found to be proportional to the number of recovery can be empirically correlated to compressive and flexural strength (Akashi & Amasaki, 1984).

Standard Operation Rebound Hammer require less mechanical skills compared with other NDT methods. Visual inspection of the concrete surface should be carried out before the test to identify a smooth surface suitable for testing. This test can be conducted at any angle in any direction calibration

chart used to reduce the effects of different. Hammer is pressed against the concrete surface until the mass is released the spring loaded plunger to cause an impact on the surface and keep the recovery measured by the indicator slide. The measured distance is referred to as the number of recovery.

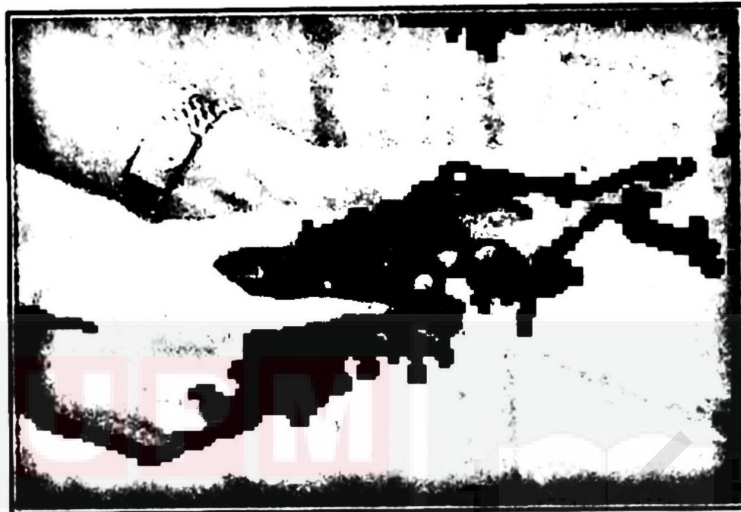


Figure 2.1: Schmidt Rebound Hammer

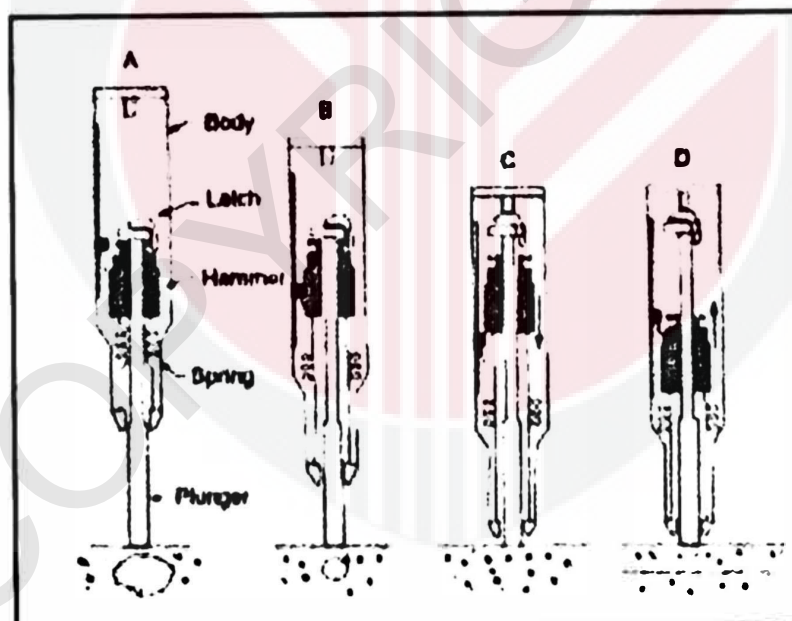


Figure 2.2: The Schmidt Rebound Hammer procedure

Empirical correlation provided by the manufacturer to associate numbers to rebound strength properties of concrete; however, the terms of the manufacturer's test may be far different situation now. Therefore, it is recommended to carry out specific tests correlation procedure in which some of the strength of concrete cylinders are provided and tested by both Standard

Rebound Hammer and compression testing machine. The results of both tests are then integrated into a simple regression model that generates empirical correlation through ordinary least squares. There are some standard guidelines that we can follow, namely:

- i. **ASTM C 805: Standard Test Method for Rebound Number of Hardened Concrete;**
- ii. **BS EN 12504-2:2012: Testing Concrete in Structures - Non-destructive Testing - Determination of Rebound Number.**

The Standard Rebound Hammer provides a simple method, easy and inexpensive way to estimate the strength properties of concrete. However, the results of tests on concrete is influenced by various factors such as surface smoothness, feature geometry test specimens, the age of the test specimen surface and moisture conditions of internal concrete, type of aggregate, cement, type of mould and carbonation concrete surface (Malhotra, 2004). The power budget of the reading recovery specimen with specimen correlation curve is the accuracy of 15% to 20% (Concrete Institute of Australia, 2008). Therefore, it is recommended that the test be used as a standard hammer rebound test methods diversity among the samples strength properties of concrete and not as a substitute for standard compression test.

2.3.2 Penetration Resistance Method

In the non-destructive testing, penetration resistance method is one of the most popular methods that are often used. This method is an invasive procedure that explores the nature of NDT of concrete strength using the correlation previously established. In addition, this method involves driving the probe into the concrete sample using uniform power. Measure the depth of the penetration probe guides the compressive strength of concrete by referring to the correlation. Due to the insignificant impact of the method of penetration resistance on the structural integrity of the sample probe, the test is considered not destroy even concrete disturbance during penetration.

The penetration resistance method most commonly used is the Windsor probe system. The system consists of a powder-actuated gun, the hard drive allows steel probes into the concrete sample while measuring the distance by measuring the depth of penetration. Following the publication of standard guidelines for the application and interpretation of the present governing penetration testing:

- i. ASTM C 803-02: Standard Test Method for Penetration Resistance of Hardened Concrete;
- ii. BS 1881-207 Testing Concrete - Recommendations for the assessments of concrete strength by near-to-surface tests.

Penetration probe Windsor creates dynamic pressure that led to the crushing and cracking of the concrete near the surface. Zone when the penetration of the cone-shaped building, which covers cracks and is opposed by the adjacent concrete. Empirical resistance associated with investigating the depth of penetration. However, the empirical relation supplied by manufacturers often produce unsatisfactory results. Therefore, a special procedure tests the correlation must be carried out using the method of penetration and compression testing machine to achieve a more accurate correlation chart.



Figure 2.3: The tools of *Penetration Resistance Method*

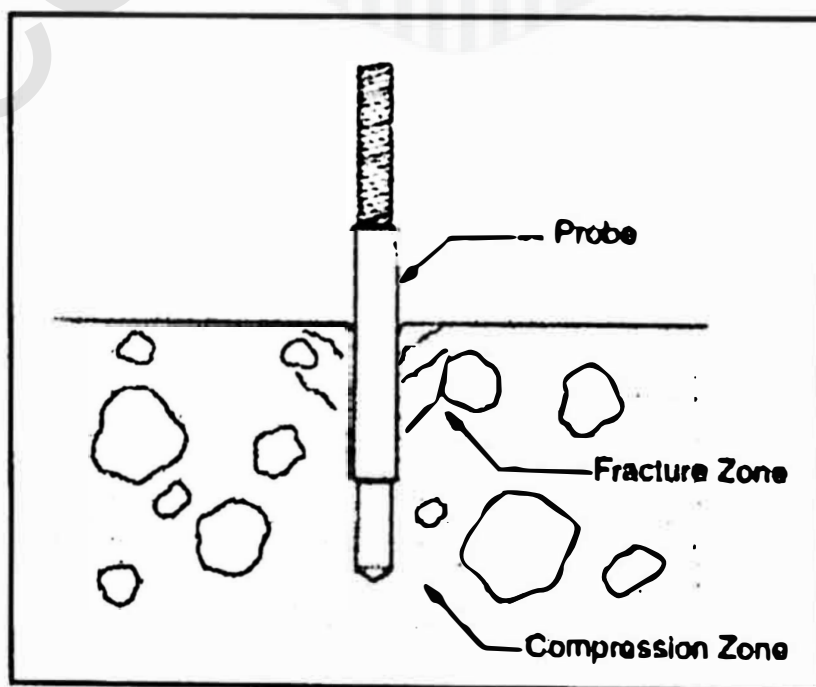


Figure 2.4: The typical concrete failure zone during penetration

Factors that contribute to the variability tests are due to operator error, equipment error, aggregate size and heterogeneous nature of concrete (Carette and Malhotra, 2004). The most important factors that affect the test variability is the size of the aggregate. For example, the coefficient of variation of 5% is expected to test samples of the aggregate size of 20mm; whereas, the coefficient of variation of 14% is expected for the sample size 55mm aggregate (Concrete Institute of Australia, 2008). However, changes in estimates of concrete early strength is low to moderate, which provide a reasonable level of accuracy and certainty for mould removal in concrete construction. In addition, a number of factors that contribute to the variability of the test is low compared to other NDT procedures such as surface hardness methods. The Windsor probe system is fast, cheap and easy to operate. As methods of surface hardness, penetration resistance method does not produce the absolute values of strength and therefore must be used as a method of testing the diversity of the nature of forces between concrete samples

2.3.3 Maturity Test Method

The next method of NDT is a Maturity Test Method which is NDT techniques to determine the strength of concrete benefits based on the measured temperature history during curing. Mature functions set out to measure the effects of time and temperature. The resulting factor is then used to determine the maturity of concrete strength by the correlation established. Method mature have various applications in the construction of concrete such as mould removal and posttensioning.

The temperature versus time recorded by thermocouples inserted into the fresh concrete. The measured time history can be used to calculate the index of maturity that provides a reasonable estimate of the age of the early strength of concrete as a function of time (Saul, 1951). Guidelines and interpretations of standards on test methods ASTM C 1074-1011 maturity are: Standard Practice for Estimating Concrete Strength by the Maturity Method.

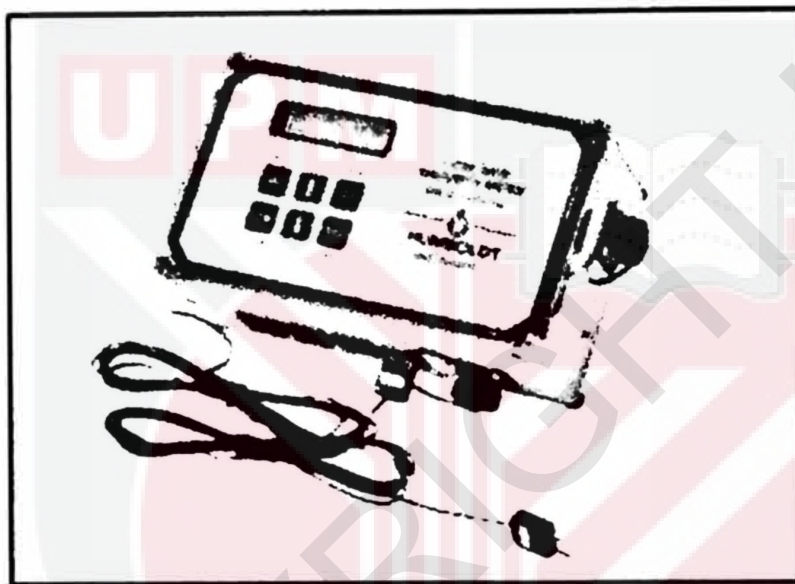


Figure 2.5: The Apparatus of *Maturity Test Method*

Factors that lead to variability in the test is the property aggregates, properties of cement, water-cement ratio and curing temperature (Concrete Institute of Australia, 2008). Before attempting to estimate the strength of in-situ concrete, laboratory tests on concrete samples of the same features must be done in order to develop the proper function of maturity while minimizing the impact of the factors described above. Temperature probe location must be chosen carefully to measure the temperature of representatives of all sections of concrete.

