APPLICATION OF THE NON-DESTRUCTIVE TEST FOR RC ELEVATED WATER TANK EVALUATION

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Thesis submitted in fulfillment of the requirements
for the award of
Diploma in Civil Engineering

Faculty of Civil Engineering Technology

UNIVERSITI MALAYSIA PAHANG

FEBRUARY 2023

ACKNOWLEDGEMENTS

Alhamdulillah, thanks to Allah S.W.T, finally I have completed my final year project report successfully. I would like to express my deepest gratitude to my supervisor Ts. Dr. Mohd Faizal Bin Md Jaafar for encouragement, guidance, critics, advice, and motivation. His guidance and advice carried me through all the stages of the writing of this thesis. I could not have imagined having a better advisor and mentor for my study. I would also like to thank my committee members for letting my defense be an enjoyable moment, and for your brilliant comments and suggestions, thanks to you. Besides that, without my supervisor's support and interest, this final year project report would not have been the same as presented here.

I would also like to thank my parents for their support and care throughout my college education. Their support has been invaluable and the reason I have succeeded to be where I am today as a person and a student. I finally would like to thank my friends. Thanks everyone.

ABSTRAK

Penilaian kualiti konkrit adalah penting untuk mengenal pasti di mana konkrit perlu dilakukan penyelenggaraan. Ujian tidak merosakkan (NDT) telah digunakan dengan lebih kerap untuk menilai dan menilai keadaan bangunan. Penilaian ini merangkumi pelbagai aktiviti, termasuk pemeriksaan visual yang mudah. Pada peringkat penyelenggaraan, bangunan lebih kerap dipantau. Usaha khas telah dilakukan pada aplikasi pelengkap pelbagai teknik NDT ke dalam sistem pemantauan kesihatan berstruktur (SHM) bersepadu. Kajian ini bertujuan untuk mengaplikasikan ujian halaju nadi ultrasonik (UPV) dan ujian tukul pantulan. Objektif utama kajian adalah untuk menilai keadaan tangki air bertingkat konkrit bertetulang (RC) di Universiti Malaysia Pahang Kampus Paya Besar, Gambang. Dua (2) bahagian struktur pada tangki air bertingkat RC telah diuji iaitu rasuk dan tiang. Untuk penilaian tukul lantunan, didapati semua bahagian struktur adalah lapisan keras yang sangat baik. Kekuatan mampatan yang diramalkan pada bahagian struktur juga mencatatkan kekuatan yang mencukupi. Dari segi bacaan UPV, keputusan menunjukkan bahawa semua bahagian struktur yang diuji adalah berkualiti. Oleh itu, didedahkan bahawa NDT adalah kaedah yang berpotensi untuk meramal tahap kerosakan dan pemulihan bangunan.

ABSTRACT

The evaluation of concrete quality is important to identify where the concrete need to do maintained. Non-destructive testing (NDT) has been used more frequently to evaluate and assess the condition of buildings. This evaluation includes a wide range of activities, including a simple visual inspection. At the maintenance stage, buildings are more often monitored. Special efforts have been placed on the complementary application of various NDT techniques into an integrated structural health monitoring (SHM) system. This study aims to apply the ultrasonic pulse velocity (UPV) and rebound hammer test. The main objective of the study is to evaluate the condition of the reinforced concrete (RC) elevated water tanks at Universiti Malaysia Pahang Kampus Paya Besar, Gambang. Two (2) structural parts on the RC elevated water tanks were tested which are beams and columns. For the rebound hammer assessment, it was found that all the structural parts were a very good hard layer. The predicted compressive strength on the structural parts also recorded sufficient strength. In terms of UPV readings, the results show that all of the tested structural parts were of good quality. Therefore, it was revealed that NDT is a potential method to predict the level of damage and building rehabilitation.

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LIST OF ABBREVIATIONS

B1	Beam 1
B2	Beam 2
C1	Column 1
C2	Column 2
KSU	Kompleks Sukan Universiti
NDE	Non-Destructive Evaluation
NDI	Non-Destructive Inspection
NDT	Non-Destructive Test
RH	Rebound Hammer
UPV	Ultra-pulse Velocity
UT	Ultrasonic Testing
RC	Reinforcement Concrete
SDG	Sustainable Development Goals
SHM	Structural Health Monitoring

LIST OF SYMBOLS

km/s	Kilometer per second
mm	Milimeter
mm^2	Milimeter square
$<$	Less than
$>$	Greater than
%	Percentage

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CHAPTER 1

INTRODUCTION

1.1 Background of Study

A water tower is an elevated structure supporting a water tank. They are built tall enough so that they can supply water without using power, water pressure is produced by the elevation of the water above ground and gravity. Elevated tanks are very important structures and consist of various types. Damage to these structures will increase the cost of maintenance and may lead to hazardous events. However, their dynamic behaviour differs greatly in comparison with other structures. The appearance of cracks was the most visible indicator of a concrete or steel structure's initial failure. Observation of the crack surfaces revealed that the separation was tangential and radial, as expected.

The overhead tanks (elevated tanks) are usually elevated from the rooftop through the column. On the other hand, the underground tanks are rested on the foundation. RC elevated water tanks are often categorised according to its volume, construction materials, and support conditions. Tall reinforcement concrete elevated water tank construction on frame staging is becoming a frequent building type and design should be based on sufficient resistance to cracking to avoid leakage and adequate strength (Bovo et al., 2020).

The safest and most durable structures are usually structures that are well-managed. Measurement and monitoring often have essential roles in management activities, (Diaferio & Varona, 2022). For this case, non-destructive test methods are selected and used in this study to evaluate the strength and quality of the reinforced concrete (RC) elevated water tank at Universiti Malaysia Pahang Kampus Paya Besar, Gambang. The goal is to assess the structure and whether it poses a risk to the community and environment or is still safe.

1.2 Problem Statement

The elevated water tank must always be in good condition and must be maintained because this structure always supports the load from the water. failure of support from the structure can cause bad things to happen. it can also cause many other harms. Effect of the climate change in Malaysia, which is hot and humid throughout the year, may affect the health and quality of concrete for existing structures that are always exposed to this thing.

However, maintenance and its impact are crucial for concrete structures in aggressive environments, where deterioration plays a major role over the term of their service life to keep the structure in a state that allows it to be used safely and increase the life cycle of the concrete. These activities can be preventive when related to the design of infrastructures preventing the possibility of damage or corrective, with a repair approach (Navarro et al., 2019).

To perform maintenance, the condition of the concrete must be assessed first to ensure that the maintenance method can be carried out. However, various ways to assess the quality of concrete exist today. Since this structure is still functioning and in use, tests that might cause irreversible damage to the building, such as compressive strength tests and flexural strength tests, are not permitted. The evaluation must not damage the existing condition of the structure because it can affect the strength of the structure and increase the cost of maintenance.

