RECENT TREND IN CIVIL ENGINEERING AND BUILT ENVIRONMENT
e-ISSN: 2773-5303

RTCEBE

Vol. 6 No. 1 (2025) 29-38
https://publisher.uthm.edu.my/periodicals/index.php/rtcebe

Assessing the Strength and Quality of Timber Construction in Masjid Kampung Patah Pedang and Masjid Kampung Parit Lapis Bangas Using Non-Destructive Testing

Fathin Najihah Ramali[1], Nor Azizah Adnan[2]*

[1] *Faculty of Civil Engineering and Built Environment, Universiti Tun Hussein Onn Malaysia, Batu Pahat, 86400, MALAYSIA*
[2] *Senior Lecturer, Faculty of Civil Engineering and Built Environment, Universiti Tun Hussein Onn Malaysia, Batu Pahat, 86400, MALAYSIA*

*Corresponding Author: noraziza@uthm.edu.my
DOI: https://doi.org/10.30880/rtcebe.2025.06.01.004

Article Info

Received: 08 January 2024
Accepted: 15 April 2024
Available online: 6 May 2025

Keywords

Mosque, Timber, NDT, UPV, MoE, MoEdyn,

Abstract

In Malaysia, structural failures in constructions pose significant risks to the safety of occupants and incur substantial repair expenses for the community. This research focuses on two historical mosques, Kampung Parit Lapis Bangas and Jamek An Nur Kampung Patah Pedang, built in 1961 and 1950, respectively. These mosques exhibit damages such as cracking, termite infestation, and fungi growth, raising concerns about their structural integrity. This project aims to evaluate the modulus of elasticity (MoE) and assess the strength of timber used in the mentioned mosques through Ultrasonic Pulse Velocity (UPV) testing. Non-Destructive Testing (NDT) is employed in these mosques by utilizing UPV testing to evaluate the quality and strength of timber without compromising its integrity. There are 65 damages structures (column and beam) involved in this testing by using direct method for column and indirect method for roof beam. Minimum MoE values for Chengal and Ponak wood are established as 14,000 MPa and 7,600 MPa, respectively based on Malaysia Standard. The analysis reveals significant differences in MoE values between the mosques due to variations in wood types, damage types, and structure heights. There are three columns in Jamek An Nur Kampung Patah Pedang mosque show weakened conditions because these columns falling below the minimum MoE of 7,600 MPa for Ponak Wood. While, all the structures columns and roof beams in Kampung Parit Lapis Bangas Mosque was in a good condition as these structures have the highest MoE value. This study suggests to carry out treatment on the damaged structure such as injected treatment using epoxy resin and fungus control chemicals to minimize the damage and increase the strength of the wood.

1. Introduction

In Malaysia, several constructions have failed, either they are still under construction or they have been built and occupied. A failure of structure can occur when a load-bearing component of a building is unable to support and transfer loads to another element. This is frequently the result of a combination of factors including excessive loading, poor structural design, and the use of low-quality materials [1]. However, the failure of building design can have an impact on the surrounding community. In general, the breakdown of the structure endangers the safety of the persons who live there. The structural engineers involved in a structure's design should have sufficient experience and a holistic mindset [2]. Wood is a natural organic material that has been used for ages to make buildings, bridges, and other constructions. Timber's enduring popularity in construction can be attributed to a variety of advantages, including fire resistance, structural properties, and insulation [3]. It is easy to work with and comes in different sizes and shapes. According to [4], timber has a high strength-to-weight ratio and is thermally insulating. Steel, concrete, and wood can be combined to create composite materials. It is the only building material that is entirely recyclable and renewable while also having no effect on greenhouse gas emissions [5].