2.3.4 Permeation Test Method

The main cause of the deterioration of the permeability of concrete is aggressively into the concrete. This is because the permeability of the property represents a control for estimating the durability of concrete structures. Absorption test non-destructive testing methods that measure transport properties near the surface of the concrete. Three categories of measuring the permeability of concrete are:

- i. hydraulic permeability which is the movement of water through concrete;
- ii. gas permeability which is the movement of air through concrete;
- iii. Chloride-ion permeability which involves the movement of electric charge.

Measurement chloride penetrability is the most commonly used non-destructive concrete permeability which provides guidance through the correlation established. Guidelines on the application of standards and interpretations chloride penetrability is ASTM C 1202: Standard Test Method for Electrical Indication of Concrete Ability to Hold. This test involves coring a cylindrical standard size of in-situ concrete. The sample is then cut, sealed with epoxy coating on both sides, saturated in water and then placed in a split test tool filled with sodium chloride solution with the applied voltage potential (Concrete Institute of Australia, 2008). Charge through which concrete is then measured:

- i. a value of between 100 and 1000 Coulombs represents low permeability
- ii. a value greater than 4000 Coulombs represents high permeability

2.3.5 Impact-echo Method

Impact-echo system is a recent development of ultrasonic method that involves measuring the thickness of the concrete and the integrity of the use of the surface. The test is also used to locate cracks, voids and delamination. It is based on monitoring the movement of the concrete surface resulting from mechanical effect of short duration. Specifically, the test measures the amplitude of reflected shock waves to detect flaws in concrete.

Impact-echo system using electromechanical transducers for generating short pulses of ultrasonic pressure waves that propagate into the plate-like concrete structure. Different materials of different density and elastic properties will reflect the pulse of stress on their border. Nadi move reflected back to the transducer, which also acts as a receiver. The oscilloscope displays the received signal and round trip travel time of the pulse is measured electronically. Distance interface reflects can be determined by knowing the speed of the pressure wave. Standard guidelines on the application and interpretation of the impact-echo method is -04 ASTM C 1383: Standard Test

Method for Measuring the P wave velocity and thickness of the plate impact Concrete Using Echo Method.

Factors that affect the detection of defects in the concrete are: the type of disability and orientation, disability and depth of contact time effects (N. Carino, 2001) it. Its impact-echo proves to be a reliable method for placing multiple defects in concrete structures. Like most of the methods for the detection of defects in the concrete, the experience needed to interpret the results of the impact-echo testing.

2.3.6 Corrosion of Reinforcement Method

Steel corrosion is an electrochemical reaction and thermodynamic inevitable happened spontaneously because of the iron metal. Corrosion of steel reinforcement in concrete require the loss of passivation, the presence of moisture and / or oxygen. This condition is often satisfied in concrete structures where corrosion can only be suspended or slowed by prevention measures and techniques. Iron oxide that have unique chemical, magnetic properties and electric power that can be exploited to determine the extent of corrosion of reinforcement through NDT.

Non-destructive testing methods require the use of corrosion of the reinforcement half-cell system and a high-impedance voltmeter (Fig. 2.6). The system is capable of detecting the current trend of migration of ions through the concrete between the anodic and cathodic sites with the same measure

effort alloys (Elsener, Müller, Suter, and Bohn, 1990). Concrete functions as an electrolyte and corrosion risk may be related empirically measured potential differences that lead to corrosion.

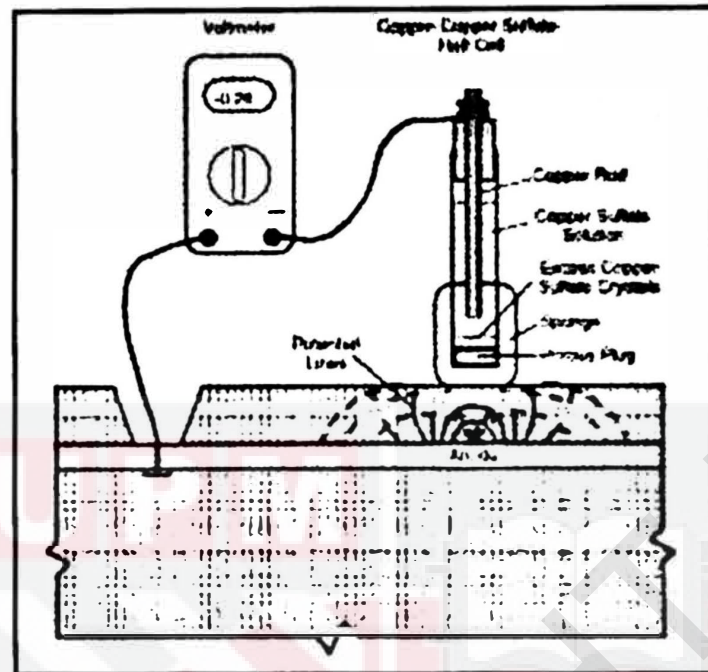


Figure 2.6: The schematic drawing half – cell of *Corrosion of Reinforcement Method*

Guidelines on the application and interpretation of standard reinforcement corrosion test is ASTM C 876-91: Standard Test Method for Half-Cell Potentials Uncoated Reinforcing Steel in Concrete. Requirements for successful test is exposure and electrical continuity of reinforcement in the test area. According to ASTM 876, there are:

- i. 90% probability of active corrosion if the potential is more negative than -350mV ;
- ii. 90% probability of no rust if the negative potential is less than -200mV ;
- iii. Uncertainty in corrosion if the negative potential is between -350mV and -200mV .

The half-cell potential test is a useful technique to look for possible areas of active corrosion. It is recommended that the study of potential coupled with tests to carbonation and chloride ion content of soluble for more accurate results.

2.3.7 Ultrasonic Pulse Velocity Method

One other popular method is NDT Ultrasonic Pulse Velocity method involves ultrasonic waves propagate in solids, while measuring the time taken for the wave to propagate between the sending and receiving points. The characteristics of the propagation of ultrasonic waves can be used to characterize the material composition, structure, elastic properties, density and geometry using the correlation previously established, recognizable patterns and mathematical relationships. Non-invasive techniques are also used to detect and describe the weakness in the material as well as their level of damage by observing the spread of the ultrasonic waves.

The basic technique of ultrasonic pulse velocity method involves the transformation of voltage pulses to ultrasonic pulses and back by transmission and each receiving transducer. The transmission transducer placed on the concrete surface and allowed to send ultrasonic pulses through the medium of the specimen. Ultrasonic pulse travels through the concrete specimen and detected by the receiving transducer on the opposite end of the ultrasonic pulse to pulse voltage (Fig. 2.7). Knowing the distance between two points, the pulse wave velocity can be determined. Ultrasonic pulse velocity provides a detailed

account of the specimen under investigation. Following the publication of standard guidelines present for ultrasonic pulse velocity test:

- i. ASTM C 597: Standard Test Method for Pulse Velocity Through Concrete;
- ii. BS EN 12504-4:2004 Testing Concrete. Determination of Ultrasonic Pulse Velocity.

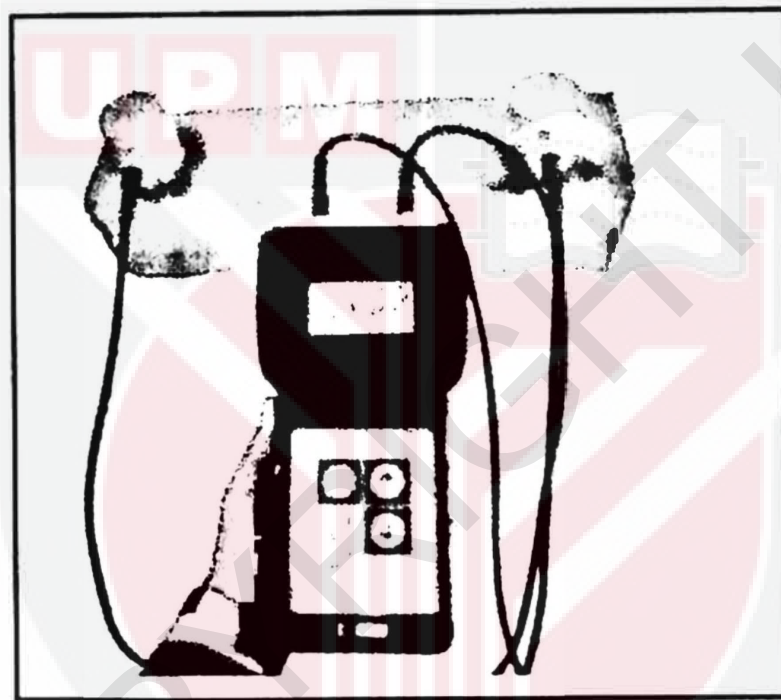


Figure 2.7: The apparatus and procedures of *Ultrasonic Pulse Velocity Methods*

Factors that contribute to the diversity of the ultrasonic pulse velocity method to be used for concrete are properties of aggregates, cement, water-cement ratio, admixtures and concrete age (Naik, Malhotra, and Popovics, 2004). In addition, the reinforcement is embedded in the heart of the route may have a significant effect on the pulse velocity measurements (Concrete Institute of Australia, 2008). Taking these factors into account during analysis, ultrasonic pulse velocity method is an excellent way to investigate the consistency and durability of concrete in a way that is easy and inexpensive.

CHAPTER 3

METHODOLOGY

3.0 Introduction

In technology of non – destructive test, many method that can we use to get the best result to make an excellent concrete. One of the methods are Ultrasonic Pulse Velocity (UPV) and for this project, we have choose this methods to test the concrete.

The Ultrasonic Pulse Velocity is non-destructive testing in-situ to check the quality of concrete and natural stones. In this test, the strength and quality of concrete or stone evaluated by measuring the velocity of ultrasonic pulses through concrete structures or natural stone formation. This test is done by passing a pulse of ultrasonic waves through the concrete to be tested and measuring the time taken for the pulse to get through the structure. Higher velocities show good quality and sustainable materials, while the slower velocity may indicate concrete with many cracks or voids.

This research will be doing by using different water – cement ratio and different grade of concrete. Besides that, choosing the different water – cement ratio is because as we know, at the site, the contractor or workers will always add the water to avoid the concrete become dry and it will make the strength of concrete changes. So, with the result that will get, we can know if the water cement ratio are changes or not. However, the selection of different grade concrete is because to know the condition or strength of structure if the water cement ratio is changes. This research will be carried out in stages as described in Figure 3.1.