Therefore, the solution to all this is non-destructive tests. The type of tests conducted in this study is the rebound hammer test and ultrasonic velocity pulse (UPV) test. These tests can be easily done as little preparation Is required as the equipment required is little and can be easily carried around. Plus, these tests do not destroy the structure or leave any permanent damage on the structure. Little to no waste is produced from these tests and it’s also very cost-effective compared to destructive tests (Navarro et al., 2019).

1.3 Objectives of Study

In this present study, the objective of study is outlined as follows:

i) To evaluate the condition of the beams and columns on the RC elevated water tank structure by using ultras-pulse velocity (UPV).

ii) To estimate the strength of the beams and columns on the RC elevated water tank structure by using a rebound hammer.

1.4 Scope of Study

In this study, the tests were carried out at Universiti Malaysia Pahang Kampus Paya Besar on an elevated water tank which is still in operation to determine the status of concrete reinforcement. There are only two types of non-destructive tests allowed which are the rebound hammer test and the ultra-pulse velocity (UPV) test. Both tests were referred to BS 1881: Part 202: 1986 and BS 1881: Part 203: 1986, respectively.

For this case study, two columns and beams from the structure (elevated water tank) were tested. The area of testing is 300 mm^2 in size with grid sizes being 50 mm for determining the compressive strength of the concrete structure by using the rebound hammer test and evaluating the condition by ultra-pulse velocity test.

All the data recorded from the testing were analysed based on British Standards. The result from the rebound hammer and ultra-pulse velocity tests were compared in other to identify the status of that concrete structure.

1.5 Significance of Study

Non-destructive testing (NDT) is a testing and analysis technique used by industry to evaluate the properties of a material, component, structure, or system for characteristic differences. NDT is the testing or examination of a material without compromising its potential for future use. Finding any structural degradation or failure that might lead to damage is the important goal of the investigation. Therefore, NDT techniques are very helpful in determining the conditions of any structure. The development of non-destructive ways to assess the status of buildings to carry out efficient repair operations. This method gives rapid results needed to focus on the rehabilitation and refurbishment of structures. The significance of this research lies in its recommendation of the optimum approach for structural assessment, among other things. It is important to understand non-destructive testing and be able to use it in a career as a civil engineer. This is because of all the purposes for which it is used.

From the requirements of SDG Goal 11 point of view, the application of NDT on structural health monitoring (SHM) is very important since it can monitor the structural response to detecting damage in an early stage. Among the SHM method, ultrasonic pulse velocity (UPV) and rebound hammer have been widely adopted recently to evaluate the structural safety in real-time as well as the health condition of structures.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Non-destructive testing (NDT) has been practised for many decades, with initial rapid developments in instrumentation spurred by technological advances. During the earlier days, the primary purpose was the detection of defects. As a part of safe design, it was intended that a structure should not develop macroscopic defects during its life, with the detection of such defects being a cause for the removal of the component from service.

2.2 Definition Non-Destructive Tests

The term 'NDT' covers a wide range of analytical techniques to inspect, test or evaluate the physical properties of a material, component, or structure without causing damage. The purpose of NDT is to determine the quality and integrity of materials, components, or assemblies without affecting the ability to perform their intended functions. Early established NDT techniques include pull-out test, penetration test, rebound hammer, and radioactive methods, which were initially developed for industry. Among these, ultrasonic pulse velocity (UPV) is also an effective inspection technique for structures (Wang et al., 2020).

It is difficult to select appropriate NDT techniques for a specific purpose because it depends on the type of component is testing and what exactly looking for. However, BS 1881: Part 202: 1986 and BS 1881: Part 203: 1986 serve as a practical guide in using NDT methods which rebound hammer and ultra-pulse velocity on materials and structures. Novel in-site testing methods have been developed to enable the evaluation of concrete during the building, commissioning, and servicing lifecycle stages of a structure to prevent the issues caused by structural deterioration (Navarro et al., 2019).

Non-destructive testing of materials in civil engineering is mainly concerned with the detection of flaws and defects in concrete elements and structures. In construction, modern diagnostic methods are applied to building structural members and structures. Many investigative methods are used for this purpose. Depending on the degree of their invasiveness. Non-destructive methods are mainly used to test strength and investigate its changes over time. Usually, samples taken from the structure, and sometimes whole members or structures, are tested in this way.

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2.3 Non-Destructive Test Methods

Non-destructive tests of concrete are a method to obtain the compressive strength and other properties of concrete from the existing structures. This test provides immediate results and the actual strength and properties of the concrete structure. Many methods of non-destructive testing can use for the evaluation of reinforced concrete and every method has limitations.

2.3.1 Rebound Hammer Test

The rebound hammer, known as the Rebound or Impact Hammer test is considered a non-destructive method, widely used for assessing rock quality materials considering surface rebound hardness that is related to the compressive strength. This test is fast, cheap and an important guide test for material description. The rebound hammer includes a spring-loaded piston with steel mass shown in Figure 2.1 as explained in BS1881 Part

202, 1986. The rebound hammer as a hardness test works in a way that the rebound of an elastic material is related to its surface hardness against the hitting material.

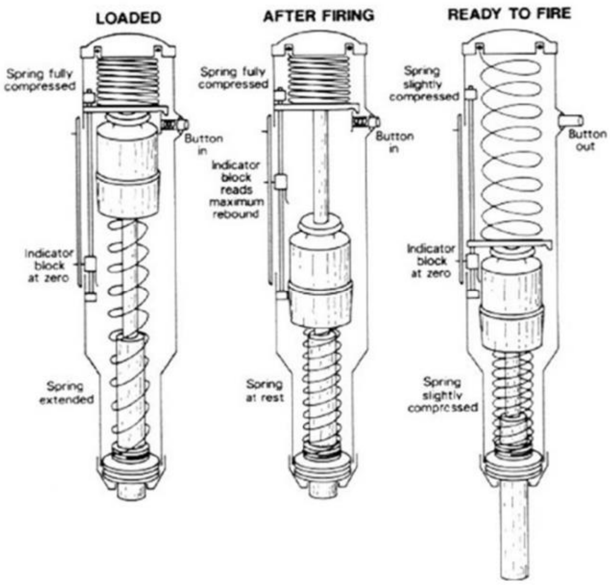

Figure 2.1 Schematic diagram of the rebound hammer

Source: Scientific Research and Essays (2019)

Based on the standard, The hammer is forced against the surface of the concrete by the spring and the distance of the rebound is measured on a scale. The test thus can be conducted horizontally on a vertical surface and vertically upwards or downwards on horizontal surfaces as shown in Figure 2.2. If the rebound hammer is held at an intermediate angle, the rebound number will be different for the same concrete. The impact energy required for the rebound hammer is different for different applications.