This study was conducted to evaluate the strength of timber construction used in Kampung Parit Lapis Bangas Mosque in Sri Medan and Jamek An Nur Kampung Patah Pedang Mosque located in Batu Pahat, Johor using non-destructive testing. The observations of this study focus only on timber structure (column and beam). This project was using Non-destructive Testing (NDT) techniques to assess the structural strength. The issues in this study are, there was several identifiable damages found in the timber structure in both mosques and this study was conducted to find out whether the damage affects the strength of the timber structure or not. Kampung Parit Lapis Bangas Mosque in Sri Medan and Jamek An Nur Kampung Patah Pedang Mosque were chosen as the study area because there several damages that have been identified in these mosques which is cracking, termites and also fungi. These cause concern to the resident of the village about the safety and stability of the mosque. Most historic buildings in Malaysia often suffer from damage problems, especially for buildings that are hundreds of years old. In the past, timber construction was widely used in the building industry, particularly in many historic buildings. However, the majority of them failed to be maintain, which leads to numerous construction flaws in traditional timber houses [6]. According to [7], many timber structures in Germany and the neighbouring foreign countries collapsed at the beginning of 2006 and the numerous recent failures demonstrate that failures must be explained by a combination of factors. The effect of adverse environmental conditions on building materials, as well as the extent of damage caused, is determined by both the materials used and the environmental conditions. Appropriate maintenance of such buildings necessitates an understanding of timber defects and related issues [8]. In 2015, there has been an incident in Berkeley, California where, the balcony has collapsed and killed six college students caused by rotted wooden beams. According to the investigators, the wood was not caulked and sealed properly at the time of construction and was damaged by moisture as a result. In addition to the six killed, seven were seriously hurt.

Basically, there are two (2) objectives to be achieved in this project which is to evaluate the modulus of elasticity of timber used in Kampung Parit Lapis Bangas Mosque and Jamek An Nur Kampung Patah Pedang Mosque by using Ultrasonic Pulse Velocity and to assess the strength of the timber used in Jamek An Nur Kampung Patah Pedang Mosque and Kampung Parit Lapis Bangas Mosque. This study was conducted to identify any potential issues or areas for improvement in the timber construction of the two mosques to aid in their preservation and maintenance. The observations of this study focus only on timber structure (column and beam) that have been damaged in both mosques. Non-destructive testing was conducted on Kampung Parit Lapis Bangas Mosque and Jamek An Nur Kampung Patah Pedang Mosque. Furthermore, the findings of this study can contribute to the development of better-quality standards and practices for timber construction in the construction industry in Malaysia. The testing that was involved in order to achieve the objective of this project are, Ultrasonic Pulse Velocity testing.

2. Ultrasonic Pulse Velocity (UPV) Test

Ultrasonic Pulse Velocity (UPV) tests was used to evaluate the condition of two-sided structural members such as elevated slabs, beams, and columns. The method can identify and map voids, honeycomb, cracks, delamination and other damage in concrete, wood, masonry, stone, ceramics, and metal materials. Based on [9], the Ultrasonic Pulse Velocity test is used to determine the strength and extent of deterioration in a timber structure. The source of an oscillating piezoelectric core sends waves between the transmitting and receiving transducers. The equipment consists of two transducers, typically in the form of metal cylindrical heads, one of which transmits an ultrasonic pulse and the other of which is a receiver. They are 'coupled' to the concrete or timber surface with the help of a gel or grease. They are linked via cable to a control box that houses a pulse

generator, timing circuit, and digital display. The time it takes for the ultrasonic pulse to travel between the transmitting and receiving transducers is displayed on the digital display.

Ultrasonic Pulse Velocity can be used to assess the quality and homogeneity of timber materials, predict their strength, assess their dynamic modulus of elasticity, estimate the depth of cracks in timber, and detect internal flaws, cracks, honeycombing, and poor patches [10]. One of the most important mechanical properties of wood is its modulus of elasticity (MOE), which measures its stiffness and ability to resist deformation under applied loads. UPV test on timber can determined the MoE by using a formula according to [11].

$$MoEdyn = \rho V^2 10^{-6} \quad (1)$$

$$MoE = 0.899\, MoEdyn \quad (2)$$

Where,
MoE_{dyn} = Dynamic elastic moduli (MPa)
ρ = Specific gravity (kg/m^3)
For Chengal Wood, ρ = 915 kg/m^{-3} [12]
For Ponak Wood, ρ = 560 kg/m^{-3} [13]
V = Ultrasonic wave velocity (m/s)

There are several benefits of Ultrasonic Pulse Velocity Test for timber which are, monitoring changes over time. Timber is a living material and it is constantly affected by moisture, temperature, and time. Next, strength and quality evaluation. The speed of sound waves is directly related to the density and elasticity of the timber. By doing UPV test, a valuable insight into the overall strength and quality of the material can be gain, and also can ensuring its suitability for specific structural applications. Lastly, compared to other more invasive testing methods, UPV is incredibly quick, easy, and cost-effective [14]. It requires minimal preparation and can be conducted on-site, saving time and resources.