3.1 Work Chart

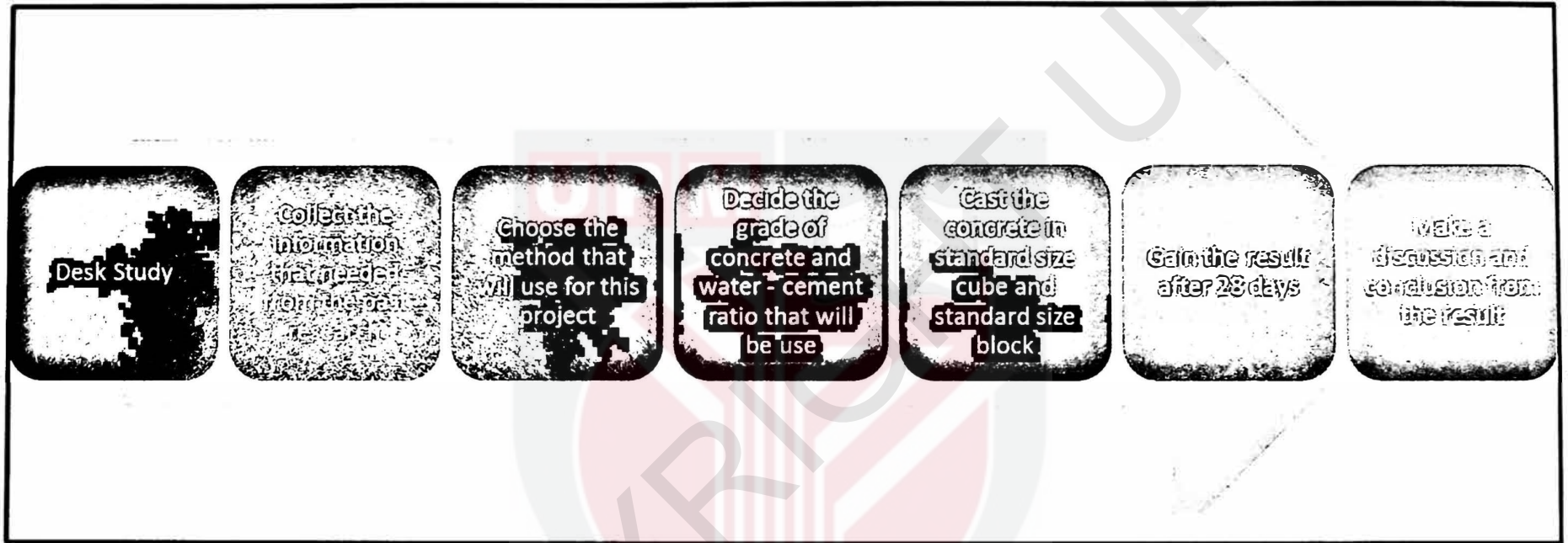


Figure 3.1: The stage of project work.

3.2 Concrete

Concrete is a building material made by mixing cement (Portland cement and water) and aggregate (sand and gravel). Cement paste is the "glue" that binds the particles aggregate together. The strength of cement paste depends on the relative proportions of water and cement; less more diluted becoming weaker. Also the relative proportions of cement paste and aggregate impact strength; higher rates paste that makes concrete stronger. Concrete hardens through a chemical reaction between water and cement without the need for air. After the initial set has taken place with good concrete cures under water. The power acquired gradually, depending on the speed of chemical reactions.

Additives are sometimes incorporated into the concrete mix to achieve specific properties. Steel reinforcement used for additional strength, particularly for tensile stress.

Concrete is usually mixed at the building site and placed in the desired shape in the form of a unit will occupy in the completed structure. The unit can also be precast either on site or in a factory building.

3.2.1 Properties of Concrete

Concrete is associated with high strength, hardness, durability, imperviousness and mould ability. It is a poor thermal insulator, but has high thermal capacity. Concrete is not flammable and has good fire resistance, but

there is a serious loss of strength at high temperatures. Concrete made with ordinary Portland cement has low resistance to acids and sulphates but good resistance to alkalis.

Concrete is a relatively expensive building material for farm structures. The cost can be lowered if some of the Portland cement is replaced with pozzolana. However, when pozzolanas are used the chemical reaction is slower and strength development is delayed.

The compressive strength depends on the proportions of the ingredients, i.e., the cement-water ratio and the cement aggregate ratio. Since the aggregate forms the bulk of hardened concrete, its strength will also have some influence. Direct tensile strength is generally low, only 1/8 to 1/14 of the compressive strength and is normally neglected in design calculations, especially in design of reinforced concrete.

Compressive strength is measured by crushing cubes having 15cm per side. The cubes are cured for 28 days under standardized temperature and humidity and then crushed in a hydraulic press. Characteristic strength values at 28 days are those below which not more than 5% of the test results fall. The grades used are C7, C10, C15, C20, C25, C30, C40, C50 and C60, each corresponding to a characteristic crushing strength of 7.0, 10.0, 15.0 N/mm², etc.

Table 3.1: Typical Strength Development of Concrete

Age at test	Average crushing strength	
	Ordinary Portland Cement	
	Storage in air 18°C 65% R H N/mm ²	Storage in water N/mm ²
1 day	5.5	-
3 days	15.0	15.2
7 days	22.0	22.7
28 days	31.0	34.5
3 months	37.2	44.1

In some literature needed concrete grade specified by the cement - sand - stone, known as nominal as compared to the compressive strength of the mixture. Therefore some common nominal mixture is included in Table 3.2. However, the amount of water added to such a mixture will have a great influence on the compressive strength of concrete cured.

A leaner mixture nominally listed otherwise C7 and C10 grade can only be implemented with well graded aggregate ranging up to relatively large sizes.

3.2.2 Cement

Ordinary Portland cement is used for most of the farm structure. It is sold in paper bags containing 50kg or about 37 litres. The cement must be stored in a dry place, protected from soil moisture, and for a period of not more than one

or two months. Despite the humid air can damage the cement. It must be consistent powder when used. If lumps have developed quality has decreased, but it still can be used if the lumps can be crushed between the fingers.

Table 3.2: Suggested Use for Various Concrete Grades and Nominal Mixes

Grade	Nominal mix	Use
C7 C10	1:3:8 1:4:6 1:3:6 1:4:5 1:3:5	Strip footings; trench fill foundations; stanchion bases; non reinforced foundations; oversite concrete and bindings under slabs; floors with very light traffic; mass concrete, etc.
C15 C20	1:3:5 1:3:4 1:2:4 1:3:3	Foundation walls; basement walls; structural concrete; walls; reinforced floor slabs; floors for dairy and beef cattle, pigs and poultry; floors in grain and potato stores, hay barns, and machinery stores; septic tanks, water storage tanks; slabs for farm yard manure; roads, driveways, paving and walks; stairways.
C25 C30 C35	1:2:4 1:2:3 1:1.5:3 1:1:2	All concrete in milking parlours, dairies, silage silos and feed and drinking troughs; floors subject to severe wear and weather or weak acid and alkali solutions; roads and paving frequently used by heavy machinery and lorries; small bridges; retaining walls and dams; suspended floors, beams and lintels; floors used by heavy,

		small-wheeled equipment, for example lift trucks; fencing posts, precast concrete components.
C40 C50 C60		Concrete in very severe exposure; prefabricated structural elements; pre-stressed concrete.

Therefore, for this project the grade of concrete that have been chosen is C30, C35 and C40 and will be added into different water – cement ratio.

3.3 Water Cement Ratio

Water-cement ratio is the ratio of the weight of water to the weight of cement used in concrete mix. A lower ratio leads to a higher strength and endurance, but can make the mixture difficult to work with and form. Workability can be solved by the use of plasticizers or super-plasticizers.

Usually, this ratio refers to the ratio of water plus pozzolana cement ratio, $w / (c + p)$. Pozzolana is usually fly ash or blast furnace slag. It may include some other material, such as silica fume, rice hull ash or natural pozzolana. Pozzolana can be added to reinforce concrete.

Concrete hardens due to a chemical reaction between cement and water (called hydration, produces heat and is called the heat of hydration). For every pound (or

kilogram or any unit weight) of cement, about 0.35 pounds (0.35kg or unit or related) of water required to fully complete the hydration reaction.

However, the mixture ratio of 12:35 may not mix well, and may not drain well enough to be placed. More water is used because it is technically necessary to react with the cement. Water-cement ratio of 0.45 to 0.60 is more commonly used. For higher concrete strength, low ratio is used, together with a plasticizer to increase flow capacity.

Too much water will cause separation of sand and aggregate components of the cement paste. Also, the water is not consumed by the hydration reaction can leave the concrete as it hardens, causing microscopic holes (bleeding) that will reduce the strength of the concrete. A mixture with too much water will have more leaf shrinkage of the excess water, causing internal cracks and fractures can be seen (especially around the corner), which again will reduce the ultimate strength.

The water – cement ratio is important in this project because of the relationship between the water – cement ratio and compressive strength. The water-cement ratio increases (i.e., more water is added to a fixed amount of cement), more concrete strength resulting reduced. This is mostly because adding more water to create a paste diluted weaker and more prone to cracking and shrinkage. Shrink lead to micro-cracks, which is a zone of weakness. When fresh concrete is placed, the excess water squeezed out of the paste by weight of aggregate and cement paste itself. When there is an excess of water, water that bleed out to the surface. Micro channels and passages are created in the concrete to allow water to flow into a ground zone and micro-cracks.

Using water-cement ratio is low is a common way to achieve high strength and high quality concrete, but it does not guarantee that the resulting concrete is always suitable for countertops. Unless the grading of the aggregate and is balanced with the right amount of cement paste, excessive shrinkage, cracking and curling may occur. Good concrete results from the design of a good mix, and water-cement ratio low is one part of the design mix well.

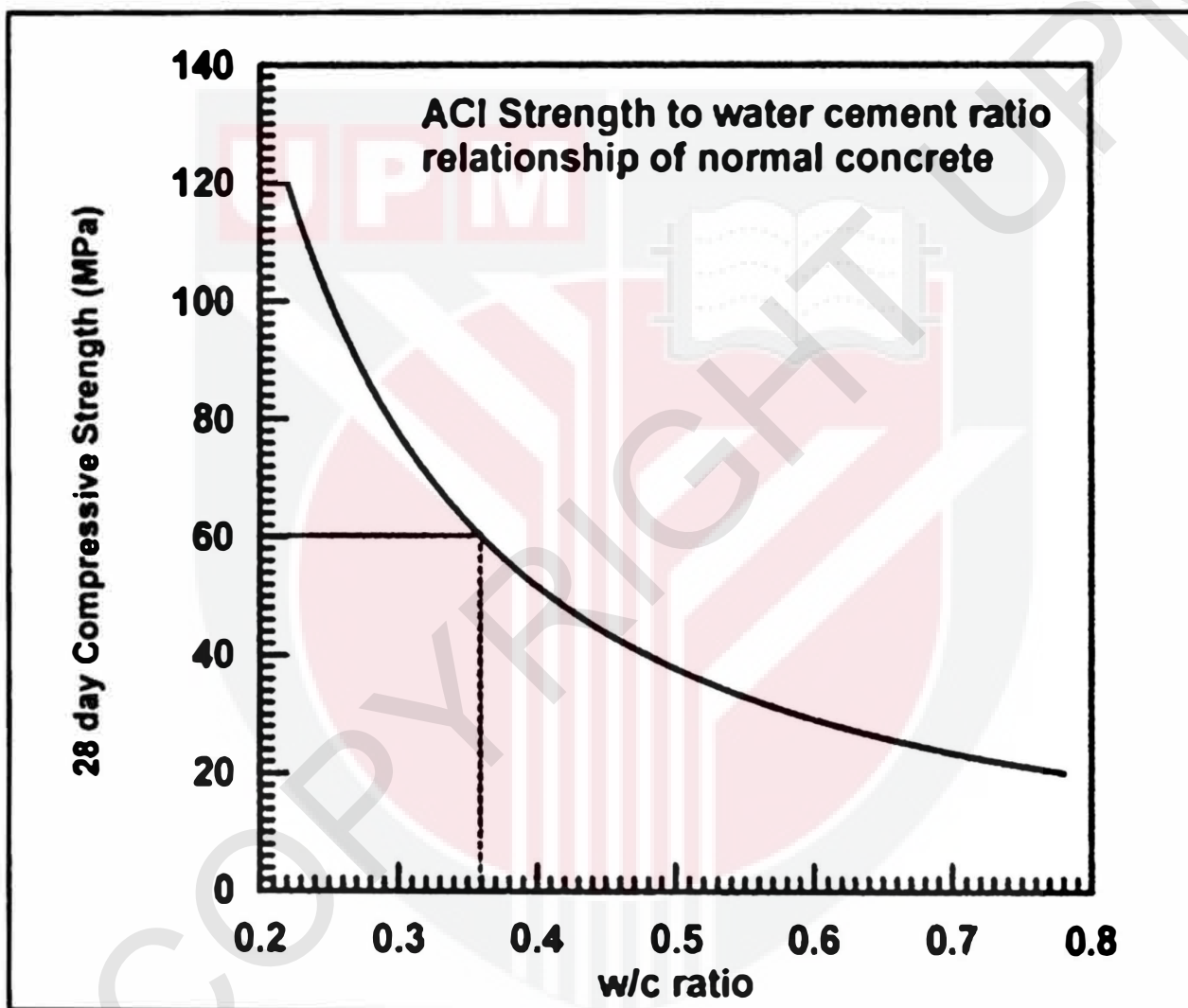


Figure 3.2: Relationship between water – cement ratio and compressive strength.