However, the results of the test on concrete are affected by various factors such as the smoothness of the surface, geometric properties of the test specimen, and age of the test specimen (Maitham Alwash et al., 2015). The concrete surface should be carefully selected and prepared to be used by polishing so that the test surface is then ground smooth. A fixed power then applies by pushing the hammer against the surface. The slope angle of the hammer also affects the result. The concrete surface should be carefully selected and prepared to be used by polishing so that the test surface is then ground smooth. A fixed power then applies by pushing the hammer against the surface. The slope angle of the hammer also affects the result.

Figure 2.2	Rebound hammer direction

Source: FPrimeC.Solutions (2019)

2.3.2 Ultrasonic Pulse Velocity Test

The ultra-pulse velocity (UPV) in the non-destructive assessment of concrete quality has been extensively investigated for decades. It is more likely to assess the quality and characteristics of at-site concrete and composed of measuring the transit time of an ultrasonic pulse velocity through the concrete. When ultrasonic pulse travelling through concrete meets a concrete-air interface, there is a negligible transmission of energy across this interface so that any air-filled crack or void lying directly between the transducers will obstruct the direct beam of ultrasonic when the void has a projected area larger than the area of transducer faces. The first pulse to arrive at the receiving transducer will have been directed around the periphery of the defect.

The velocity of the signals passing through concrete depends on density and elasticity. According to the theory of sound propagation in solids, the sound transmission velocity is depending on the density and the elastic modulus of the concrete, and it is independent of the excitation frequency that causes the agitation. Typically, the ultrasonic testing (UT) inspection system consists of an ultrasonic transducer, pulse/receiver, and display unit. A pulser/receiver is an electronic device shown in Figure 2.3 that can produce high-voltage electrical pulses to the transducer.

Figure 2.3 Proceq's PUNDIT
Source: Pundit Lab. Ultrasonic Pulse Velocity Tester (2020)

When driven by the pulse, the transducer generates high-frequency ultrasonic sound energy into the material in the form of sound waves. When there are discontinuities such as inclusions, porosity, cracks, etc. In the sound path, part of the mechanical energy will be reflected from the discontinuities surface. Figure 2.4 illustrate how UPV work during the testing.

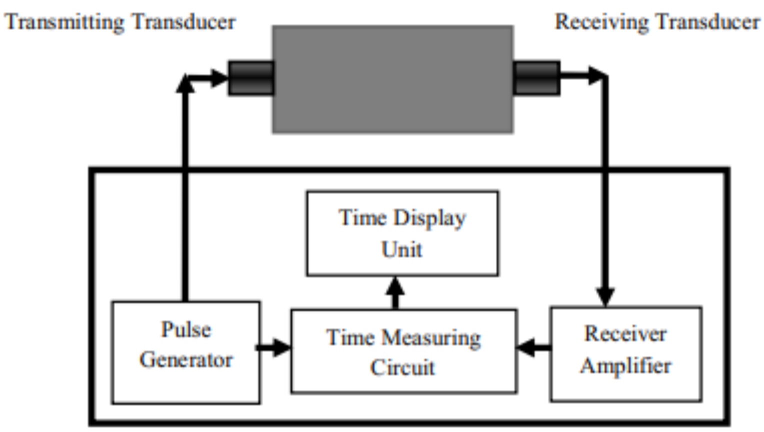

Figure 2.4 Schematic diagram of UPV apparatus
Source: Agunwamba et al (2012)

The reflected sound wave signal is received by the transducer. After that, it's transformed back into an electrical signal and its intensity is shown on the display unit. The sound waves travel time can be directly related to the distance that the signal has travelled. From the signal, information about reflector location, size, orientation, and other features can be determined. Concrete quality can be defined by the reading of UPV. Table 2.1 illustrate the concrete quality classification based on pulse velocity.

Table 2.1 Concrete quality classification based on pulse velocity

Pulse Velocity	Concrete Quality
>4.0 km/s	Very good to excellent
3.5 – 4.0 km/s	Good to very good, slight porosity may exist
3.0 – 3.5 km/s	Satisfactory but loss of integrity is suspected
< 3.0 km/s	Poor and loss of integrity exist

Source: BS 1881: Part 202 (1986)

The quality of concrete in terms of uniformity, incidence or absence of internal flaws, cracks, segregation, etc, indicative of the level of workmanship employed, can thus be assessed using Table 2.1 earlier, which has been evolved for characterizing the quality of concrete in structures in terms of the ultrasonic pulse velocity.

2.4 Advantages of Non-destructive test

The distinct advantage of NDT is the reusability of the tested components. On top of that, non-destructive testing can often be employed on components that are still in operation. Devices and testing equipment used to conduct most methods of NDT are compact and portable. This makes it easier to test components that still function and working.

2.4.1 Advantages of Rebound Hammer

The Schmidt hammer offers a low-cost, straightforward, and rapid way to determine the strength of concrete. The advantages of rebound hammer tests are:

- Apparatus is easy to use.
- Determines uniformity properties of the surface.
- The equipment used is inexpensive.
- Used for the rehabilitation of old monuments.

2.4.2 Advantages of Ultra-pulse velocity

Advantages: -

- Concrete testing equipment that uses ultrasonic pulses provides faster and more accurate results.
- The test can be conducted without causing any destruction or damages to the concrete element.
- Using an ultrasonic pulse velocity test may help save money and time at the same time.
- Ultrasonic pulses also provide a reliable measure of the changes in concrete.
- Access to only one side of the component is needed.

2.5 Factors That Affect and Result

The usage of various aggregates will change the compressive strength of concrete. Using typical aggregates like gravel and crushed aggregates, regular correlations in the data are achieved. It will take specific calibration to put lightweight aggregates through the test. When compared to regular Portland cement, concrete constructed with high alumina cement should have greater compressive strength. Concrete's compressive strength is reduced by 50% when super sulphated cement is used in place of OPC (Gopal Mishra, 2018).

As time passes, the relation between the strength and hardness of concrete will change. The curing conditions of concrete and their moisture exposure conditions also affects this relationship. Concrete with an age between 3 days to 90 days is exempted from the effect of age. For greater aged concrete special calibrated curves is necessary. Temperature variations have considerably affected the rebound index and the compressive strength of concretes as well. The temperature rise resulted in increased surface hardness of specimens resulting in an ambiguous rebound index.

Concrete's compressive strength and average rebound index are time-dependent material characteristics. A single function cannot explain it directly. As a result, the connection requires numerous functions, with cement type, curing environment, compaction technique, and temperature change acting as independent variables.

CHAPTER 3

METHODOLOGY

3.1 Introduction

In this chapter, the actions taken throughout this study from the beginning to the end to accomplish the study's goal and objectives are included in the methodology study. The phases included in this study's approach planning were literature review and critical analysis, site appraisal and data collection, data analysis, and conclusion. The flow process of the study is shown in flow chart and presented in Figure 3.1.