3. Methodology

This study was conduct at Jamek An Nur Kampung Patah Pedang Mosque and Kampung Parit Lapis Bangas Mosques are through site visits, observations and perform UPV Test on damaged structure (column and roof beam). Site visit for this study is to obtain the information about the structure of the mosques, to know the history of the mosques and to do planning regarding the test that will be conducted. Fig. 1 shows the interior of both mosques.

(a) **(b)**

Fig. 1 *Interior of Mosques (a) Jamek An Nur Kampung Patah Pedang; (b) Kampung Parit Lapis Bangas*

Table 1 *Sizes of columns in Jamek An Nur Kampung Patah Pedang Mosque*

Sizes (m)	Codes
0.16 X 0.17 X 5.0	C10, C16
0.18 X 0.17 X 5.0	C28, C34, C23, C29, C16, C22, C36
0.21 X 0.25 X 5.0	C11, C17, C35
0.15 X 0.15 X 5.0	C40, C45, C1, C2, C7, C8, C38, C44, C50
0.15 X 0.15 X 7.0	C12, C13, C14, C15, C18, C24, C30, C31, C32, C33, C27, C21, C15.

0.15 X 0.15 X 10.0	C19, C20, C25, C26
0.14 X 0.14 X 5.0	C37, C41, C6, C3, C4, C
0.14 X 0.16 X 5.0	C46, C47, C48
0.15 X 0.14 X 5.0	C42, C43, C49, C5, C39

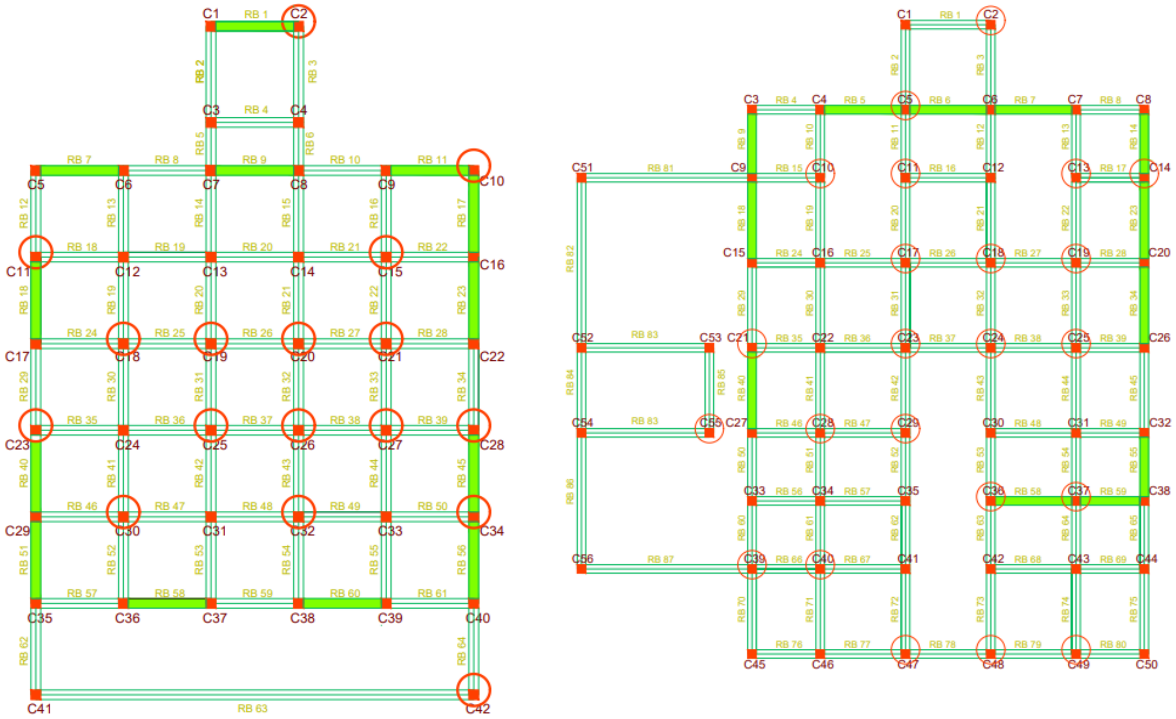
Table 2 *Sizes of columns in Kampung Parit Lapis Bangas Mosque*