Therefore, to complete the research of this project, the water – cement ratio that will be use is 0.4, 0.6 and 0.8. It will be added with the different grade of concrete to make a mix design.

3.4 The Sample

The sample for this research will be made into two size which is in cubic and block size. The size that will be use is 150mm x 150mm x 150mm for cubic and 100mm x 100mm x 500mm for block. The cubic sample will have 27 pieces which is will be divide into three (3) different water – cement ratio and three (3) grade of concrete like the chart below:

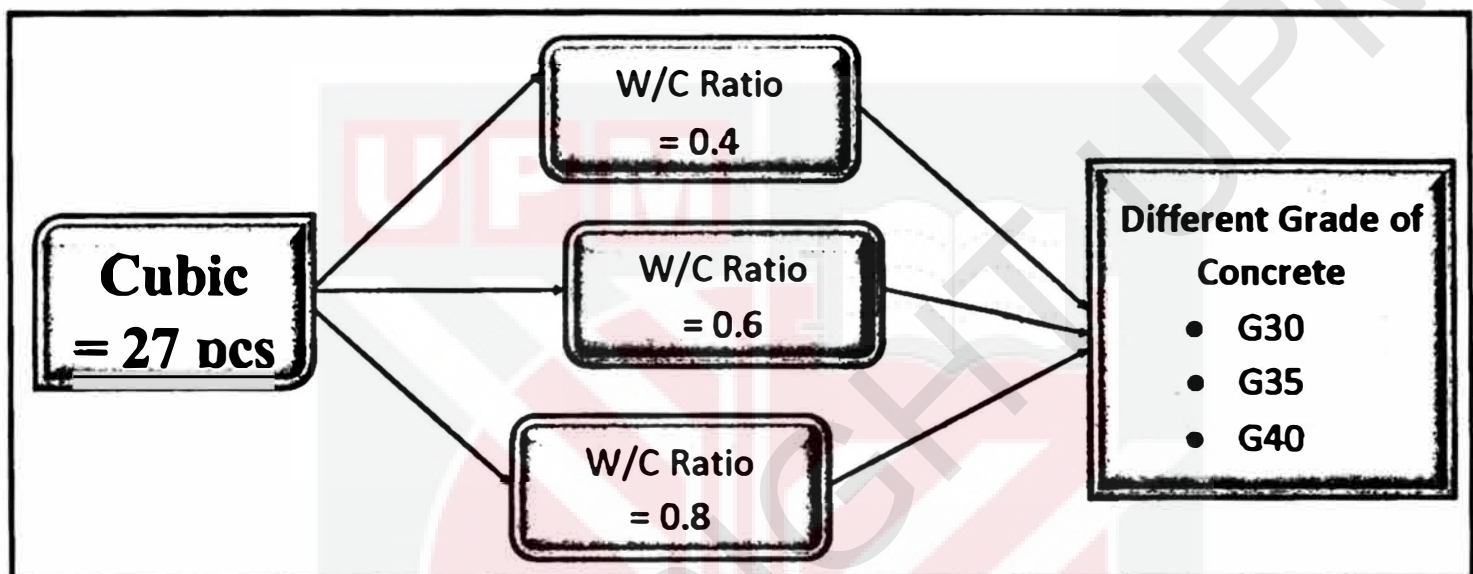


Figure 3.3: The cubic sample with different water – cement ratio and grade of concrete

However, for the block, there is 9 pieces of block and will be cast with the 8mm diameter of reinforcement bar. The block also will divide into three (3) different water – cement ratio and three (3) different grade of concrete. Chart 3 will explain more details about the block structure.

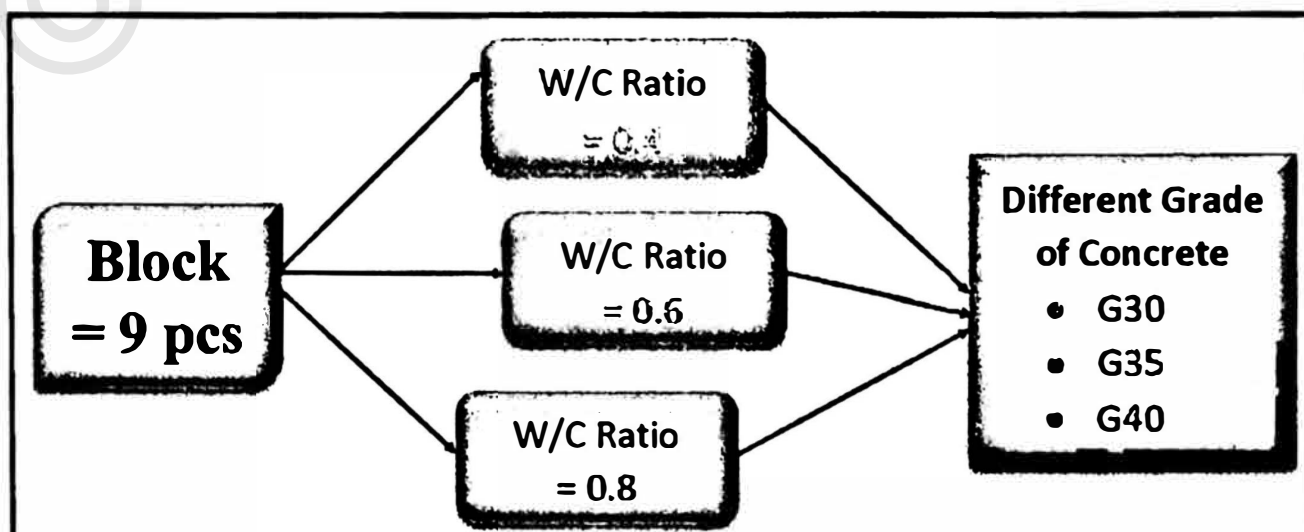


Figure 3.4: The block sample with different water – cement ratio and grade of concrete

3.5 The Procedure

For make any research or experiment, there are some procedure and step that must be followed to get a good result. It also same like this project, it is have some procedure before we can get the result according to the type of sample.

3.5.1 Sample of cubic

The first thing that must be do is mix the concrete with a mix design that have been chosen which is three (3) different value of water – cement ratio (0.4, 0.6, and 0.8) and three (3) different grade of concrete (G30, G35 and G40). After the sample has been remixed, immediately fill the cube moulds and compact the concrete, either by hand or by vibration. Any air trapped in the concrete will reduce the strength of the cube. Hence, the cubes must be fully compacted. However, care must also be taken not to over compact the concrete as this may cause segregation of the aggregates and cement paste in the mix. This may also reduce the final compressive strength.



Figure 3.5: Filling the moulds with concrete

3.5.1.1 Compacting with compacting bar

150 mm mould to be filled in three layers approximately equal (50 mm deep). A bar is available for compacting concrete compaction. It is a long steel bar 380 mm, weight of 1.8 kg and has a 25 mm square end of the ramming. During compaction with a compacting each layer, the whipping should be distributed in a uniform manner on the concrete surface and each layer should be compacted to full depth. During the first layer compaction, compaction bar must not forcibly strike the bottom of the mould. For the next layer, the compaction should get into the layer immediately below. The minimum number of strokes per layer required to produce full compaction will depend on the workability of concrete, but at least 35 strokes will be necessary except in the case of a very high workability concrete. After the top layer has been compacted, trowel should be used to finish the surface level with the top of the mould and the outer mould should be wiped clean.