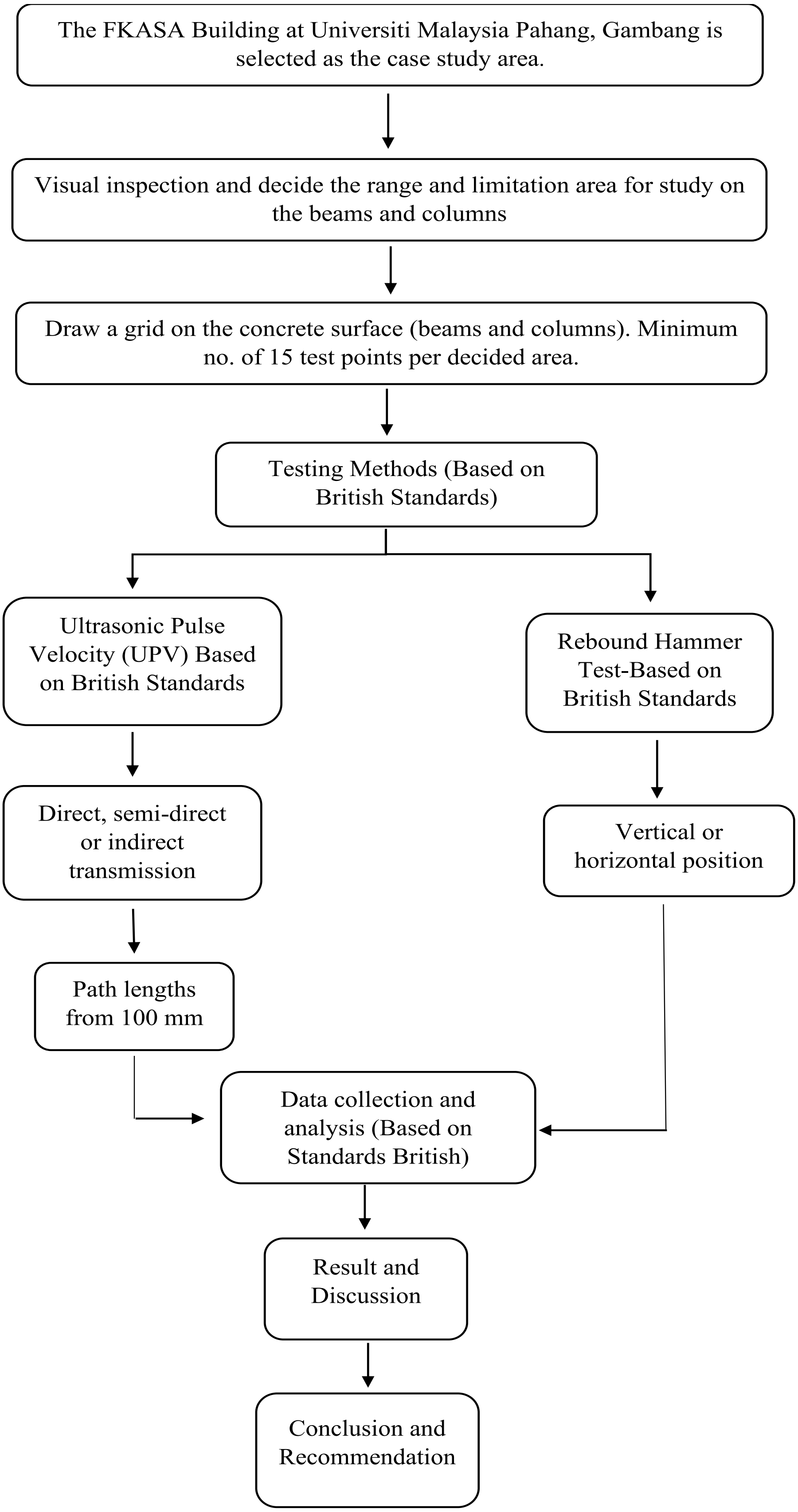

Figure 3.1 Flow chart of the methodology

3.2 Selection of the Area of Study

RC Elevated water tank (near KSU) at Universiti Malaysia Pahang Kampus Paya Besar, Gambang (Figure 3.2) was chosen because this structure continually supports the weight of the water on top. Elevated water tanks must always be in excellent condition and maintained because extreme weather exposure over an extended length of time will have an impact on both the quality and strength of the concrete.

Figure 3.2 Location of RC elevated water tank

3.3 Visual Inspection

A civil infrastructure visual inspection was carried out in the area in Figure 3.3 to identify which elements should be chosen for monitoring the concrete condition. Two columns and two beams were illustrated in Figure 3.4 and Figure 3.5 were selected, these two elements play very important roles in this structure system. This is because, it continually supports the load from the water tank directly to the foundation. The element chosen is located at the corner of the structure and another one in the middle of the structure for both the columns and beams.

Figure 3.3 RC elevated water tank structure

ELEMENT	Column 1 (C1)	Column 2 (C2)
PICTURE		

Figure 3.4 Selected columns for testing

ELEMENT	Beam 1 (B1)	Beam 2 (B2)
PICTURE		

Figure 3.5 Selected beams for testing

3.4 Method Approach

Non-destructive testing (NDT) is a wide group of analysis techniques used to evaluate the properties of a material, component, or system without causing damage. Non-destructive testing plays an important role in assuring that structural and mechanical components perform their function in a safe, reliable, and cost-effective manner, (Hong et al., 2020). NDT technicians perform the necessary tests to locate the indicators and discontinuities that may cause failures or shutdowns in such structure systems.

These tests are performed in a manner that does not affect the future usefulness of the object or material. NDT allows for careful and thorough materials evaluation without the need for deconstruction or damage. NDT is typically used at various points in a part's life cycle. NDT can be used prior to the use of a component for the sake of quality control. NDT is also employed while components are in use to detect service-related conditions caused by wear, fatigue, corrosion, stress, or other factors which affect reliability (Omer & Jaf, 2019).

In this study, the non-destructive which is rebound hammer and ultra-pulse velocity is used because it is a very simple method of testing, but it requires skilled and experienced persons having some special knowledge to interpret and analyse test results.

3.5 Testing Procedures

The test for this study must follow the guidelines to achieve accurate results during the test. This is very important because the results obtained from the test will determine the concrete situation. A slight error may result that does not reflect the true condition of the structure and only waste time and effort.

3.5.1 Ultrasonic Pulse Velocity (UPV) Test

For the UPV test, the length of the path for each column and beam has been measured first to divide by the travel time of pulses which gives the average velocity of wave propagation. Figure 3.6 illustrate the equipment for ultra-pulse velocity test.