Sizes (m)	Codes
0.15 X 0.14 X 3.5	C5, C10
0.14 X 0.14 X 3.5	C16, C22, C28, C29, C30, C13, C19, C25, C31, C6
0.12 X 0.12 X 3.5	C34, C35, C37, C40, C41, C43, C8
0.16 X 0.15 X 3.5	C11, C12
0.19 X 0.19 X 5.4	C17, C18, C23, C24
0.15 X 0.15 X 3.5	C12
0.19 X 0.18 X 3.5	C7
0.12 X 0.13 X 3.5	C36, C46, C9, C15, C21, C27, C33, C39, C14, C20, C26, C32, C38, C44
0.15 X 0.11 X 3.5	C47

The types of timber structures used in Jamek An Nur Kampung Patah Pedang Mosque are Ponak Wood while Kampung Parit Lapis Bangas are using Chengal Wood. Based on Schedule of Timber Species in Accordance with Strength Grouping (S.G) according to [15], Ponak Woods are in SG4 and Chengal Wood are in SG1. For this study, a total of 5 readings were taken for each structure to get the average and there are two methods delivering that been used for UPV Test in both mosques which is Direct Method and Indirect Method. Direct Method is used for column while Indirect Method is used for roof beam. Direct method is the transmitting and receiving transducers are placed directly opposite each other on opposite sides of the test object. While, Indirect Method is placing both the transmitting and receiving transducers on the same surface of the test object. There are about 30 damaged structures which is 17 column and 13 roof beams in Jamek An Nur Kampung Patah Pedang Mosque while in Kampung Parit Lapis Bangas Mosque, there are 23 column and 12 roof beam which involved in UPV test as shown in Fig 2. The total structures that involved in this testing are 65 damaged structures for both mosques.

After the test was carried out, calculations are made to obtain the value of Modulus of Elasticity (MoE) using formulas (1) and (2). Next, the value will be compared with the standard specifications MS 544-2:2017 as shown in Table 3. According to MS 544-2:2017 [16], the minimum MoE for Chengal Wood is 14 000 Mpa, while minimum MoE for Ponak Wood is 7600 Mpa. If the result shows the MoE value exceeds the minimum MoE value, the structures are in good condition while, if the result shows otherwise, the structure is in a weak condition

Recent Trend in Civil Engineering and Built Environment Vol. 6 No. 1 (2025) p. 29-38



(a) **(b)**

Fig. 2 *The location for UPV test (a) Jamek An Nur Kampung Patah Pedang Mosque; (b) Parit Lapis Bangas Mosque. C=Column, RB= Roof Beam*

Table 3 *Strength Group of Timbers based on MS 544-2:2017*

Strength Group	Condition	Minimum MoE
S.G.1	Wet	13 300
	Dry	14 000
S.G.2	Wet	11 700
	Dry	12 600
S.G.3	Wet	9800
	Dry	10 300
S.G.4	Wet	7400
	Dry	7600
S.G.5	Wet	6100
	Dry	6300
S.G.6	Wet	4900
	Dry	5200
S.G.7	Wet	3000
	Dry	3400

4. Types of Damage

There are several damaged that were found on the structures (column and beam) in both mosques. Fig 3. illustrates the structural damaged that found in Jamek An Nur Kampung Patah Pedang Mosque and Fig. 4 shows the structural damaged in Kampung Parit Lapis Bangas Mosque.