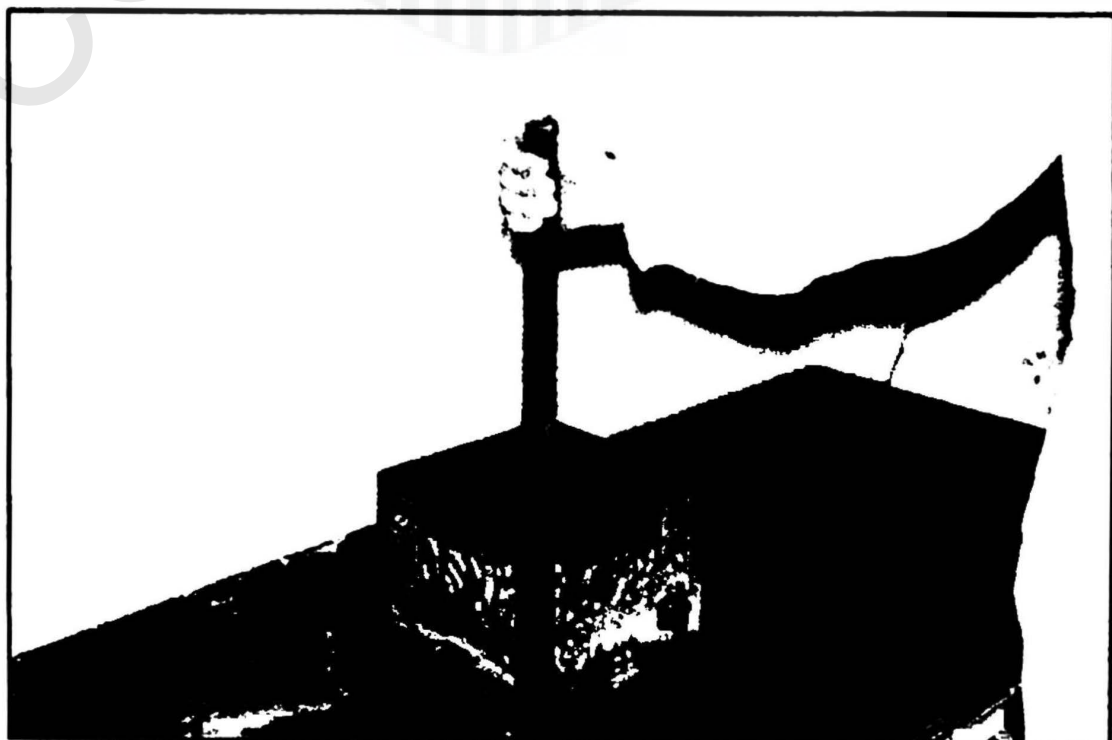


Figure 3.6: Compacting the concrete in the mould

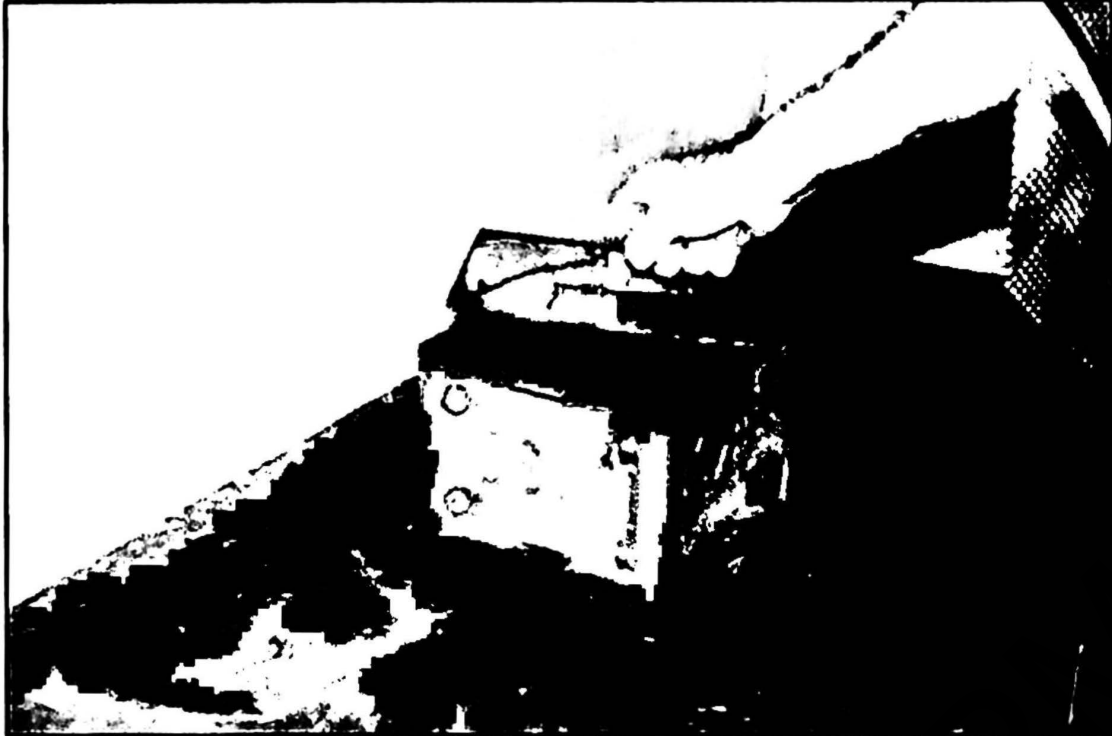


Figure 3.7: Finishing

3.5.1.2 Demoulding the cubes

Test cube should be demoulded between 16 and 24 hours after they were made. If after this period of time the concrete does not reach sufficient strength to enable demoulding without damage cubes then demoulding to be postponed for another 24 hours. When removing the concrete cube of the mould, taking the mould apart completely. Make sure you do not damage the cube because, if there are cracks due to compressive strength can be reduced.

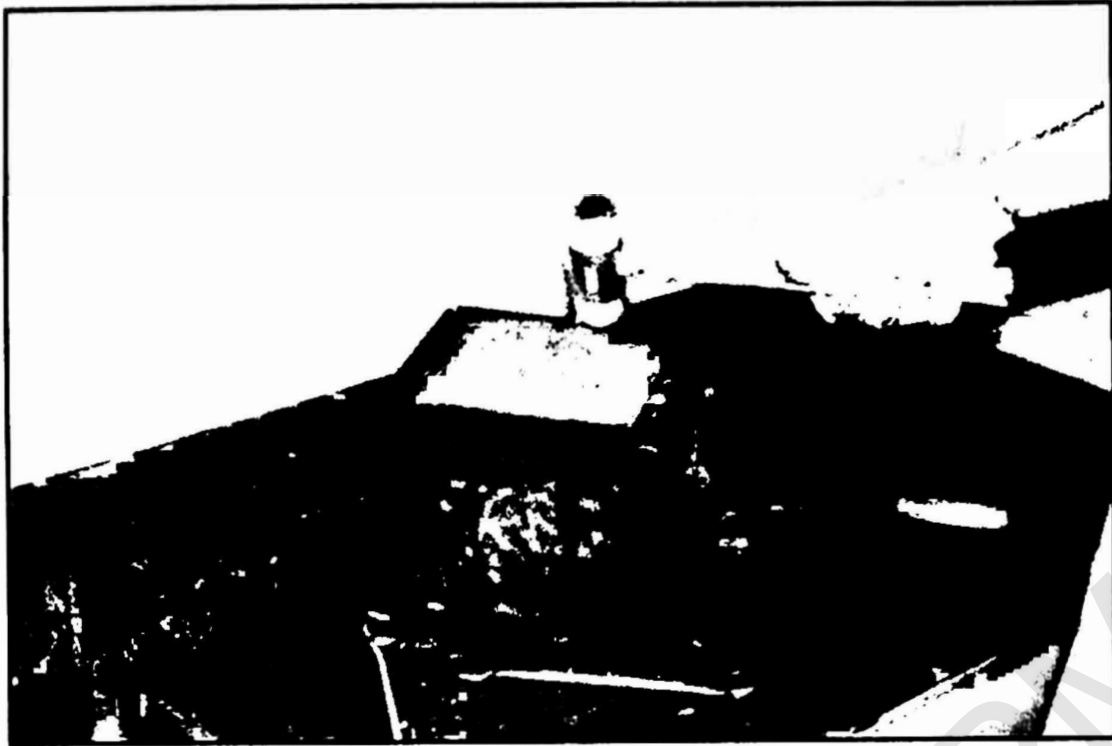


Figure 3.8: Demould the cubes

After demoulding, each cube must be marked with the introduction of easy to read at the top or bottom waterproof crayon or ink. Mould must be cleaned thoroughly after demoulding cubes. Make sure the oil or dirt does not accumulate between flange face, if not, the two parts will not fit together properly and will leak through the joints and irregularly shaped cubes may apply.

3.5.1.3 Curing the cube

Cubes need to be cured before it is tested. Unless required for the test in 24 hours, the cube should be placed in a tank after demoulding curing or mist.

Curing temperature curing water in the tank should be maintained at 27-30 ° C. If curing is in a fog, the relative humidity

should be maintained at no less than 95%. Preservation should continue as long as possible until the time of testing.



Figure 3.9: Marking and curing concrete cubes

In order to provide adequate air circulation, adequate space must be provided between the cubes, and the cubes and the pickling tank. If curing is in a fog, there should be enough space between the cubes to ensure that all surfaces of the cube is moist at all times.

After 28 days of curing, the UPV test will be carried out to gain the results of strength of the concrete. All this step of procedure will be carried out to all 27 pieces of cubic.

3.5.2 Sample of block

Steps to make the sample block is the same as the solid sample after the sample has been remixed, immediately fill the mould block and put the reinforcement bars of 8mm diameter at the bottom of the block and compacting concrete, either by hand or with vibration. Any air trapped in the concrete will reduce the power cube. Therefore, the cube must be completely solidified. However, care should be taken not to over solid concrete as this may cause the separation of aggregates and cement paste mix. It also can reduce the ultimate compressive strength.

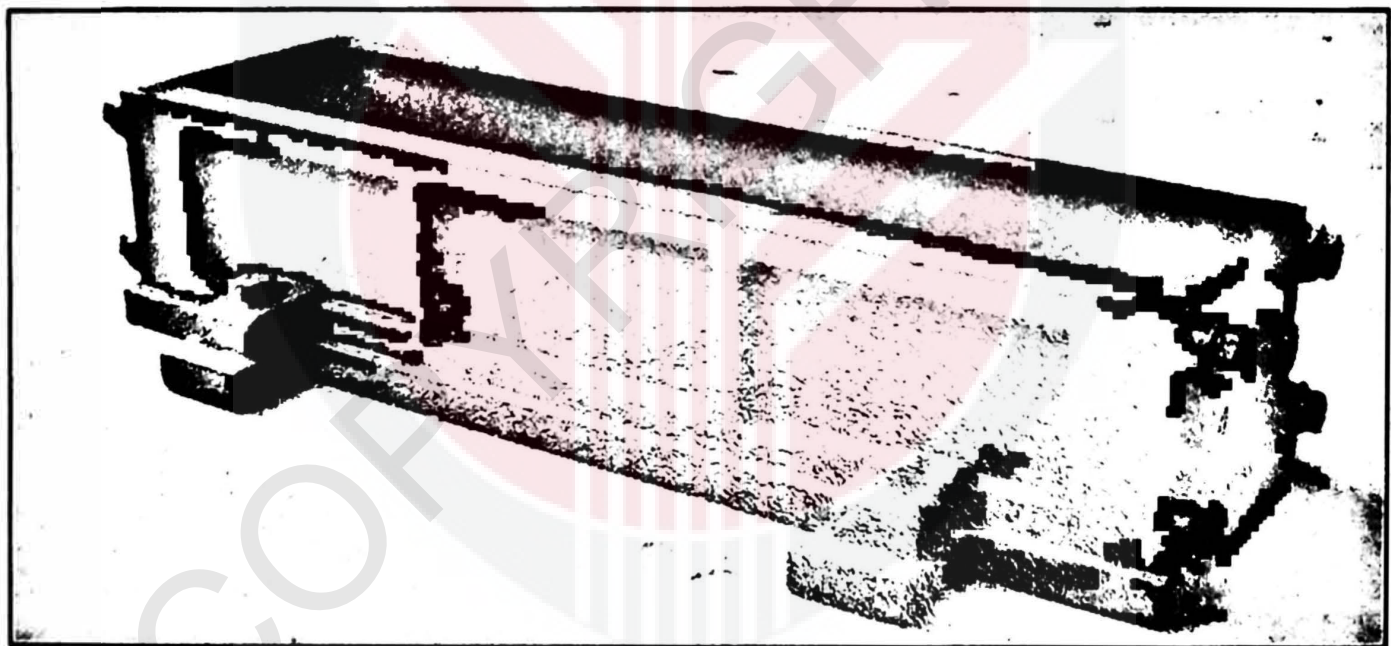


Figure 3.10: The block mould with size 100mm (W) x 100mm (H) x 500mm (L)

3.5.2.1 Compacting with compacting rod

100 mm mould to be filled in two approximately equal layers (50 mm deep). A bar is available for compacting concrete compaction. During compaction with a compacting each layer, the whipping should be distributed in a uniform manner on the concrete surface and each

layer should be compacted to full depth. During the first layer compaction, compaction bar must not forcibly strike the bottom of the mould. For the next layer, the compaction should get into the layer immediately below. The minimum number of strokes per layer required to produce full compaction will depend on the workability of concrete, but at least 35 strokes will be necessary except in the case of a very high workability concrete. After the top layer has been compacted, trowel should be used to finish the surface level with the top of the mould and the outer mould should be wiped clean.

3.5.2.2 Demoulding the block

At the end of about 24 hours removing the concrete block from the mould, taking the mould apart completely. Make sure not to damage the block because, if there are cracks due to compressive strength can be reduced.

After demoulding, each block must be marked with an identification readable on the top or bottom waterproof crayon or ink.

Mould must be cleaned thoroughly after demoulding block. Make sure the oil or dirt does not accumulate between flange face, if not, the two parts will not fit together properly and will leak through the joints and irregularly shaped cubes can cause.

3.5.2.3 Curing the block

Blocks must be cure before it is tested. Unless required for the test in 24 hours, the cube should be placed in a tank after demoulding curing or mist.

Put the sample blocks in lime-saturated water bath 24 hours before the test. Lime-saturated water bath should be $73.4^{\circ}\text{F} \pm 9^{\circ}\text{F}$. Storing specimens in a water-saturated chalk up time test. Preservation should continue as long as possible until the time of testing. Also, keep moist monitored block during curing. Even a few minutes of exposure to the drying beam can seriously affect the strength test.

After 28 days of curing, the Ultrasonic Pulse Velocity (UPV) test will be conducted to obtain the results of the strength of concrete. All of these steps will be carried out procedures to all nine pieces of block.

3.6 Laboratory Test

3.6.1 Ultrasonic Pulse Velocity Test

After completion of the curing process for blocks and cubes, the Ultrasonic Pulse Velocity Testing was conducted. Ultrasonic Pulse Velocity (UPV) concrete test is based on the pulse velocity method to

provide information on the uniformity of concrete, cavities, cracks and defects. The presence of voids, honeycomb or other discontinuity.