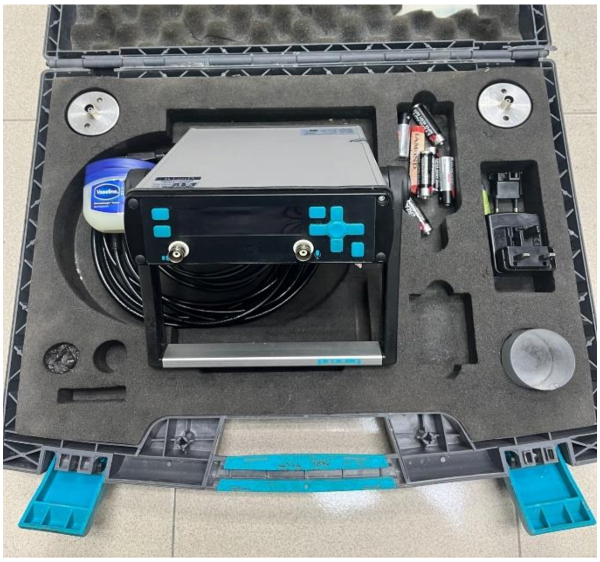

Figure 3.6 Ultra-pulse velocity equipment

The surface of the concrete and transducer will be smeared with grease to get the reading because the transducer was very sensitive due to the rough surface that possible to give Inaccurate reading. Figure 3.7 illustrates the direct method for ultra-pulse velocity.

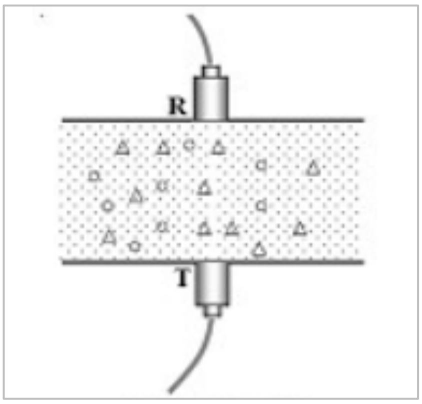

Figure 3.7 Direct method for UPV test
Source: PT Hesa Laras Cemerlang (2023)

The direct method is used for this test because the maximum pulse energy is received at the receiving head, and there are five (5) readings that were taken for each element. The reading was taken at the top, mid-height, and bottom of the columns, while in the beams, the readings were taken on the right side, left side, and mid-span. The data analysis was done based on BS 1881: Part 203: 1986. Figure 3.8 illustrate the direct method was used for column testing at mid-height.

Figure 3.8 Direct method on mid-height of the column

3.5.2 Rebound Hammer Test

The rebound hammer test was carried out for this study in accordance with BS1881: Part 202: 1986. Figure 3.9 below shows the rebound hammer and grindstone that use for this study.

Figure 3.9 Rebound hammer and grindstone

Concrete of columns and beam to be tested were carefully selected, the concrete surface was prepared and smoothened by grindstone. Then, a 500 mm by 500 mm grid are drawn on a sheet of paper as shown in Figure 3.10. The grids will serve as testing grounds for the experiments. The preparation of the grid sheets will precede the testing of the beams and columns for the rebound hammer test. The rebound hammer was positioned against the test surface and the rebound hammer was pushed against the surface at a moderate speed with a fixed amount of energy applied until an impact is triggered.

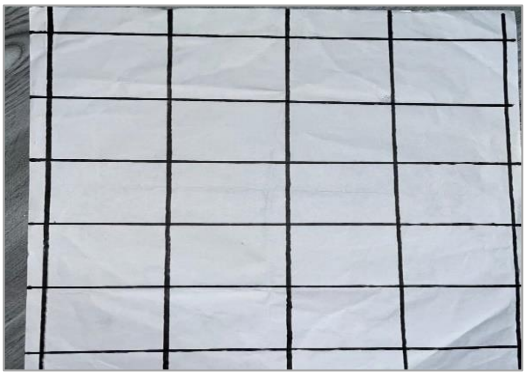

Figure 3.10 Grid size 500 mm x 500 mm on sheet paper for rebound hammer testing

For this test, the direction that has been used is dependent of the location of element. Figure 3.11 illustrate the horizontal direction on column for testing. On other hand, Figure 3.12 shown the horizontal position of rebound hammer on beam during testing. The rebound values after impact were recorded taking at least 36 readings from each part which is three (3) parts for the whole elements which means 432 readings were recorded for two beams and two columns.

Figure 3.11 Rebound hammer testing (horizontal) on the column

Figure 3.12 Rebound hammer testing (horizontal) on the beam

For accuracy of the rebound value, its lowest and highest values were deducted before calculating the Average Rebound Value to determine the actual rebound value for each of the element were choose.

3.6 Analysis of Results

In this section, after a test has been completed data analysis comes next. This is a crucial step since it will demonstrate if the goal has been accomplished or not. Data analysis is important because it allows to distinguish between the data gains from each element's test by conducting the rebound hammer test and the ultra-pulse velocity test. The accuracy and superiority of the two methods which Rebound Hammer and UPV for evaluating structures or buildings may also be determined from the data analysis.

Figure 3.13 show the graph compressive strength for rebound hammer test. A rebound hammer test graph is prepared after obtaining the correlation between compressive strength and rebound number (rebound index), the strength of the structure can be assessed.

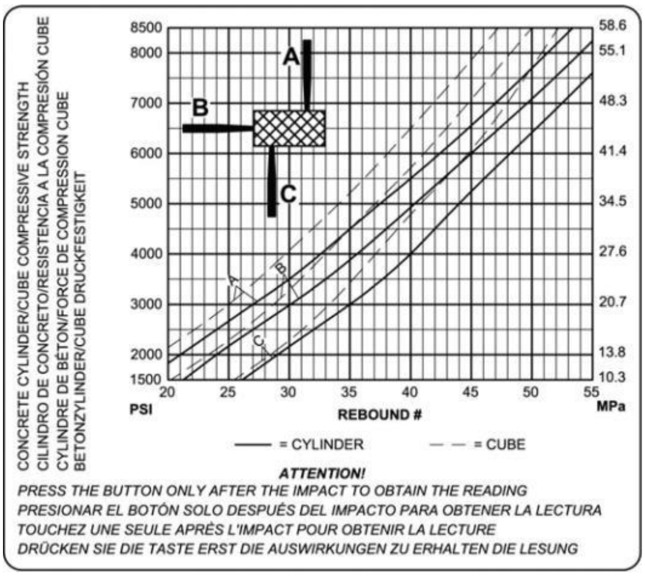

Figure 3.13 Graph compressive strength for rebound hammer test

Source: epc (2020)

The correlation between rebound index (rebound number) & compressive strength can be found by tests on core samples obtained from the concrete structure or standard specimens made with the same concrete ingredients and mix proportion. In general, the rebound number increases as the strength increases and is also affected by several parameters such types of cement, types of aggregate, surface condition of the concrete, moisture content of the concrete, etc. Table 3.1 shows the quality concrete for rebound hammer test based on BS1881: Part 202: 1986.