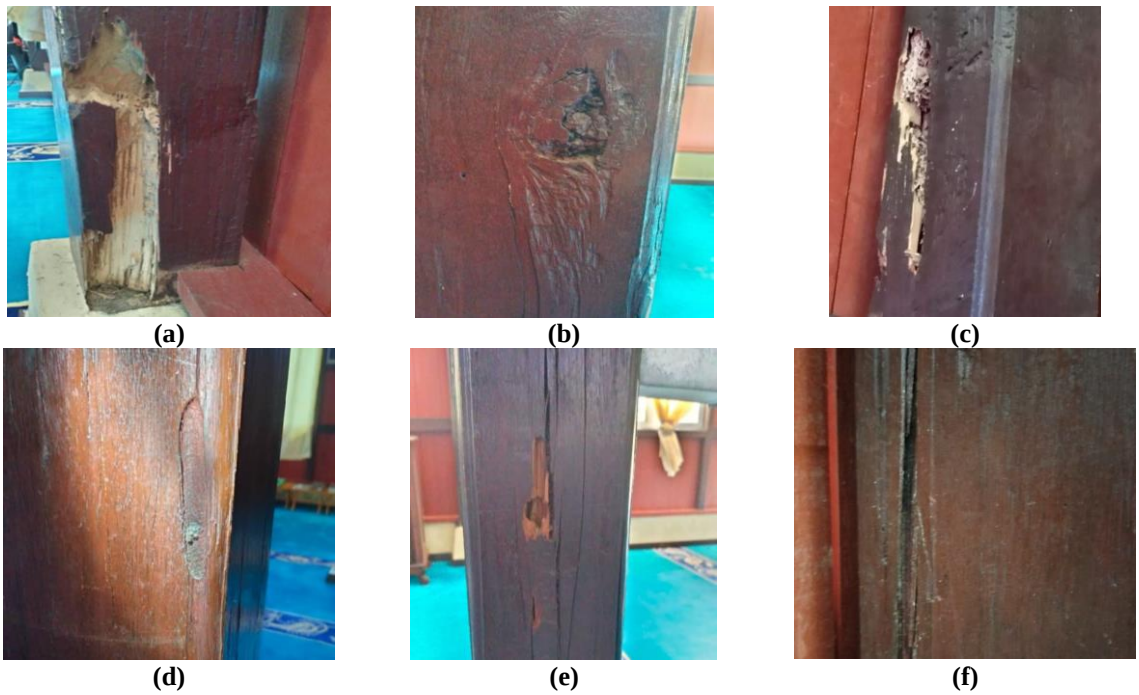


Fig. 3 *Structural Damaged in Jamek An Nur Kampung Patah Pedang Mosque (a) Decay; (b) Knot; (c) Beetles; (d) Termites; (e) Decay + Crack; (f) Crack.*

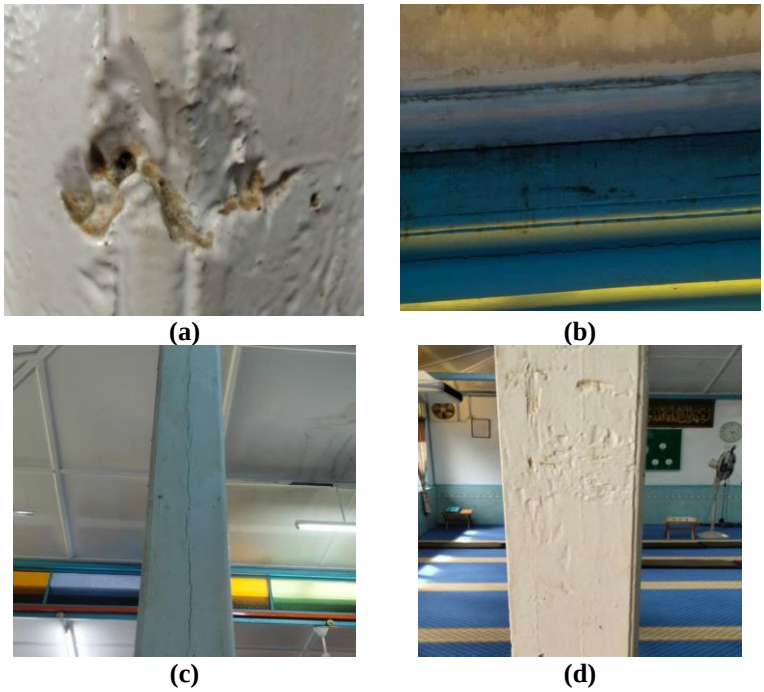


Fig. 4 *Structural Damaged in Kampung Parit Lapis Bangas Mosque (a) Termites; (b) Leakages; (c) Crack; (d) Beetles.*

4.1 Results

Fig 5 and Fig 6 shows the graph for UPV test on column and beam in Jamek An Nur Kampung Patah Pedang Mosque while Fig 7 and Fig 8 indicates graph for UPV test on column and beam in Parit Lapis Bangas Mosque.