The pulse velocity in a material depends on the density and elastic properties, which in turn is related to the quality and compressive strength of concrete. The test method is applicable to assess the relative uniformity and quality of the concrete, to indicate the presence of voids and cracks, and to evaluate the effectiveness of the repair of cracks. It is also used to indicate a change in the properties of concrete, and in the study of the structure, to estimate the degree of deterioration or cracking.

3.6.1.1 Test Equipment

The UPV equipment including transducer, receiver and indicator to show the travel time from the transducer to the receiver.

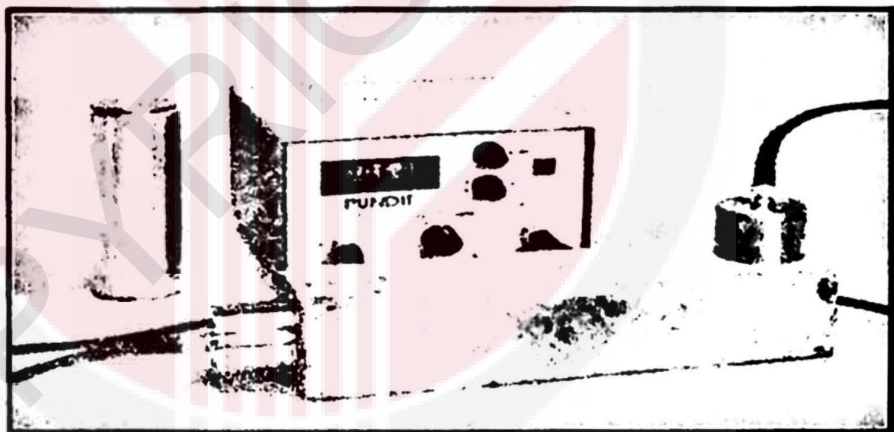


Figure 3.11: Pundit manual 1998

Ultrasonic pulse uses fast potential changes to create vibration that leads to its basic frequency. The transducer is firmly attached to concrete surface to vibrate the concrete. The pulses go through the concrete and reach the receiver. The pulse velocity can be determined from the following equation:

$$V = \frac{L}{T}, \text{ where; } V = \text{pulse velocity (km/s)}$$
$$L = \text{path length (cm)}$$
$$T = \text{transit time } (\mu\text{s})$$

Based on this technique, the velocity of sound in a concrete is related to the concrete modulus of elasticity:

$$V = \sqrt{E/\rho}, \text{ where; } E = \textit{modulus of elasticity}$$
$$\rho = \textit{density of concrete}$$

3.6.1.2 Arrangement of Equipment

Ultrasonic method implemented by sending ultrasonic pulses to generate a pressure wave in the concrete specimen using a transducer and a transducer sends recipients to receive waves. Knowing the time and distance travelled pressure wave through the specimen, ultrasonic method that can calculate and concrete properties can be estimated. Ultrasonic waves into the concrete is directly proportional to the strength and longevity of concrete. The use of echo pulse amplitude is difficult because changes can cause mistakes.

When the ultrasonic pulse of electro-acoustic transducer is produced it will undergo multiple reflections at the boundaries of different materials in the concrete phase. So, the pressure waves developed complex systems such as longitudinal (compressional) waves, shear (transverse) and surface (Rayleigh). During measurement, the probe in contact with the surface structure and a small air gap is formed.

There are three different methods to place the probe toward the specimen:

a. Direct or Cross Probing (Opposite Faces)

This method is done by placing the probe of the transmitter and receiver opposite to each other of the specimen.

b. Semi Direct Probing (Adjacent Faces)

This method is done by placing the transmitter and receiver are on any two of the perpendicular face of the specimen.

c. Indirect (Same Faces)

This method is done by placing the transmitter and receiver on the same surface of the specimen

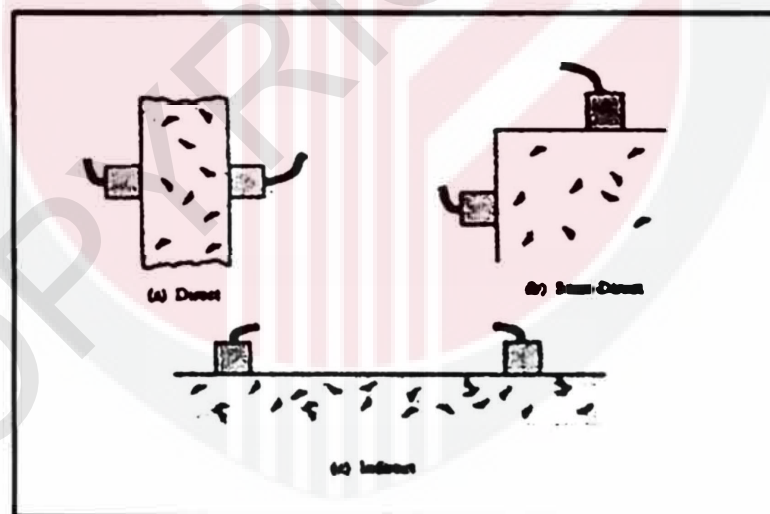


Figure 3.12: The arrangement of equipment

However, for this research, there are only two methods already been selected which is direct and indirect methods. Direct delivery is the delivery of the most sensitive and most sensitive indirectly.

Indirect transmission should be used when only one face of the concrete can be accessed, when the depth of surface defects or

cracks will be determined or when the quality of the concrete surface relative to the overall quality is good.

Pulses are transmitted through large air voids in the material. Therefore, if any vacancy is located directly in the heart of the instrument will show the route taken by the pulse time intercepting the vacuum via the fastest route. Therefore, it is possible to detect large voids in the concrete when the grid pulse velocity measurements made through a region where the voids were.

3.6.1.3 Interpretation of Results

Quality concrete in terms of uniformity, the incidence or absence of internal flaws, cracks and segregation, and shows the level of workmanship employed, can thus be evaluated using the guidelines given below, which were born to characterize the quality of the concrete in the structure in terms of pulse velocity ultrasound.

Pulse Velocity (km/second)	Concrete Quality (Grading)
Above 4.5	Excellent
3.5 to 4.5	Good
3.0 to 3.5	Medium
Below 3.0	Doubtful

Figure 3.13: The pulse velocity and quality of concrete

3.7 Data Analysis

After all the procedure step have going through, the test will gain the result. From the result, one graph will be built up to compare with other same test in the future. The example of the graph is like at below:

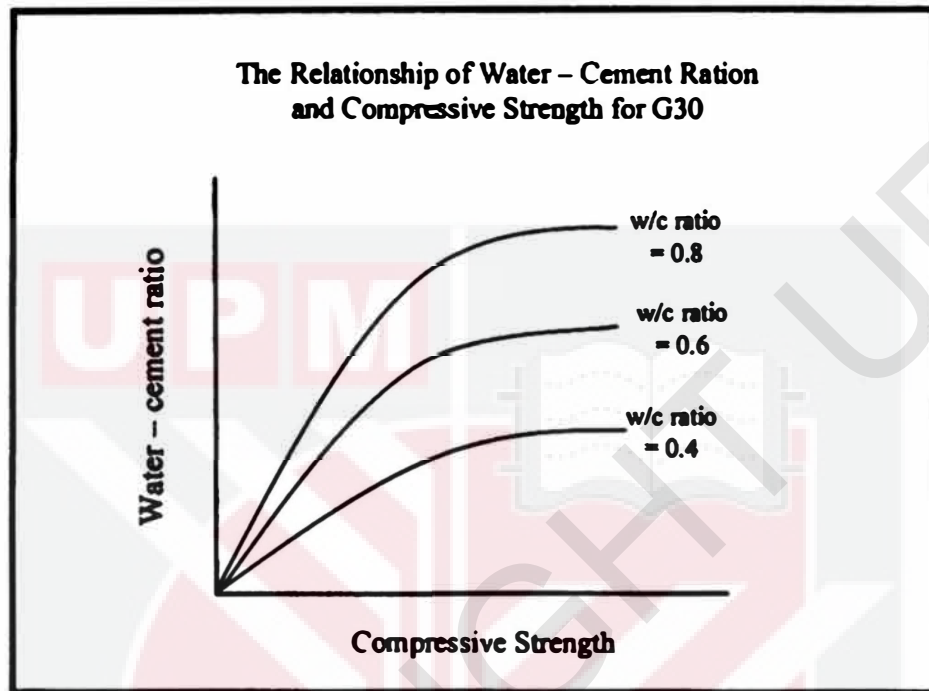


Figure 3.14: The example of graph that will obtain from the result of test

CHAPTER 4

RESULT AND DISCUSSIONS

4.0 Introduction

This chapter will discuss about the result and analysis of the study. The obtained result including graph is presented. The data that only consider are grade concrete of G30; w/c 0.6 and G40; w/c 0.4. The set of data for strength of concrete will also presented be and discussed in this chapter.

4.1 Grade G30

For this section, the result from the compressive strength test of grade G30 will be discussed and analysed. The data from the compressive strength test of grade G30 are recorded and analysed to become the reference value or data for ultrasonic – pulse velocity (UPV) test. The data that be considered only on water – cement ratio of 0.6 for both structure which is cube (100mm x 100mm x 100mm) and prism (100mm x 100mm x 500mm). The data was collected from two different type which is from previous lab data and experimental research data. So that, the data was shown the different value for both test and data.

4.1.1 Cube

Previous Laboratory Data:

Table 4.1: The laboratory data for cube of grade G30 with w/c 0.6

Grade	Days	Water Cement Ratio	Ultra-pulse Velocity (km/s)	Compressive Strength (MPa)
30	28	0.6	5.077	29.80
30	28	0.6	5.061	31.84
30	28	0.6	5.366	24.76
Average =				28.80

Experimental data:

Table 4.2: The experimental data for cube of grade G30 with w/c 0.6

Grade	Days	Water Cement Ratio	Ultra-pulse Velocity (km/s)	Compressive Strength (MPa)
30	28	0.6	5.069	37.71
30	28	0.6	5.240	39.75
30	28	0.6	5.550	32.67
Average =				36.71

The data that is shown in Table 4.1 are collected from previous laboratory data that have been done by others and Table 4.2 are collected from the experiment data for cube of grade G30; water cement ratio 0.6. This data was collected at the compressive strength test and ultrasonic – pulse velocity test. Then the data are plotted on the graph which is on Chart 4.1 and used for reference on built the suggested graph like shown in previous chapter on Figure 3.8.