Table 3.1 Quality of concrete surface for average rebound number

Average rebound number	Quality of concrete surface
>40	Very good hard layer
30 – 40	Good layer
20 – 30	Fair
<20	Poor concrete
0	Delaminated

Source: BS 1881: Part 202 (1986)

For ultra-pulse velocity, the data get was compute into the average for all reading. The quality of concrete in terms of uniformity, incidence or absence of internal flaws, cracks, and segregation, etc, indicative of the level of workmanship employed, can thus be assessed using the guidelines given in Table 2.1 section Ultrasonic Pulse Velocity Test , which have been evolved for characterizing the quality of concrete in structures in terms of the ultrasonic pulse velocity.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

In the present chapter, the assessment of the in situ compressive strengths and quality of the concrete structural elements of an elevated water tank by using a rebound hammer and ultra-pulse velocity are discussed. The structural elements on the RC elevated water tank structures were tested which is beams and columns. The data that get from the testing was analysed based on BS 1881: Part 202: 1986 for rebound hammer and BS 1881: Part 203: 1986 for ultra-pulse velocity to get the result for the objectives of this study.

4.2 Results on Rebound Hammer

Figure 4.1 demonstrates the results on the average rebound number (index) for the beam on RC elevated water tank. There are three different locations (areas) were tested which are A1, A2 and A3. The result in the figure shows the quality of the concrete surface for the RC elevated water tank. The rebound number for beam 1 (B1) located at A1, A2 and A3 was found to be 48.10, 45.83 and 46.63, respectively. For beam 2 (B2), the rebound number attained for A1 was 46.44, A2 is 47.01 and A3 is 48.85. The quality of concrete for B1 and B2 can be identified as a very good hard layer where the rebound number obtained is greater than 40. The figure also illustrated that the higher value of the rebound number was marked on B2 (A3) followed by B1 (A1).

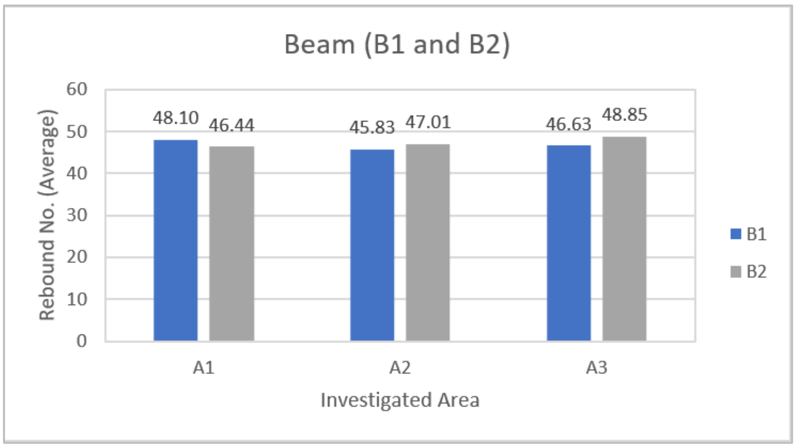

Figure 4.1 Rebound number for beams

The prediction of concrete strength for the RC elevated water tank is presented in Figure 4.2. The graph shows that the compressive strength for B1 and B2 was 51.03 MPa and 49.00 MPa, respectively.

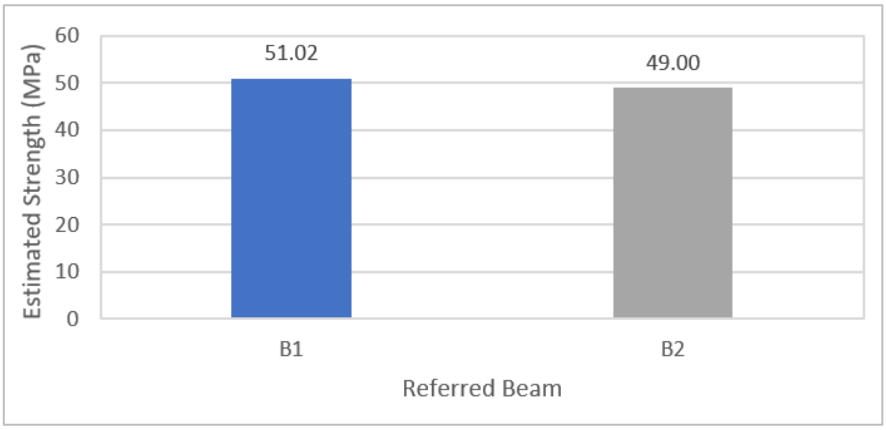

Figure 4.2 Prediction of concrete strength for beams

However, Figure 4.3. below are show the results on the average rebound number (index) for the columns. This element also was tested about three (3) different locations which is A1, A2 and A3. The result in the figure shows the quality of the concrete surface for the RC elevated water tank. The rebound number for column 1 (C1) is 50.89, 52.12

and 40.67 which located at A1, A2 and A3 for each value. For column 2 (C2), the rebound number at A1 was 46.44, A2 is 47.01 and A3 is 48.85. The quality of concrete for both columns are in condition very good hard layer where the rebound number is greater than 40.

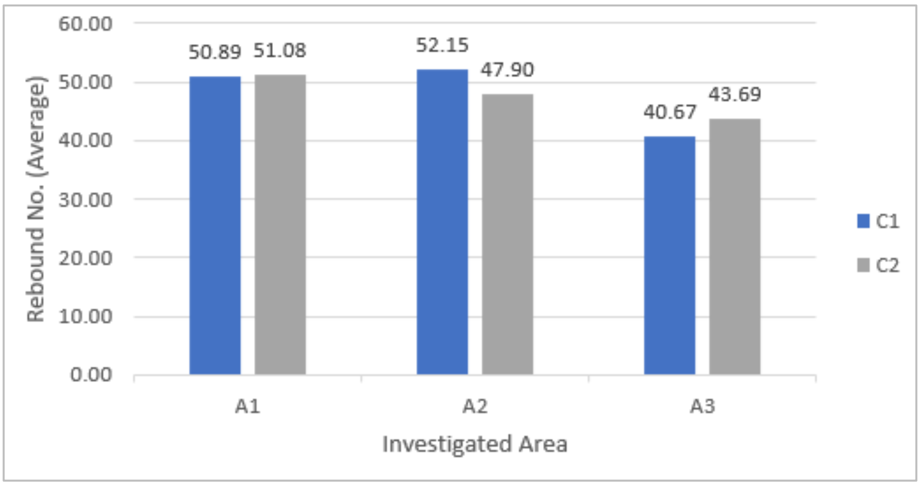

Figure 4.3 Rebound number for beams

Figure 4.4 shows the predicted concrete strength for the RC raised water tank. According to the graph, column 1 (C1) and column 2 (C2) compressive strengths were 51.03 MPa and 49.00 MPa, respectively.