Recent Trend in Civil Engineering and Built Environment Vol. 6 No. 1 (2025) p. 29-38

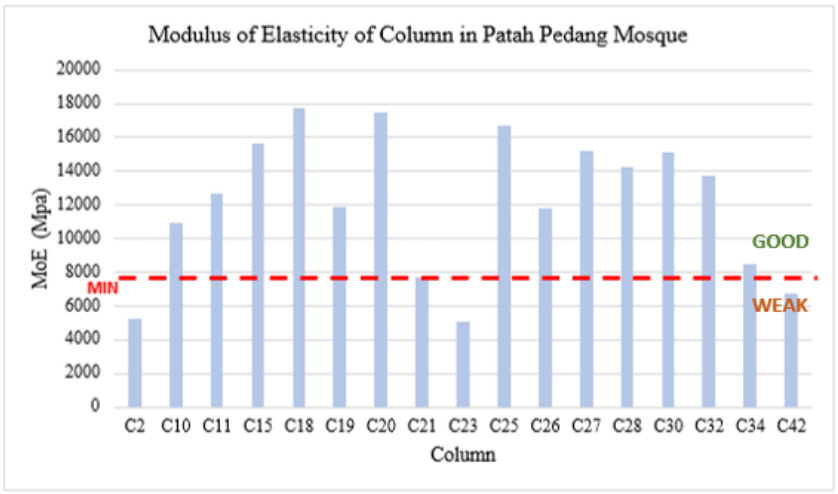


Fig. 5 *Graph for UPV Test on Column in Jamek An Nur Kampung Patah Pedang Mosque.*

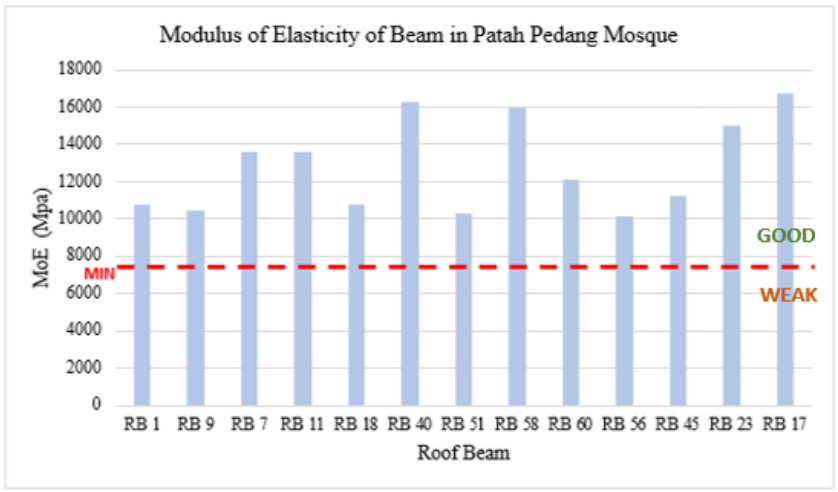


Fig.6 *Graph for UPV Test on Roof Beam in Jamek An Nur Kampung Patah Pedang Mosque.*