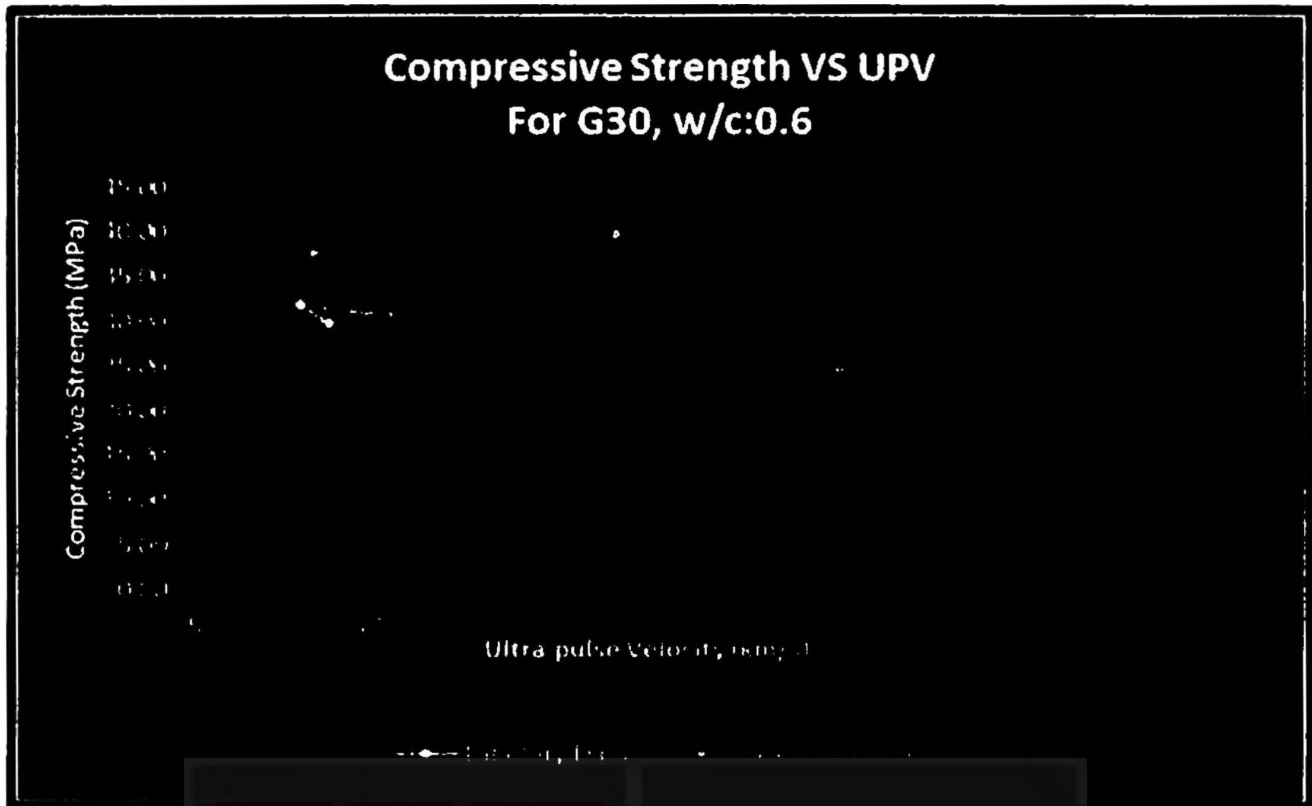


Chart 4.1: The Graph for Cube (grade G30; w/c 0.6) of Compressive Strength VS Ultrasonic – Pulse Velocity (UPV)

4.1.2 Prism

Previous Laboratory Data:

Table 4.3: The laboratory data for prism of grade G30 with w/c 0.6

Grade	Days	Water Cement Ratio	Ultra-pulse Velocity (km/s)	Compressive Strength (MPa)
30	28	0.6	5.077	29.80
30	28	0.6	5.061	31.84
30	28	0.6	5.366	24.76
Average =				28.80

Experimental data:

Table 4.4: The experimental data for prism of grade G30 with w/c 0.6

Grade	Days	Water Cement Ratio	Ultra-pulse Velocity (km/s)	Compressive Strength (MPa)
30	28	0.6	5.195	37.71
30	28	0.6	4.282	39.75
30	28	0.6	4.718	32.67
Average =				36.71

The data that is shown in Table 4.3 are collected from previous laboratory data that have been done by others and Table 4.4 are collected from the experiment data. However, this data was for prism structure of grade G30; water cement ratio 0.6. This data was collected at the compressive strength test and ultrasonic – pulse velocity test. Then the data are plotted on the graph which is on Chart 4.2 and used for reference on built the suggested graph like shown in previous chapter on Figure 3.8.

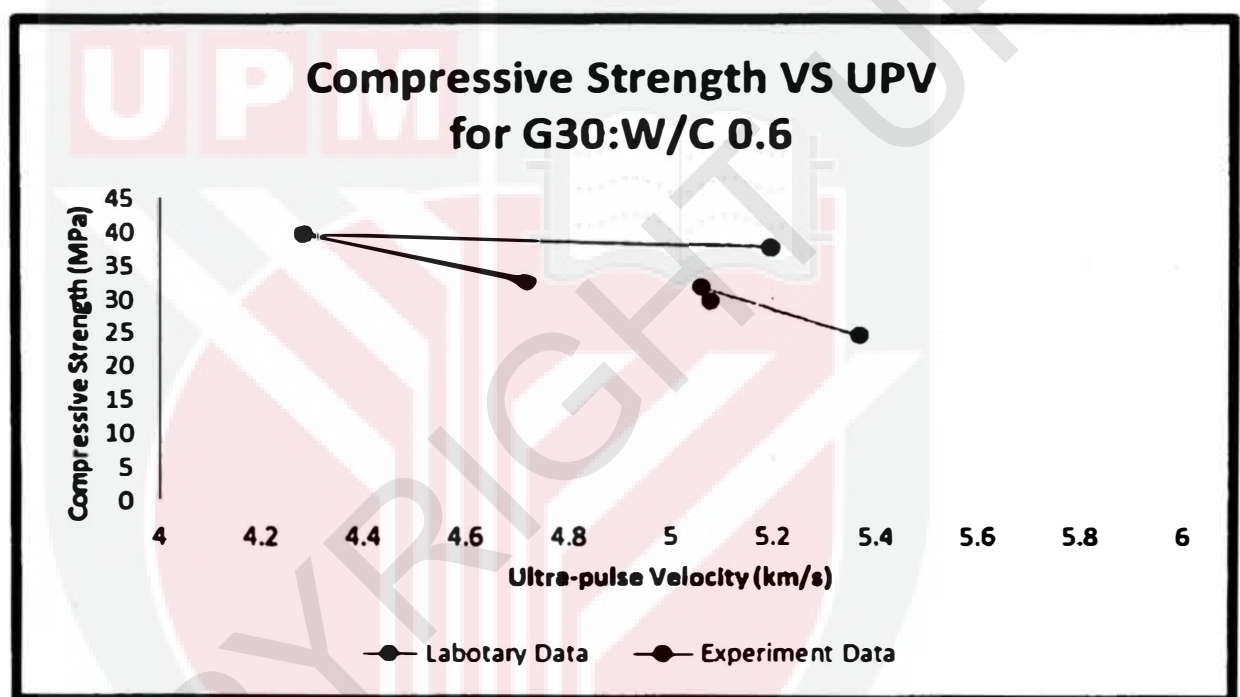


Chart 4.2: The Graph for prism (grade G30; w/c 0.6) of Compressive Strength VS Ultrasonic – Pulse Velocity (UPV)

4.2 Grade G40

For the grade G40, the water cement ratio only consider is 0.4. For this section also the data that be considered for both structure which is cube (100mm x 100mm x 100mm) and prism (100mm x 100mm x 500mm). It is also, was collected from two different type which is from previous lab data and experimental research data. So that, the data was shown the different value for both test and data.

4.2.1 Cube

Previous Laboratory Data

Table 4.5: The laboratory data for cube of grade G40 with w/c 0.4

Grade	Days	Water Cement Ratio	Ultra-pulse Velocity (km/s)	Compressive Strength (MPa)
40	28	0.4	5.413	31.76
40	28	0.4	5.590	37.87
40	28	0.4	5.413	36.52
Average =				35.80

Experiment Data:

Table 4.6: The experimental data for cube of grade G40 with w/c 0.4

Grade	Days	Water Cement Ratio	Ultra-pulse Velocity (km/s)	Compressive Strength (MPa)
40	28	0.4	5.369	21.42
40	28	0.4	5.240	27.53
40	28	0.4	5.369	26.18
Average =				25.04

The data that is shown in Table 4.4 are collected from previous laboratory data that have been done by others and Table 4.5 are collected from the experiment data. This data was for cube structure of grade G40; water cement ratio 0.4. This data was collected at the compressive strength test and ultrasonic – pulse velocity test. Then the data are plotted on the graph which is on Chart 4.3 and used for reference on built the suggested graph like shown in previous chapter on Figure 3.8.

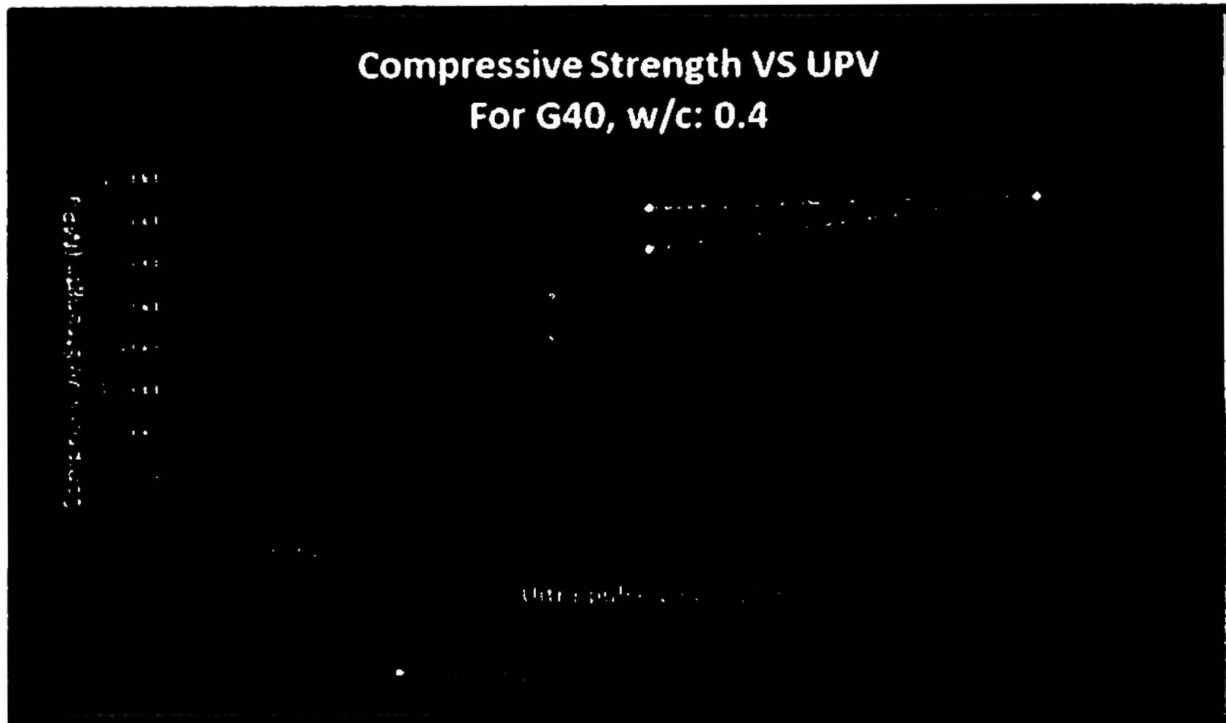


Chart 4.3: The Graph for Cube (grade G40; w/c 0.4) of Compressive Strength VS Ultrasonic – Pulse Velocity (UPV)

4.2.2 Prism

Previous Laboratory Data:

Table 4.7: The laboratory data for prism of grade G40 with w/c 0.4

Grade	Days	Water Cement Ratio	Ultra-pulse Velocity (km/s)	Compressive Strength (MPa)
40	28	0.4	5.413	31.76
40	28	0.4	5.590	37.87
40	28	0.4	5.413	36.52
Average =				35.80

Experiment Data:

Table 4.8: The experimental data for prism of grade G40 with w/c 0.4

Grade	Days	Water Cement Ratio	Ultra-pulse Velocity (km/s)	Compressive Strength (MPa)
40	28	0.4	5.410	21.42
40	28	0.4	7.342	27.53
40	28	0.4	2.752	26.18
Average =				25.04

The data that is shown in Table 4.7 are collected from previous laboratory data that have been done by others and Table 4.8 are collected from the experiment data that was obtained for prism concrete grade G40 with water cement ratio of 0.4. This data was collected at the compressive strength test and ultrasonic – pulse velocity test. Then the data are plotted on the graph which is on Chart 4.4 and used for reference on built the suggested graph like shown in previous chapter on Figure 3.8.