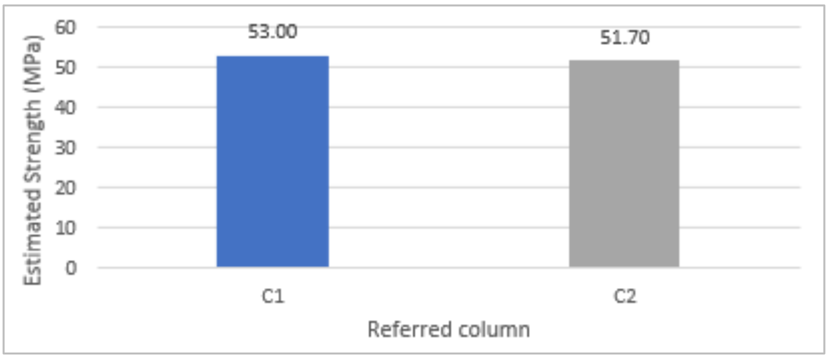

Figure 4.4 Prediction of concrete strength for columns

The rebound hammer method of estimating concrete strength is not very accurate, and the probable accuracy of predicting concrete strength in a structure is 25% (The Contractor, n.d). For concrete work, the target mean strength should be more than 30

MPa. As a result, the outcomes were well over what was necessary to meet the criteria. Additionally, it shown that the anticipated compressive strength for column C1 and beam B1 is greater than column 2 (C2) and beam 2 (B2) respectively.

4.3 Results on Ultra-Pulse Velocity

Ultra-pulse velocity was conducted during the test to evaluate the condition of the beams and columns on the RC Elevated Water Tank structure. As can be seen from Figure 4.5, the results of UPV readings for two (2) different beams. It is discovered that the UPV readings are impacted by the various of lengths between the UPV transducers. The UPV readings significantly improved when the path length increased, when the transducers were positioned widely apart from one another, higher UPV measurements were obtained. The value of UPV reading is directly proportional to the length of path.

The direct path length between both transducers may affect the UPV readings. The minimum UPV reading was found for path length is 200 mm for beam 1 (B1) and beam (B2). The UPV reading for both beams, B1 and B2 only 3.26 km/s and 3.27 km/s, respectively. The maximum UPV reading was recorded in B1, which is 4.53 km/s. Based on BS 1881: Part 203 (1986), the quality of beams B1 and B2 can be indicated as excellent because the UPV readings are marked greater than 4.00 km/s at a path length of 300 mm.

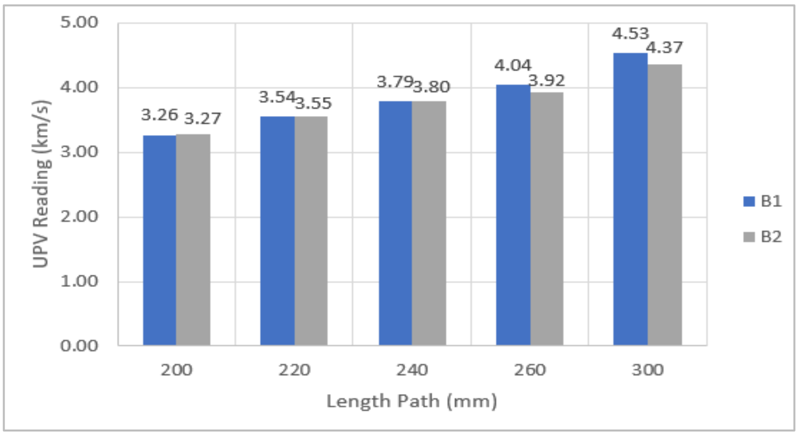

Figure 4.5 Effect of path length on UPV readings for the beams

Figure 4.6 shows the typical UPV measurements for beams placed. While B2's UPV measurement was 3.78 km/s, B1's was discovered to be 3.83 km/s. Both in excellent condition in accordance with BS 1881: Part 203 (1986). UPV measurements for B1 and B2 are between 3.5 and 4 km/s, indicating that the quality of the concrete is high but that the concrete beam may have a small amount of porosity.

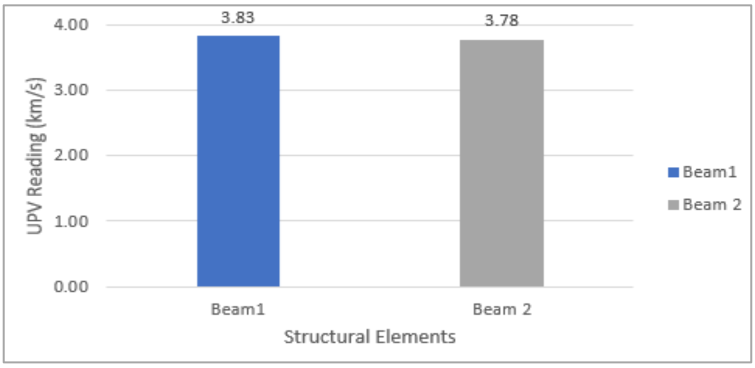

Figure 4.6 Average UPV reading for beams

However, from Figure 4.7 only 3.26 km/s and 3.27 km/s, respectively, were measured by the UPV for both columns, C1 and C2 as shown in graph for 200 mm length of path. The highest UPV value of 3.40 km/s was found at C1 for 300 mm path length.

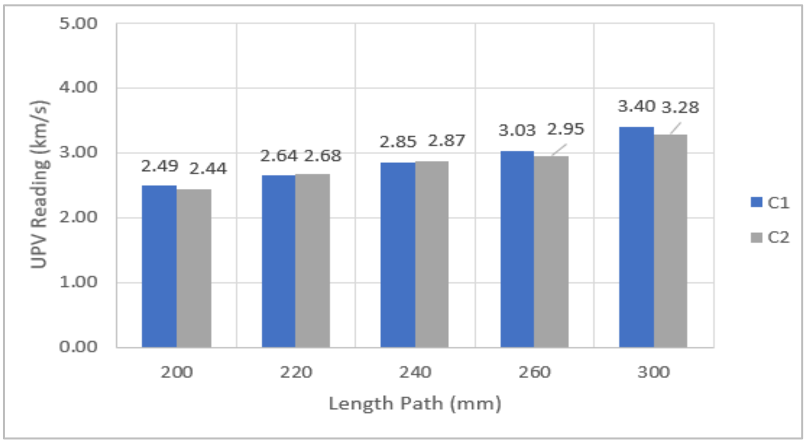

Figure 4.7 Effect of path length on UPV readings for the columns

Figure 4.8 shows the average UPV for both columns. The graph shows UPV measurement for C1 was 2.88 km/s while C2 is 2.85 km/s. Based on the standard as mentioned before, both columns in poor condition because UPV measurements for C1 and C2 are below 3.0 km/s, indicating that the quality of the concrete is poor, and loss of integrity exist.