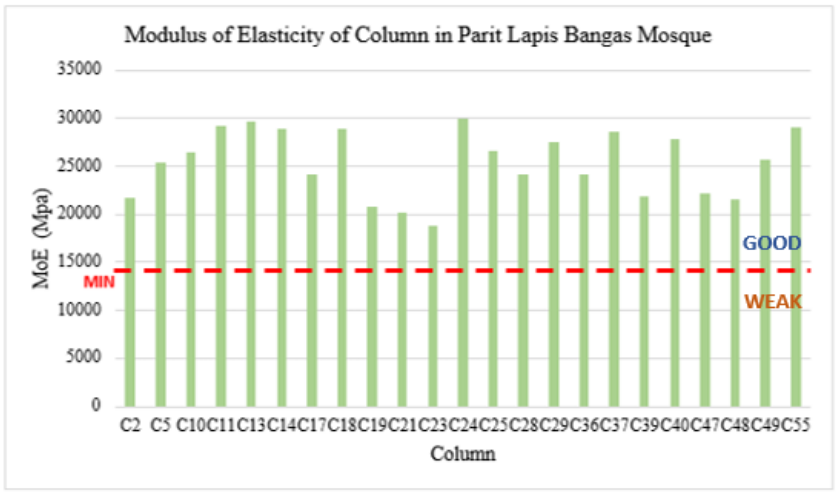


Fig. 7 *Graph for UPV Test on Column in Kampung Parit Lapis Bangas Mosque.*

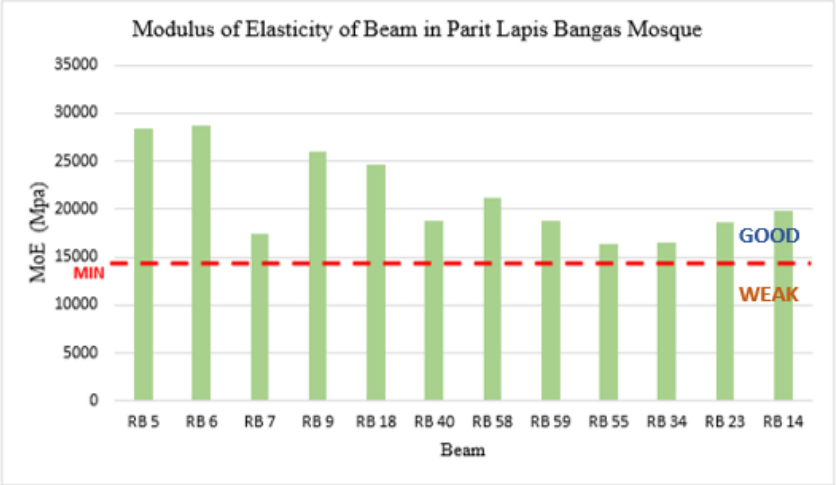


Fig. 8 *Graph for UPV Test on Roof Beam in Kampung Parit Lapis Bangas Mosque.*

4.2 Discussion

For this study, UPV test was carried out on timber column and beam structures which were found a damaged on it. The damage includes decay, check, knots and fungi. The aim of using UPV Test is to get the modulus of elasticity (MoE) of the timber. The higher MoE value, the strong the timber. The result of the analysis that has been made, found that the MoE value for both mosques is different and the difference is very significant. This difference is due to different types of wood, different types of damage and difference height of structures for the beam and column structures in both mosques.

In addition, there are three columns in Jamek An Nur Kampung Patah Pedang Mosque are in a weak condition because these columns does not exceed the minimum MoE value of SG4 which is 7600 Mpa based on Malaysia Standard (MS 544-2:2017)[17] which are C23, C2 and C42 with the lowest MoE reading values recorded are, 5058 Mpa, 5240 Mpa and 6691 Mpa. These columns C23, C2 and C42 have the same damages which is decay. However, all the structures (column and beam) in Kampung Parit Lapis Bangas Mosque are in a good condition as it recorded the higher MoE value and exceeded the minimum MoE for SG1 which is 14 000 Mpa even though there is a damage on each structure but the damage does not affect the strength of the timber for that mosque.

Moreover, the height of the structures also affected the strength of the timber because the height of column in Jamek An Nur Kampung Patah Pedang Mosque are higher than the column in Kampung Parit Lapis Bangas mosque and make the MoE value in Jamek An Nur Kampung Patah Pedang Mosque become lower and not exceed the minimum MoE value. This can be concluded that, the higher the column, the higher the chance of the structure becoming weak.

5. Conclusion

Based on the results of the study that has been conducted, it can be conclude that, it has successfully achieved the objectives of the study that were set at the beginning of the study, which are:

- To evaluate the modulus of elasticity of timber used in Kampung Parit Lapis Bangas Mosque and Jamek An Nur Kampung Patah Pedang Mosque by using Ultrasonic Pulse Velocity.
- To assess the strength of the timber used in Jamek An Nur Kampung Patah Pedang Mosque and Kampung Parit Lapis Bangas Mosque.

Overall, the Non-Destructive Test that has been carried out is very important to know whether the Mosque is safe or not. The structure of the mosque will not be disturbed, and the aesthetic value of the building can be preserved. In addition, the quality of the timber in the Mosque can be known. Based on the test results that have been carried out which is, Ultrasonic Pulse Velocity (UPV) test, found that there are 3 columns in Jamek An Nur Kampung Patah Pedang Mosque that do not exceed the minimum modulus of elasticity (MoE) for Ponak Wood, which is 7600 Mpa. Meanwhile, for all the beam and column structures in Kampung Parit Lapis Bangas Mosque recorded a high MoE value and exceeded the minimum MoE value for Chengal Wood which is 14 000 Mpa.

Through this test and MoE values as well, the strength of timber can be identified. Where, the higher the value of modulus of elasticity (MoE), the stronger the structure. From the results that have been obtained, maintenance and treatment need to be done to prevent the structure of the Mosque from being further damaged without repair.