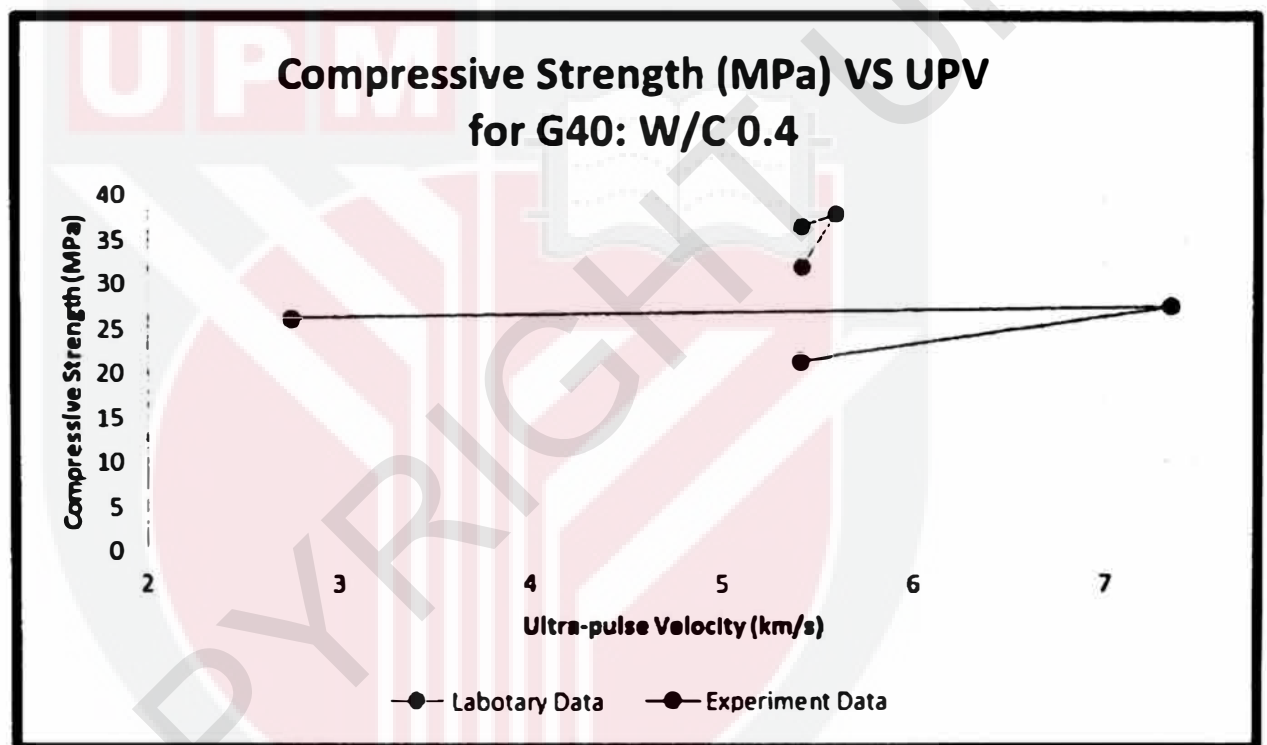


Chart 4.4: The Graph for Prism (grade G40; w/c 0.4) of Compressive Strength VS Ultrasonic – Pulse Velocity (UPV)

From the result, the data shown that the concrete strength of concrete grade G30 with w/c 0.6 are too high for experimental data (36.71 MPa) compare to the laboratory data that achieve the target strength (28.80 MPa). However, for concrete grade G40 with w/c 0.4, the result that have been obtained are lower than the laboratory work, 35.80 MPa which is 25.04 MPa. Due to some reason, the G35 concrete grade with w/c 0.8 can't be shown. However, it is same happened which is it have lower value of concrete strength from the allowable value of concrete strength.

However, for UPV test result, data shown that the cumulative results of the testing of ultrasonic pulse velocity (UPV) is greater than 4.5 km / s except for concrete prism of grade G40 with w/c: 0.4 which have the highest value 7.342 km/s and also the lower value 2.752 km/s. Due to some error that happened while doing the test which are the reading should be taken in three readings, but because of misunderstanding, readings taken just one reading. This has resulted in readings received cannot be used with good effect. Besides that, all the result for concrete grade G30; w/c: 0.6, are in the range of excellent quality. So, this indicates that the quality of the concrete is mixed for 28 days has a good quality of concrete and can be used for other concrete mix in the future.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.0 Introduction

This chapter summarize all the finding about this project. Based on the project, future works are recommended to broaden the using of ultrasonic on the advanced instrumentation.

5.1 Conclusion Based on Objective

As a conclusion, all objectives have been achieved except the third objective because the results produced did not show an appropriate graph to obtain details regarding the structure of the design, features, and past performance needed by using Non-Destructive characterization.

Since, the data that only consider are grade concrete of G30; w/c 0.6 and G40; w/c 0.4, the concrete strength of concrete grade G30 with w/c 0.6 are too high for experimental data (36.71 MPa) compare to the laboratory data that achieve the target strength (28.80 MPa). However, for concrete grade G40 with w/c 0.4, the result that have been obtained are lower than the laboratory work, 35.80 MPa which is 25.04 MPa. It is same happened with concrete grade G35 with w/c 0.8 that have lower value of concrete strength from the allowable value of concrete strength.

Besides that, the concrete grade rating was successfully carried out. However, due to concrete mix error, the results obtained were not as expected. As the graph that is required cannot be produced, it has a very profound impact on the study. The impact was, this study cannot prove that the graph of UPV against Compressive Strength can determine the grade and also water-cement ratio in a concrete structure.

Therefore, it is important to ensure that the concrete mix is correct and recover the data at least three (3) readings because each reading will affect the results required. In addition, by obtaining the correct reading, all the data obtained can be used, and graphs that are intended to be formed.

5.2 Future Work

For future research, experimental setup can be done using the data from this project as a reference. Experimental setup can be done either to confirm or use the data to develop a real expectation graphs that can be easily used for industrial or people.

To avoid a repeat of a similar incident in the future, researchers need to get accurate information, especially when brewing the correct ratio of concrete required. In addition, they should also form the concrete mix with exact calculations. After mixing required was available, researchers should take or reading data to the test at least three or more readings.

In addition, to get more accurate data in the future, the rules need to be more detailed like building columns or beams. In addition, defects or other countries outside the concrete should be tested to get better results.



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APPENDICES



Figure 7.1: Prepared the Ultrasonic Pulse Velocity (UPV) device for testing.



Figure 7.2: Covered the concrete by wet cloth



Figure 7.3: The concrete after demoulding.



Figure 7.4: Doing the mixed work for concrete mixture.

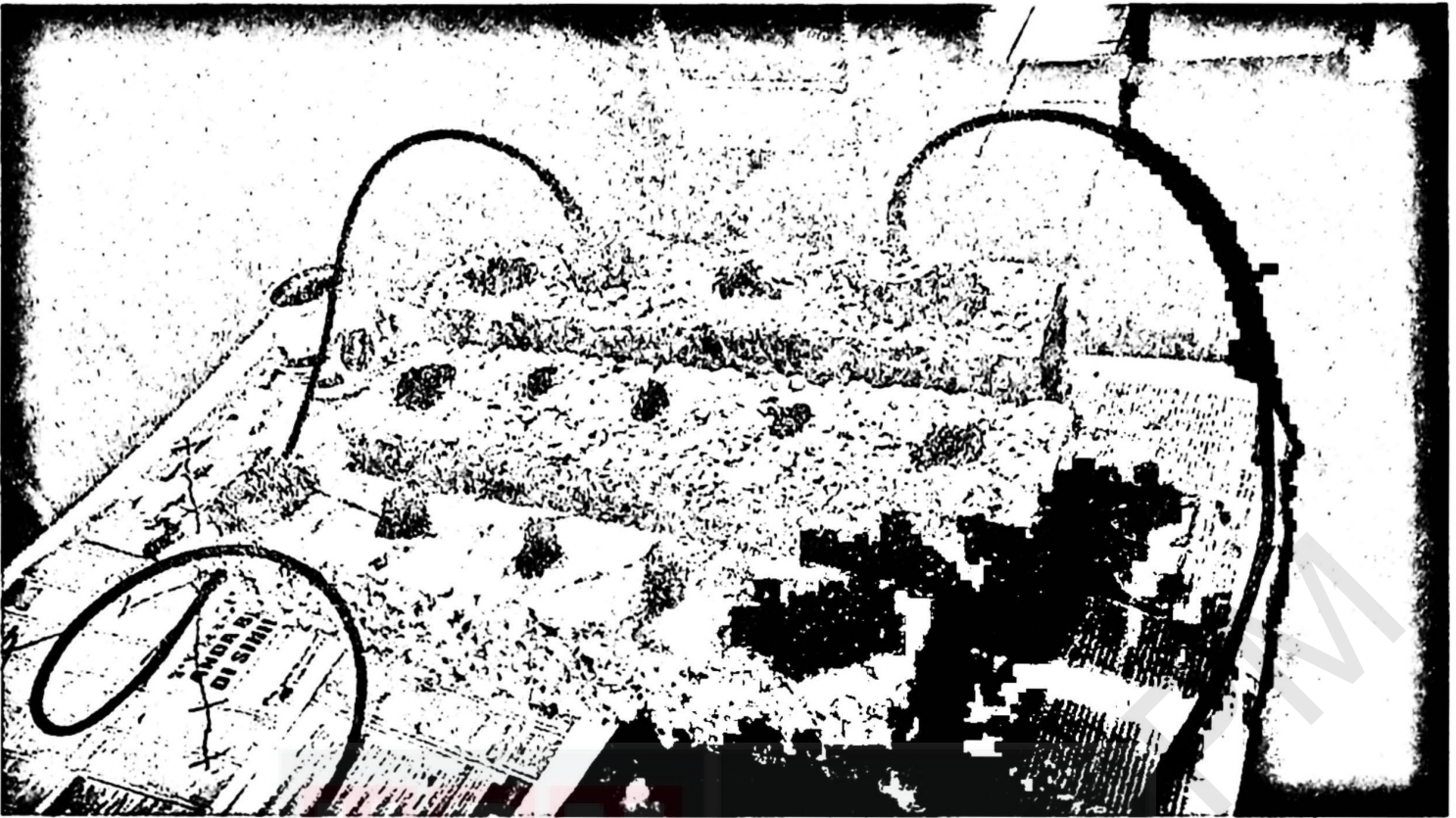


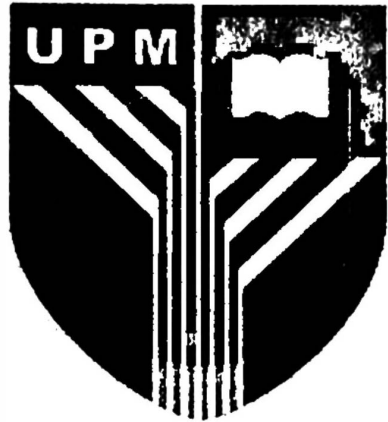
Figure 7.7: Doing the test by Ultrasonic – Pulse Velocity (UPV) device (indirect).



Figure 7.8: Doing the horizontal method (direct method) of Ultrasonic – Pulse Velocity (UPV)



Figure 7.9: The Ultrasonic Pulse Velocity (UPV) device.



FEM 6002

INTERPRETATION OF RESEARCH DATA

Assignment Submission

- 1. Article Review**
- 2. One-way ANOVA**
- 3. Multiple Linear Regression**
- 4. Binary Logistic Regression**
- 5. Final Report on One-way ANOVA**
- 6. Final Report on Multiple Linear Regression**

HAMIZAM B. ABDULLA ZABIDI | GS47042 | 19 JUNE 2017

Dr. Husniyah Abdul Rahim @ Abdul Wahab

FEM 6002