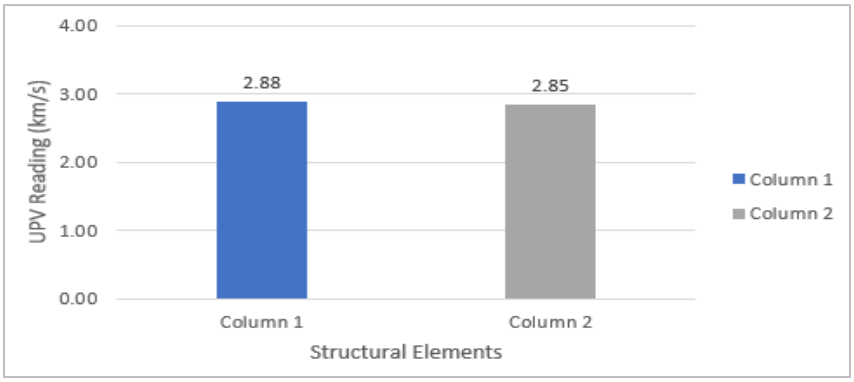

Figure 4.8 Average UPV reading for columns

4.4 Summary of the Results

On the other hand, after the data were analysed for all the elements of the structure, the result for the entire tested elements is shown in Table 4.1. The results indicated the condition of the elevated water tank in Universiti Malaysia Pahang, Kampus Paya Besar Gambang using a non-destructive test (NDT). From the table, it

Table 4.1 Quality of concrete beam and column for both test

Quality of concrete							
Ultra-Pulse Velocity				Rebound Hammer			
Beam 1	Beam 2	Column 1	Column 2	Beam 1	Beam 2	Column 1	Column 2
Good	Good	Poor	Poor	Very Good Hard Layer	Very Good Hard Layer	Very Good Hard Layer	Very Good Hard Layer

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Introduction

The present study presented the results of non-destructive testing (NDT) on the RC elevated water tank located at Universiti Malaysia Pahang Kampus Paya Besar, Gambang. The prediction of compressive strength and quality of the concrete on the RC elevated water tank have been determined using NDT namely rebound hammer test and ultra-pulse velocity (UPV) test.

5.2 Conclusion

Based on the findings obtained from the present study, the following conclusions are derived as follows:

1. It was found that the quality of the concrete surface obtained from rebound numbers for B1, B2, C1 and C2 was a very good hard layer.

2. The predicted compressive strength for the beams and columns obtained from the rebound hammer was sufficient strength in accordance with BS1881: Part 202: 1986. The predicted compressive strength attained for B1, B2, C1 and C2 was found to be 51.02 MPa, 49.00 MPa, 53.00 MPa and 51.70 MPa, respectively.

3. The UPV readings obtained classified the B1, B2, represented good quality for the RC elevated water tank meanwhile for C1 and C2 in poor condition.

There are few things that affect the concrete quality after several year. Been exposed to extreme weather may cause the strength of concrete was decrease. The humidity throughout the year causes the concrete to feel damp allowing the reinforcement to be exposed to corrosion. This shouldn’t happen because reinforcement bar and concrete play a role in supporting the building structure. Failure on one of these components may cause the structure system are shutdown.

5.3 Recommendation

There are several recommendations that can be employed in future. The recommendations are:

1. Ensure the concrete surface should be smooth, clean, and dry before testing is conducted.
2. Ant loose particles should be rubbed off from the concrete surface with a grinding wheel or stone, before hammer testing.
3. For UPV, constant pressure is achieved through good contact between the transducer and the concrete surface, and the use of a thin layer of grease between the transducers.
4. For inaccurate test results, some additional tests need to be done such as destructive tests.

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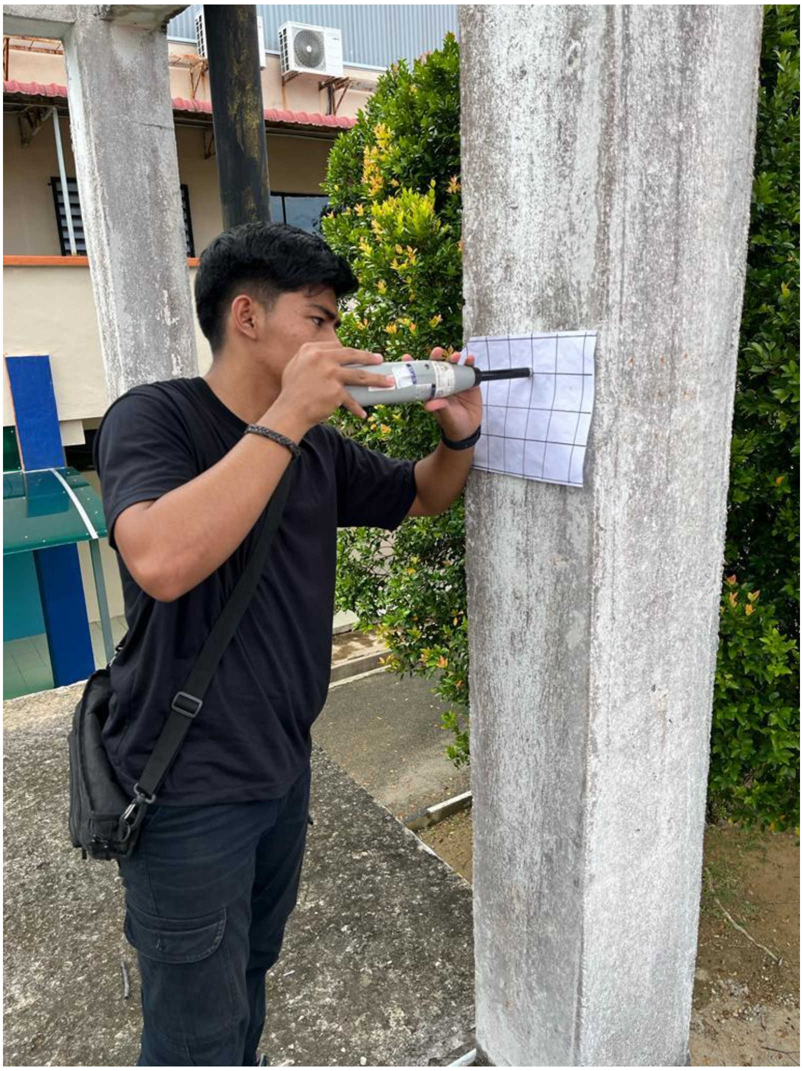
APPENDICES

Appendix A: Ultra-pulse velocity (UPV) test on column at mid-height

Appendix B: Ultra-pulse velocity (UPV) test on column at bottom

Appendix C: Rebound hammer test on column at bottom

Appendix D: Rebound hammer test on column at mid-height



Appendix E: Rebound hammer test on beam