Acknowledgement

A major thanks to Faculty of Civil Engineering and Built Environment of University Tun Hussein Onn Malaysia, Lectures, Family and Friends for the endless support in this research.

Conflict of Interest

Authors declare that there is no conflict of interests regarding the publication of the paper.

Author Contribution

The author confirms sole responsibility for the following: study conception and design, data collection, analysis and interpretation of results, and manuscript preparation.

References

[1] Jean Claude Tchamba, & Théodore Gautier L. J. Bikoko. (2015). *Failure and Collapse of Building Structures in the Cities of Yaoundé and Douala, Cameroon from 2010 to 2014*. Modern Applied Science, 10(1), 23–23, https://doi.org/10.5539/mas.v10n1p23

[2] Anders Klasson, I. B. (2018). *Slender Roof Structures - Failure Reviews and a Qualitative Survey of Experienced Structural Engineers*. 174-183 https://doi.org/10.1016/j.istruc.2018.06.009.

[3] Żmijewki, T., & Wojtowicz-Jankowska, D. (2017). *Timber - Material of the Future – Examples of Small Wooden Architectural Structures*. IOP Conference Series: Materials Science and Engineering, 245. https://doi.org/10.1088/1757-899X/245/8/082019

[4] Asdrubali, F., Ferracuti, B., Lombardi, L., Guattari, C., Evangelisti, L., & Grazieschi, G. (2017). *A review of structural, thermo-physical, acoustical, and environmental properties of wooden materials for building applications*. Building and Environment, 114, 307-332, https://doi.org/10.1016/J.BUILDENV.2016.12.033.

[5] Johar S., Ahmad A.G., Che-Ani, A.I. Tawil N.M., Usman I.M.S.. *Analisa Kajian Lapangan ke atas Kecacatan Pada Bangunan Masjid Lama di Malaysia*. Universiti Sains Malaysia and Universiti Kebangsaan Malaysia.

[6] Dayang Sufeane Shuib, F. B. (2015). *Assessment Of Building Defects Of Traditional Timber Houses In Penang, Malaysia*. Jurnal UTM Teknologi. https://doi.org/10.11113/jt.v75.5081

[7] Matthias Frese, H. J. (2011). *Statistics of damages to timber structures in Germany. Engineering Structures*, Volume 33, Issue 11, 2969-2977. https://doi.org/10.1016/j.engstruct.2011.02.030

[8] Ishak, N. H., Ali, Z. M., Omar, Y., & Hashim, H. A. (2007). *Case studies on timber defects of selected traditional houses in Malacca*. Journal of Design and Built Environment, 3(1). Harte, A. (2009). *Introduction to timber as an engineering material*. National University of Ireland Galway.

[9] Geeta, D. R. (2020). *Assesment of in Situ Structural Properties of Timber*. India. https://www.irjet.net/archives/V7/i7/IRJET-V7I7249.pdf

[10] Ettelaei, A., Layeghi, M., Hosseinabadi, H.Z., & Ebrahimi, G. (2019). *Prediction of modulus of elasticity of poplar wood using ultrasonic technique by applying empirical correction factors*. Measurement. https://ui.adsabs.harvard.edu/link_gateway/2019Meas..135..392E/doi:10.1016/j.measurement.2018.11.076

[11] Yosafat Aji Pranata, Muhammad Rusli (2019). *Non-Destructive Testing of the Existing Timber Columns of Minahasa Traditional House*. Bandung, Indonesia https://sdbindex.com/Document/document_search?title=Non-Destructive Testing Of The Existing Timber Columns Of Minahasa Traditional House&Type=1

[12] Forestry Department of Peninsular Malaysia *https://www.forestry.gov.my/en/biodiversiti/item/chengal*

[13] Quilhó, T., Pereira, H., & Richter, H. G. (2000). *Within–Tree Variation In Phloem Cell Dimensions And Proportions In Eucalyptus Globulus. Iawa.* Journal, 21(1), 31-40. https://doi.org/10.1163/22941932-90000234

[14] Shaji, T.L., Somayaji, S., & Mathews, M.S. (2000). *Ultrasonic Pulse Velocity Technique for Inspection and Evaluation of Timber*. Journal of Materials in Civil Engineering, 12, 180-185.

[15] JKR standard Specifications For building Works (2014). Schedule Of Timber Species in Accordance with Strength Grouping (S.G)

[16] Malaysian Standard (2017). *Strength Group of timbers.* MS 544-2